Development and Implementation of a Hybrid Model for Integrating Online Learning in Interdisciplinary Engineering Design Courses

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Abstract— **The following paper reports on the results of efforts at integrating online learning to the junior-level and capstone fifth-year-level interdisciplinary electromechanical and electromechanical/biomedical engineering design courses at Wentworth Institute of Technology. The motivation was to enhance student time management as well as develop an effective model of hybrid interdisciplinary engineering design course with the most appropriate technology. The junior-level course is an intense course where students are expected to complete an original design and a prototype in one semester. Project and time management are critical. The capstone project is made of a sequence of 2 semester courses and involves the same requirements as the junior design course. Groups typically include 3 to 5 members. Much of the work involves testing and prototype development in the labs and therefore requires the students' presence on campus. On the other hand, a substantial amount of work does not require actual physical meetings or student presence on campus. This includes the writing of reports (proposal, 2 progress reports, weekly memos, and a final report), research work and communication. Also, the current meeting with the instructor at the weekly lab sessions for "consultations" and the weekly one-hour lecture may readily be provided online. The author has been teaching the junior design course every year for the last 5 years. Student feedback indicated consistently difficulties managing their time. As a possible improvement, the author has introduced, in the spring semester of 2010, the formation of virtual online groups whereby each group shares editing capability and the possibility of group videoconferencing. The author thought this would be especially helpful during Spring Break, and for commuting group members. It was expected this would help group members complete their reports more efficiently, and would lead to improved time management and efficiency, while making it easier for groups to manage and complete their projects. Assessment is based on a carefully designed anonymous survey of the students, and quantification of improvements in student performance, as well as the effects on teaching. Results were encouraging but indicated the need for some improvements, particularly in the software used. Benefits were observed both for the students and the instructor. In Fall 2010 and Spring 2011, the author taught capstone fifth-year electromechanical design. In addition, he taught again junior-level electromechanical and biomedical engineering design in Spring 2011 in Fall 2011, a senior capstone design and research project in biomedical engineering. He decided to extend the initiative introduced in junior design since Spring 2010. From both the student and instructor perspectives the experience has been very positive after implementation of improvements based on previous feedback. A number of the projects had a significant applied research component. The above approach provides a good model for a hybrid project-based education. This paper discusses the results of both the junior-level and capstone design experience and the lessons learned. Though the model was implemented in the context of interdisciplinary electromechanical and biomedical engineering, the author believes it applies to other areas of project based interdisciplinary engineering design.**

***Index Terms*— Project-based, interdisciplinary engineering, online education**

I. INTRODUCTION

Every spring semester, for the last 4 years, the author has been teaching Electromechanical Design (ELMC 461). This is a junior–level design course required in the interdisciplinary electromechanical engineering program at Wentworth Institute of Technology. The electromechanical engineering program is a faculty-driven, high-quality EAC-of-ABET accredited five-year interdisciplinary electromechanical engineering program.[1] It was established in 1992 at Wentworth Institute of Technology. Under EAC rules, the electromechanical engineering program had to simultaneously meet the accreditation criteria for electrical engineering and for mechanical engineering. The graduates of this program are true interdisciplinary engineers proficient in tackling interdisciplinary projects in all their electrical and mechanical complexity. In addition, the graduates have excellent laboratory and machine shop skills. Recently,[1,2] a biomedical systems engineering specialization was established in the form of a concentration within this well established electromechanical engineering program.

In addition to its interdisciplinary approach, the electromechanical engineering program along with the biomedical systems engineering concentration is primarily project-based. This is done as follows: in the 2nd semester of their freshman year, students enrolled in the program take a freshman introduction to engineering design course, ENGR 160, having 4 credits (2 lecture hours, 4 lab hours). In the spring semester of their junior year (3rd year), students take a three-credit junior-level design course (ELMC 461) having 1 lecture and 4 lab hours (in the form of consultations) per week. This course *integrates* the knowledge acquired in their previous courses into the design of a full prototype of an original product. The following is the Wentworth catalogue[4] description for ELMC 461:

> *Students work in teams to design and construct an interdisciplinary project. Teams, with clearly defined individual responsibilities, are required. During the course of the semester, each team undertakes the necessary activities to bring about a successful design project that is well understood, documented, and presented in both oral and written form. Emphasis is placed on research, innovation, project management, decision-making, prototyping, design for manufacturing, design for testability, environmental and ethical issues in design, depth and breadth of analysis, quality of hardware, documentation, and communications.*
> *Prerequisites: Junior Status; ELMC160 Electromechanical Design I; MECH302 Mechanics of Materials; ELEC244 Digital Systems; ELEC443 Analog Circuit Design.*

Students are subsequently required to take 2 semesters of capstone design course (4 credit hours each), ELMC 831 and ELMC 881, in their 5th year. Therefore, the design projects provide a focus and *integrator* of other, more traditional, courses. In addition the junior-level design course provides valuable preparation to the capstone design project. This approach has been very successful as is shown by the winning of numerous competitions, both regional (ASME, IEEE) and national, as well as the high demand in industry for graduates of this program.

Recently[36,37] a biomedical systems engineering specialization was established in the form of a concentration within this well-established electromechanical engineering program. The addition of the concentration required only limited additional resources. The result is a high-quality program that is competitive with other biomedical engineering programs offered in Massachusetts. Effectively, this further integrates the electromechanical engineering program by incorporating the important biological dimension. The program has attracted a substantial number of students, and has expanded opportunities for our graduates. The Electromechanical Engineering Faculty Committee[38] composed of eleven faculty members drawn from various disciplines, thoroughly researched, planned, and obtained administrative approval for the program, implemented, and is continuously assessing and fine-tuning this novel concentration. The endeavor was very much faculty driven. The faculty exercised care so that the addition of the new concentration did not alter or weaken the structure of the existing electromechanical engineering program but rather strengthened it, and provided greater opportunities for the graduates. The choice of elective courses from the life sciences, co-op employment in the biomedical field, and design projects with life-science applications made the implementation of this concentration possible. Graduates of such a program receive a Bachelor of Science degree in electromechanical engineering with a concentration in Biomedical Systems Engineering that is producing 3 engineers integrated in one.

Over the course of his 5 years teaching the junior-level Electromechanical Design course, the author has been continually assessing the course and introducing improvements. In prior years, this course was taught by his colleague Dr. Loutfallah Georges Chedid. When he first taught this course in 2007, the author inherited an excellent syllabus and approach from Dr. Chedid. Assessment was based on a carefully designed grading system, a comprehensive end-of-semester questionnaire, student evaluations, an end-of-semester summary by the instructor (the author), and assessment of qualified peers who attend the final presentations. The effectiveness of this design course is demonstrated by the generally excellent performance of students and the positive evaluation by experienced electromechanical engineering faculty who were present at the final project presentation. Student feedback generally indicated a high level of satisfaction regarding both the amount of multidisciplinary learning achieved as well as its quality. It consistently indicated that the course objectives were fulfilled. On the other hand, students generally indicated they experienced a lot of time pressure and some suggested increasing the number of credits (above the current 3). Some suggested cutting down on requirements such as reducing the number of progress reports (from the current 2) or reducing the semester course load. None of these potential solutions seemed to the author currently feasible. Reducing the number of progress reports, while feasible, would not be advisable as it would probably affect the quality of communication skills to be learned.

Lately, in his search for a solution, the author has concluded that the junior-level Electromechanical Design course could be more efficiently organized. He looked for a way to help students manage their projects more effectively within the current time constraints. Groups include typically from 3 to 5 members. In the first week of the semester, students are to form their groups and brainstorm for the choice of a suitable group project. This is followed with a formal written proposal and presentation of the proposal by the end of the second week. Much of the project work involves testing and prototype development in the labs and therefore requires the students' presence on campus. On the other hand, a substantial amount of work does not require actual face-to-face meetings or students' presence on campus. This includes substantial writing of formal reports (1 proposal, 2 progress reports, weekly memos, and a final report), sharing results of research work and other types of communication. Along with the formal written reports, each group makes a twenty-minute formal presentation. The instructor meets each group once a week at a "consultation" session and also outside regular hours on a need basis. In addition, there are frequent email communications between group members and between them and the instructor, to discuss problems or share information. Aside from this, a one-hour lecture is presented once a week. In this one-semester intense course, time and project management are obviously critical. Because of the multidimensional demands of the projects, typically more than half of the groups end up not completing the expected full prototype for "lack of time," even though their performance may be otherwise excellent. The author has often read student comments in their course evaluations such as this: "all we needed is another week of testing." Typically, students try to use the week of Spring Break to "catch up." However, most of them are then off campus, which limits severely what they can do.

As a possible improvement and solution, the author, with the help of DTS (the Division of Technology Services at Wentworth), has introduced an online structure of virtual groups whereby each group shares real-time editing capability and the possibility of videoconferencing. In the author's mind, this would be especially helpful during Spring Break, for commuting group members, and for the many students who work off campus. It helps students to save time and complete their reports more efficiently. It was expected that this would lead to improved time management and efficiency, while making it easier for groups to manage and complete their projects. The planned assessment[8,10,16,18] is based on 2 carefully designed anonymous surveys of the students, at the end of the semester, and quantification of improvements in student performance, including comparison to previous classes. Results by the end of Spring 2010 were encouraging but suggested a need to change the software used. In Fall 2010, the author taught the first semester of capstone Electromechanical Senior Design I (ELMC 831). The college catalogue course description is as follows:

This course is only for electromechanical students with senior status and the required prerequisite courses. Students will work in the electrical and mechanical fields aloneand in small project groups to study, analyze, design, and sometimes build and test concepts in a field of their choosing. The study will be performed under the direction of one or more faculty advisors. Projects from industry will be encouraged to increasethe interaction and cooperation with local engineering firms. Course requirements include regular, oral, and written progress reports throughout the semester. The finaltechnical report will detail the plans and schedule for the following Senior Design II course. Prerequisites: MECH620 Engineering Thermal Design; ELEC820 Feedback and Control; MECH600 Advanced Mechanics of Materials.

Based on the student feedback obtained in the junior-level Electromechanical Design class of Spring 2010, another software, Dropbox,[33] was used instead of Google Docs and resulted in a much higher level of student satisfaction. The above approach may be considered as a good example of a hybrid or blended online project-based education in engineering. The discussion of this experience with the junior design course taught in Spring 2010, not including the assessment, was presented at the New-England ASEE conference of May 2010 in Boston.[34] The present paper presents a more comprehensive discussion of the model and reports on its further implementation and enhancement in capstone Senior Electromechanical Design I in Fall 2010. This experience was presented at the 2*011 ASEE* National Conference, Vancouver, BC, Canada.[35] The present paper builds on the above model and experience and includes an analysis of the experience gained in teaching again capstone Senior Design and Junior-level design in electromechanical and biomedical engineering Design in Spring 2011 and in Fall 2011.

II- DEVELOPMENT OF THE ONLINE SYSTEM

Prior to 2010, there was no significant online component to this course. The author had used Blackboard[5] minimally while teaching this course in the past, essentially to post relevant information such as syllabi, announcements and short tutorials of general interest on topics such as microcontrollers, motors, and servos. However, the author had no other experience or knowledge of the state of the art in online education and technology, especially the part relevant to the design course of interest. The author asked himself and set to answer the following questions:

- What is the state-of the art in online technology?
- What technology is most appropriate and how does it work?
- What is the experience of faculty in other institutions?
- How can online education be integrated to the interdisciplinary electromechanical design course?

To answer the third question, the author has carried out extensive research by studying professional journals[6-18] and attending workshops provided by Cristy Maldonado and Ron Frattura of DTS at Wentworth. This research and workshops convinced him that online education satisfies a real need, is rapidly growing, and will probably be a significant component of higher education in the future. He also concluded that, depending on the particular course being taught, the optimal solution in the future would generally be a "hybrid" solution, combining on-site and face-to-face education, as in traditional college settings, and online education. Many courses may be entirely effectively provided online such as in some current reputable online MBA programs.[19] It became also clear to the author that a significant segment of the population will be well served by online education, especially adult learners, but also younger students who are capable but cannot afford the costly education of traditional colleges and universities. His research also indicated that online education has so far typically dealt with lecture-based courses, and when a lab component is included it is in the form of simulations[14] only.

Based on his research, and because the interdisciplinary electromechanical engineering program at Wentworth is unique[1-2] the author concluded he had to custom design an approach suitable to this program. He estimated that probably half or more of the activities, involved in electromechanical design do not require a face-to-face meeting or real-time synchronous communication between team members. Similarly, face-to-face meeting with the instructor such as at consultations may be done as effectively online. For example, the editing of reports and memos, and the project literature research. On the contrary, online communication is probably more effective because of its flexibility, especially for the large number of students who have at least one job off campus, in addition to their demanding semester schedule. On the other hand, the building of product modules and testing requires some physical presence on campus to use lab facilities. Convinced of the potential benefits of the introduction of online education into the course, the author started by attending two workshops provided by Cristy Maldonado and Ron Frattura of DTS, in order to educate himself in the state-of-the-art technologies. This was followed by several consultations with them regarding the most suitable technologies to use.

III- THE VIRTUAL INFRASTRUCTURE

Based on the above research, workshops, and consultations, the author developed the following plan in his Spring 2010 teaching of junior-level Electromechanical Design:

1- Use Blackboard for general announcements and as a resource for relevant tutorials and information of general interest to the class. In other words, in the author's mind, use Blackboard essentially as an online specialized library for the group projects. The reason is that Blackboard could not provide all the functionality required of group projects such as simultaneous online editing of documents. Actually, some other open-source software packages[31-32] seem to be more suitable in that respect.
2- Create a "Google Docs" website in the Google Apps that is affiliated with Wentworth with the instructor as "owner."

Google Docs[20,21] is "*a free, Web-based word processor, spreadsheet, presentation, form, and data storage service offered by Google. It allows users to create and edit documents online while collaborating in real-time with other users.*"[21]. Google Apps[22,23] is "*a service from Google for using custom domain names with several Google products. It features several Web applications with similar functionality to traditional office suites, including: Gmail, Google Calendar, Talk, Docs and Sites.*"[22] The Education edition is free and provides 7 GB space for emails. After the site was created by the author, he constructed 2 *virtual sections* in the form of folders one for each section (ELMC461-01 and ELMC461-03). Within each virtual section, he created 7 subfolders in ELMC 461-01 and 6 subfolders in ELMC 461-03. Each subfolder represents the virtual space allotted to each group project. No student is allowed access to another group space. The instructor (the author) named the subfolders with the respective project names. The author then proceeded to "invite" all group members to their respective group project, giving each group member editorial rights. He also provided a link to an online Google Docs video explaining how Google Docs works.[24] The instructor is a team member in each group project. This was done not only to monitor student progress but also to better communicate relevant information between group members and the instructor.

Earlier in the semester, the instructor asked each team to elect a "project leader" or "coordinator" to facilitate communication both within groups and between groups and the instructor. Group leaders were also tasked with making sure the online group operation worked effectively and reporting any difficulties encountered to the instructor. Prior to his invitation, the instructor discussed the online plan in a session involving all group leaders who were tasked in turn to report to their respective groups. Groups were expected to put all information regarding their projects in creatively labeled folders in their respective virtual space. While this online structure was implemented, students were also encouraged to contribute with any ideas they may have. One primary objective was that the structure be in place prior to Spring Break so students would be able to use it during the break.

Next, the author wanted to expand this online format to create a comprehensive and effective model that would incorporate videoconferencing. Further research and consultations with Cristy Maldonado and Ron Frattura of the DTS showed that Google Docs, while quite effective for online asynchronous and synchronous communication and real-time editing, does not provide opportunity for videoconferencing. There are many videoconferencing technologies.[25-30] Dimdim[26-27] was chosen for the following reason: It is free and suitable for groups of up to 5 members. Beyond this number, it is not suitable because of limitations on the bandwidth. Therefore, groups could videoconference at any time following an email invitation by the group leader. The author then invited Cristy Maldonado and Ron Frattura to conduct a 45 minutes workshop in class to demonstrate to the students how to use Dimdim prior to going on Spring Break. The level of interest by students was evident.

The author went further by introducing videoconferencing at the class level. Cristy Maldonado and Ron Frattura of the DTS recommended the use of Adobe Connect[28-30] as their experience indicated that it is a quality videoconferencing software that can accommodate numbers larger than the class size (currently about 25) and has good bandwidth and more functionality than Dimdim. This software was demonstrated to the author who deemed it suitable. In addition, this proprietary software is available at Wentworth. Videoconferencing at the class level may be used for lecturing and for meetings between the instructor and the 13 group leaders. Since the current class structure involves face-to-face meetings as students are on campus, the author has not implemented this format, but he plans to test it in the future.

IV-ASSESSMENT OF JUNIOR-LEVEL ELECTROMECHANICAL DESIGN

Assessment[8,10,16,18] was performed as follows: From the instructor's point, from the student's point of view, and from changes in student performance. From the instructor's point of view, immediate benefits were obtained as soon as the online structure was completed. He incorporated some articles discovered in his research relating to particular projects into their respective virtual space in a folder which he uploaded. Without the Google Docs virtual infrastructure, he would either have waited many days until consultation time to report the articles or email the articles which is time consuming and not efficient. Another advantage both for the instructor and group members is the ability to share all relevant information with anyone anywhere there is an internet connection. The instructor himself experienced this benefit as follows: During a weekend he visited a friend, a senior engineer specializing in radars, and consulted with him regarding a particular project involving the design of a collision-avoidance system for the MBTA (Massachusetts Bay Transportation Authority). The author spent a good hour discussing the possible solutions. At that time the Google Docs site was not set up yet. In retrospect, having the site would have facilitated significantly the discussion, by simply logging in and reviewing the group project proposal with him. Another example is a group of students involved in the design of a leg brace for injured horses. They visited a professor of veterinary medicine at Tufts University, some 30 miles from the Wentworth campus, to consult with him regarding their project. These students could more efficiently communicate with the professor because of their ready access to their virtual project space in the Google Docs website.

On an anecdotal basis, the instructor (the author) met with the above-mentioned MBTA collision avoidance project members, one day after their presentation of their first progress report, in order to discuss their project. They stated that they were happy about the initiative and that it helped them save time in their writing of the progress report and weekly memos. A comprehensive questionnaire was distributed at the end of the Spring 2010 semester. This questionnaire focuses on quantitatively and qualitatively gauging student satisfaction level with all aspects of this online initiative, and analyzing their comments on ways they propose to improve it. The survey included questions such as:

1- In what way did you find Google Docs helpful?
2- In what way did you find Google Docs not helpful?
3- How often did you use Dimdim? In what way did you find it helpful?
4- In what way did you find Dimdim not helpful?
5- Did you find the overall online experience was helpful in conducting your project?
6- What are your thoughts on improving this online experience?

Student feedback regarding the important question 5 was as follows: positive for 36%, neutral for 34%, and negative for 30%. Many students, including those who gave an overall positive evaluation provided their reasons for their dissatisfaction which the author thought were reasonable:

1- It is difficult to upload documents to Google Docs.
2- Many students found it difficult to join Google Docs.
3- Dimdim is too restrictive: Only one speaker can appear on the computer screen.

A number of students indicated their preference for some other software. The author concluded that student feedback was not as positive as he anticipated, and decided that changes in the software should be implemented.

V- REFINEMENT OF THE MODEL AND IMPLEMENTATION IN CAPSTONE SENIOR ELECTROMECHANICAL AND BIOMEDICAL RNGINEERING DESIGN

In Fall 2010, the author was assigned to teach the capstone Senior Electromechanical Design I, for the first time. He decided to introduce this online method in this particular class, while making the improvements suggested by the feedback from junior-level Electromechanical Design taught In Spring 2010. At the beginning of the semester, he arranged for Cristy Maldonado of DTS to give a lecture and demonstration on both Google Docs and Dimdim to the class. The author taught these students junior-level Electromechanical Design in Spring 2009, and Network Theory in 2008, and he found them generally more capable and motivated than those he taught in Spring 2010. After Cristy's lecture, the students were given a few days to experiment with the software, and a class discussion was conducted. The main criticism they had against Google Docs was as follows:

1- The limit of total memory of 1 GB for the storage of documents was inadequate.
2- The difficulty associated with translating ordinary documents and spreadsheets into Google Docs format.
3- Yes, Google Docs provided "free" alternatives to Microsoft's PowerPoint and spreadsheets, though not as comprehensive as Microsoft's, but the students didn't need them since they already have Microsoft Office in their laptop which is provided by Wentworth.

The students then suggested their own “solution:” Dropbox.[33] One group then met with the author and provided him with all the details regarding this particular software. After researching this software, the author concluded that:

4- Dropbox offers more memory, 4 GB free instead of 1 GB with Google Docs’
5- Is more user friendly
6- Allows the formation of virtual groups just as with Google Docs.

Thus, Dropbox provided the required functionality of Google Docs without the inconveniences of the latter. At the end of the semester, the instructor obtained student feedback in a detailed course questionnaire similar to the one he used in junior-level Electromechanical Design in Spring 2010. All 15 students used Dropbox and were highly satisfied with it. All students on the other hand did not use Dimdim and it seemed this was because, living on campus they did not see the need for it. Based on this experience, the author decided that, an effective implementation of this initiative of hybrid instruction is as follows:

1- Use Dropbox to implement virtual groups
2- Use Blackboard as is currently being used as repository of information
3- Inform students about Dimdim and let them use it if and when they feel a need for it.

In the student end-of semester evaluations, and a detailed questionnaire, at the end of Fall 2012, students unanimously felt the online experience using Dropbox was very positive.

In Spring 2011, the author taught junior-level Electromechanical Design and capstone Senior Electromechanical Design II, which is a continuation of capstone Senior Design I he taught in fall 2010. The continued using Dropbox and at the end of the semester student evaluations of the experience was similarly positive. Currently, he teaches a senior level/electromechanical and biomedical engineering research and design project in which Dropbox is heavily used. Students satisfaction with this experience has been as high. Because Wentworth is a small college with most students living on-campus, there was not enough incentive in fostering the Adobe Connect videoconferencing method for some lectures associated with the design classes. The author however hopes to introduce this approach in the future.

It may be too early at this stage to establish a more reliable quantitative assessment of the actual impact on student performance, as, in the author’s opinion, this requires several years of implementing this experience and monitoring it, and ultimately comparing it to past student achievement statistics. In addition, this quantitative assessment is complex as student achievement depends on many other variables, some of which are difficult to quantify. In the author’s opinion, students’ use of the virtual infrastructure and their perception of the experience are for now the most significant measures of its desirability and effectiveness. This is because the original goal was to provide online means to enhance student time and project management, to make it easier for them to perform better. In addition, in the author’s view, the proposed virtual infrastructure model is a dynamic model meant to continually improve in its details, based on student assessment and evolving technologies. As discussed above, the replacement of Google Docs with Dropbox illustrates this dynamics. It is the author’s observation as well as the students perception, however, that the quality of student projects has been consistently high and that the online experience has contributed to better project and time management.

VI- CONCLUSIONS

In order to improve the teaching of the interdisciplinary junior-level electromechanical design course, the author has developed a hybrid model by integrating an online model to the traditional interdisciplinary project course structure. This online model partly involves the use of Blackboard as a virtual repository of information of general interest such as syllabi, announcements and tutorials. But the specificity of the model is the online virtual group structure. At first the model involved a Google-Docs site “owned” by the instructor, where each group is “invited” to its specific virtual space, the instructor being a member of all virtual groups. Group members have editorial rights but can access only their respective group space. They may edit PowerPoint-like presentations and spreadsheets within Google Docs and upload or export all types of multimedia files. In addition, free videoconferencing using Dimdim[26-27] is available for each group. Class-level videoconferencing is incorporated by using the proprietary videoconferencing software Adobe Connect which is available at Wentworth. In principle, the class-level videoconferencing may be used to replace the face-to-face weekly lectures.

The instructor’s (the author) assessment at the end of Spring 2010 junior-level Electromechanical Design was that this experiment led to more efficient mentoring of the groups by facilitating communication and research. Student feedback indicated however a general dissatisfaction with the use of Google Docs. Based on this feedback, the instructor replaced Google Docs with Dropbox in his capstone Senior Electromechanical Design I class he taught in Fall 2010, as suggested by his students. The level of satisfaction of his students with this software was 100%. Dropbox provides all the required functionality of Google Docs, but in a more efficient way. In particular, it was found to be more user-friendly and provides more free storage. Dimdim on the other hand was not used, as, in the author’s opinion, since most students resided on campus, they had no incentive for using it. A few others indicated that they preferred to use alternative videoconferencing software.

The above model was fine-tuned, based on the above student feedback, in junior-level

Electromechanical Design and capstone Senior Electromechanical Design II that the author taught again in Spring 2011, and a senior-level capstone biomedical engineering design project in Fall 2011. Student response to the use of Dropbox was as positive. Though desirable, there was little incentive delivering lectures with Adobe Connect as the overwhelming majority of students live on campus. Based on the above multi-year experience, the author has concluded that the use of Dropbox, along with Blackboard, and when needed, videoconferencing such as with AdobeConnect, has resulted in enhanced hybrid project-based education. He will continue to implement and evaluate this approach. It should also be noted that some of the design projects had a significant applied research component and that they benefited as well from the integration of online learning as implemented in the present hybrid model.

The model presented in this paper provides an integrated online infrastructure that may not only be used to enhance the design and student experience, but also to lay the foundations for possible future online or hybrid interdisciplinary project-based courses. The experience described in this paper also indicates the need to be on the lookout for rapid advances in technology to further enhance the implementation of this model, and that the students' input and involvement in this effort is valuable.

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[32]- Sakai project: http://sakaiproject.org/, April 2010.

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[34]- *Integrating Online Learning to Junior Level Electromechanical Design,* S. Badjou, peer-reviewed paper presented at and published in the proceedings of the 2*010 ASEE* Northeast Section Conference. Boston, MA,M*ay* 7, *2010 – May* 8, 2010.

[35]-*Integrating Online Learning to Junior-Level and Capstone Electromechanical and Biomedical engineering Design,* S. Badjou, paper presented and published in the proceedings of the 2*011 ASEE* National Conference, Vancouver, BC, Canada, June 26-29, 2011.

[36]- Salah Badjou, Loutfallah Georges Chedid *Implementation of a Novel Biomedical Systems Engineering Concentration Within An Established And EAC-of-ABET Accredited Electromechanical Engineering Program* Proceedings of the 2009 ASEE Annual Conference, Illinois/Indiana Section Conference, June 14-17, 2009.

[37]- Loutfallah Georges Chedid, Salah Badjou, *Introduction of a Novel Biomedical Engineering Concentration into an Interdisciplinary Engineering Program and Lessons Learned,* 2007 Illinois/Indiana ASEE Section Conference, March 30-31, 2007.

[38]- Internal documents about the Electromechanical Engineering Faculty Committee structure: In summary, this eleven-member interdisciplinary and interdepartmental committee is composed of four faculty members with electrical engineering, one with physics/biophysics, four with mechanical engineering, one with interdisciplinary electrical and manufacturing engineering, one with mathematics, and one with industrial psychology background and expertise. This standing committee has worked together as a cohesive team for more than ten years, and has been responsible for designing, implementing, and overseeing a unique-in-the-nation five-year electromechanical engineering program. This program is the only one of its kind in the US that is currently accredited by EAC of ABET.

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