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Lessons Learned From a Covid-impacted Capstone

Dr. Alicia A. Modenbach P.E., University of Kentucky

Alicia A. Modenbach is a Lecturer in the Biosystems and Agricultural Engineering Department at the University of Kentucky. She completed her bachelor's degree in Biological and Agricultural Engineering at Louisiana State University in 2006, before pursuing her graduate education at the University of Kentucky, completing her MS in 2008 and her PhD in 2013. She teaches an introductory sophomore course and senior design, as well as serves as an academic advisor to students in the Biosystems Engineering program.

Prof. Michael "Mick" Peterson, University of Kentucky

Michael "Mick" Peterson is a Professor in the Biosystems and Agricultural Engineering Department and Director of the Racetrack Safety Program at the University of Kentucky. He completed his bachelor's degree in Mechanical Engineering at what is now Kettering University in 1985, and an MS in 1987 and a PhD in 1993 in Theoretical and Applied Mechanics at Northwestern University. He teaches senior design and works with monitoring and testing of racing surfaces for the Thoroughbred racing industry.

Lessons Learned from a COVID-Impacted Capstone

Abstract

This paper is an evidence-based practice complete work that details positive and negative elements resulting from the sudden transition to emergency remote instruction and learning for a biosystems engineering capstone course, as well as defines how these experiences have shaped the decision making for the upcoming offering. Due to the COVID-19 pandemic, the overnight transition from an in-person capstone course to a fully remote capstone course in March 2020 required instructors to think creatively about the capstone experience and how the core learning objectives could be met in the presence of a new set of constraints. The continued restrictions and challenges associated with in-person meetings for Fall 2020 continued to shape decision making around course design and structure. This paper addresses some of the lessons the instructors learned during the last weeks of the Spring 2020 semester, and how they are shaping the capstone experience going forward.

Reflecting on the last few weeks of the Spring 2020 semester, the instructors recognized several positive elements that emerged from the course. Students were very patient and flexible with the transition to remote instruction. Instructors were still able to provide meaningful and productive interactions with the whole group, smaller teams, and individual students using virtual meeting platforms like Zoom. Certain assignments were quickly redesigned for the new virtual platforms being used. Everyone involved learned and practiced new skillsets to continue working collaboratively in a virtual environment, and the class was more effective at including external stakeholders in the process.

However, several challenges also became apparent. The loose structure of the course, hasty adjustment of the project scope to accommodate remote work, and loss of access to information and resources had a significant impact on the students' experiences. Final project outcomes were limited by circumstances, since the second semester is focused on fabrication and test. For some students, the experience and expectations for the more hands-on part of the project were particularly impacted. Added challenges associated with grieving the loss of a final semester, graduation ceremonies, and uncertain career prospects, and dealing with the uncertainty of the unknown added to the stress and anxiety felt by all involved.

Modifications implemented starting with the Fall 2020 capstone courses address some of the challenges experienced during the Spring 2020 semester, including adding more structure and organization to course content and communications, introducing cloud-based software programs, in particular looking at specific new CAD software, to support remote collaborations, and providing more intentional guidance for keeping students on track and organized during the design process. The possibility of returning to remote instruction mid-semester also influenced projects proposed by capstone partners.

Introduction

The Senior Design course experience in the Biosystems Engineering program at the University of Kentucky is organized into a two-semester sequence with each course accounting for two credit hours (four credit hours total). Approximately 25-40 students enroll in the capstone sequence each year, so there are typically seven to ten teams consisting of three to four members each. The meeting pattern for the course is such that the students meet for a one-hour lecture period each week, then have individual team updates or design reviews (10-15 min per team) during a weekly two-hour lab meeting. Students are encouraged to use the lab period as a dedicated work session each week since it should be a guaranteed time when all team members are available, as well as additional times outside of class time identified by individual teams.

Students may choose to focus within any one of six specializations offered by this program, so the project topics tend to vary significantly every year. Five years ago, the course transitioned from having a single instructor to one that is taught by two co-instructors with complementary backgrounds. This structure is advantageous since topics vary broadly across the discipline, and it also provides students with different perspectives for approaching design problems. The co-instructor model also helps to engage a wider range of students and allows the students to both participate in and to observe work collaborations with instructors exhibiting different styles, backgrounds, and expertise.

The instructors request project proposals from faculty, industry connections, and other collaborators in areas relevant to the discipline prior to the start of the fall semester. Proposers pitch their project ideas to the students during the first week of the semester. Students then rank their interest in the projects, and teams are selected based on the students' reported level of interest. Typically, students are assigned to either their first or second project choice (~95%), with few instances (<5%) of students assigned to their third choice. Instructors also consider several other factors when assigning teams, including a student's self-assessment of the skills they can bring to the project, experience gained from experiential education (i.e., co-ops or internships), and suggestions made by the students of one peer with whom they are compatible. The goal of this process is to ensure that all voices within the group are heard and to minimize the impact of a potentially dominant group member.

The first semester focuses on the first steps of the design process: developing a problem statement, researching the problem, generating design ideas, evaluating and selecting a design, and detailing a design solution with a supporting engineering analysis using foundational knowledge learned in prior courses and independently as needed (Figure 1). The final outcome for the first semester is a design package, which will allow for the system to be built to print in the second semester. The second semester focuses on enhancing the design solution using feedback received from instructors, clients, and technical staff, fabricating prototypes, executing performance tests, analyzing results, and developing final design specifications.

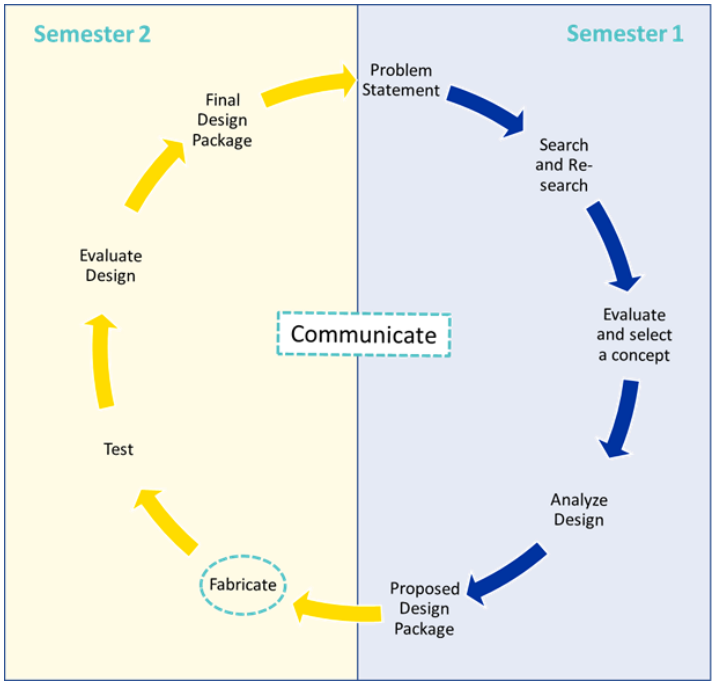

Figure 1. Typical design process used in the Biosystems Engineering Design I/II courses at the University of Kentucky. During the Spring 2020 semester, most teams were in the thick of the fabrication stage at the time COVID-19 forced the University to shut down for an indefinite period.

While the capstone experience requires individual effort by the students, it is extremely team-oriented and hands-on (applied) learning. Like many other capstone courses in similarly named programs, the first semester is mainly design work on paper. The second semester is the realization of the design. Parts are ordered and prototypes are manufactured. For the 2019-2020 academic year, all the actualization of the projects happened simultaneously with the global shut down due to the COVID-19 pandemic. Seven months of design work suddenly had to pivot into projects and deliverables that could be completed remotely without access to much of the tools, equipment, and resources typically used by teams. This transition was much easier for some projects than others.

Upon completion of the Spring 2020 semester, the instructors reflected upon the outcome of the course and acknowledged several positive and negative aspects and used those to guide changes implemented on the next iteration of the capstone course. This practice seemed to follow trends observed nationally. According to a survey conducted by Every Learner Everywhere, one of the emergent themes was that many faculty members indicated they learned lessons during their transition to emergency remote teaching that will inform their practice moving forward, whether teaching remotely or in-person [1]. Since the teaching modality for the 2020-2021 academic year was highly uncertain at the close of the Spring 2020 semester, the instructors recognized that modifications to teaching strategies would be critical for a successful course for the next academic year.

This paper is an evidence-based practice complete work that details positive and negative elements resulting from the sudden transition to emergency remote instruction and learning for a biosystems engineering capstone course, as well as defines how these experiences have shaped the decision making for the upcoming offering. Due to the COVID-19 pandemic, the overnight transition from an in-person capstone course to a fully remote capstone course in March 2020 required instructors to think creatively about the capstone experience and how the core learning objectives could be met in the presence of a new set of constraints.

The positives of the Spring 2020 semester

The instructors acknowledged several positive elements that emerged from the course, amid the chaos and uncertainty that came with the impending pandemic. That list is detailed in the discussion below.

Students were generally patient and flexible with the transition to remote instruction. Student attitudes are often viewed poorly even in the best of times. The instructors noted that the students were generally patient and flexible given the circumstances of the situation. The quick transition to remote instruction emphasized several challenges like the need to learn new technology, to deliver course content and engage the students virtually, and to modify projects to ensure students could still have achievable outcomes. The instructors believe the students were tolerant because they recognized the fact that all parties involved were learning and developing new skills in the face of a constant barrage of new information and uncertainty. The timing of the transition may have been in the instructors' favor as it coincided with the University of Kentucky's Spring Break. While the transition was quick, it was not an overnight change. The students were able to step away from classwork for the first week of the imposed isolation. This timing also provided the instructors with a modicum of breathing room in making decisions about projects and making some preparations for the adjustment.

Meaningful and productive design review sessions were still possible. Meeting with teams individually to discuss issues, concerns, or questions relating to their projects on a weekly basis was standard practice for this course pre-COVID-19. Of course, this practice continued virtually post-COVID-19 with the objective being to bridge the gap for the two weeks initially expected necessary to "flatten the curve" since many anticipated a much quicker return to in-person instruction than what occurred. The instructors did not want to disrupt the students' progress on their projects, especially early on when returning to in-person instruction was still a possibility. If anything, these weekly meetings gave the instructors the opportunity to check in with students on a more individual and personal level. These meetings were a way to maintain connections with the outside world as everything seemed to be collapsing. These meetings also provided a little bit of consistency for the students as things were growing increasingly uncertain around them.

Assignments and project scopes were adjusted for the new virtual platforms being used. Many students left campus and returned home expecting to be able to resume in-person instruction a few days later. Many students left behind critical supplies and course materials. Many students

did not have access to reliable network resources, and the absence of standardized computer hardware meant software, which was readily available for download, often could not be run on student computers. To accommodate students and projects, the instructors adapted assignments for a virtual experience, which appeared to be a widespread practice for many faculty members nationally (52%) [1]. For example, students typically display their work in a final poster session held at the end of the semester, where they celebrate their accomplishments with their peers, faculty, clients, and other stakeholders. The in-person event was modified by requiring teams to pre-record their poster presentations, then followed up with a live, virtual session for further discussion. An unanticipated benefit of this change was that many project clients who are normally scattered across the globe could view the pre-recorded presentations and attend the live, virtual discussion session. Students were able to directly interact with their clients, when in typical years, that would not have been feasible.

Additionally, as project materials were abandoned on campus as students retreated, many teams no longer had the necessary resources to continue with their earlier plans. Instructors helped guide teams to work on other significant final deliverables, so they could still come away from the course with a meaningful experience.

Everyone learned and practiced professional skills. The Senior Design experience is already an exercise in collaboration under the best of circumstances. The shift to remote work magnified the need to refine professional skills, like clear communication and teamwork, to produce a successful project. Students and instructors alike were able to practice working collaboratively in a remote fashion, which more closely mirrors the current global profession. At the time of composition of this manuscript nearly a year into this pandemic, it seems apparent that many things may very well remain virtual for the foreseeable future.

The negatives of the Spring 2020 semester

The COVID-19 pandemic exposed several weaknesses in the Senior Design experience in the Biosystems Engineering program at the University of Kentucky that the instructors vowed to address for future iterations of the course, whether it remained virtual or returned to in-person instruction. That list is detailed in the discussion below.

Not all projects, teams, computers, and software (CAD) were created equally. With the abrupt shift to remote work and with the anticipation that it was only a temporary pause to in-person activities, many students left campus and returned home, leaving behind project components, files, and resources. It quickly became apparent that not all teams could successfully continue with their projects from their new locations. Projects that required more fabrication, could not make progress without access to the machine shop. While remote fabrication is common in industry, the department continues to use a model based on personal communication for fabrication. Other projects that had more electronic components could not make progress because components were abandoned on campus, or students did not have remote access to the software or files they had been working on using campus resources (i.e., computer labs and

licensed software). As respondents of the Every Learner Everywhere survey indicated, an adequate substitution for hands-on experience in a lab or STEM environment does not exist [1]. Even though virtual conferencing tools aided in continuing group reviews and lectures when in-person meetings in classrooms were disrupted, other inequities including digital inequalities, lack of access to resources, and limited fabrication skills with little to no support away from campus were exacerbated.

The lack of structure and organization supporting a very unstructured course became very apparent. The two courses making up the Senior Design experience in the Biosystems Engineering program had been in a transition period even pre-COVID-19. One of the instructors, while having taught Senior Design for 20+ years, was relatively new to this department. The second instructor had only started teaching the Senior Design courses the previous spring. The benefit of co-teaching a course like Senior Design is that the two co-instructors bring complementary skills and perspectives to the classroom, giving the students a richer experience. However, that can also lead to differing attitudes and priorities for the structure of the course. The organizational approach taken with the course structure pre-COVID-19 had been to discuss topics relevant to the specific group projects of that current term. With seven to ten teams in any given year covering a range of design challenges and specialization areas, the topic outline for the course could be irregular and inconsistent from year to year. One advantage of the unstructured nature of the course was that students often had to learn to how to work within such an unconstrained environment, requiring students to spend some effort on organizing their team and project, as well as to maintain motivation and organization over the course of the two semesters. The instructors believe that was a more realistic portrayal of the engineering workplace many students would experience post-graduation. However, the idea that companies are expected to have employee handbooks and internal resources readily accessible online to their employees went unrecognized and underutilized in the class. One lesson learned by the instructors was that a lack of structure surrounding the projects does not have to equate to lackluster communication and inaccessible information and documentation of policies and procedures to support the students as they progress through these courses.

Clear, consistent, and frequent communication was critical. Prior to the disruptions caused by the COVID-19 pandemic, communication in Senior Design tended to be verbal reminders and feedback presented during class lectures and weekly design team updates, with written communication for announcements and reminders used much less often. With the transition to remote work, clear and consistent communication was critical to keeping everyone apprised of the ever-changing situation, as well as ensure everyone received the same messaging, since it was not a guarantee that students could access the course synchronously.

Since the Spring 2019 semester, when the current instructor pairing was established, the number of announcements sent through the course Learning Management System (LMS) increased 10-fold. For example, during the Spring and Fall 2019 semesters, only two announcements were sent in each of those semesters through the course LMS. In the subsequent respective semesters (i.e., Spring 2019 to Spring 2020), 19 and 20 announcements were sent in Spring 2020 and Fall

2020 semesters, respectively. If the Spring 2020 semester communication patterns are examined more closely, two announcements were sent early while in-person learning was in place, two announcements were sent as the transition to remote learning started to become apparent (during the mid-point of the semester), and 15 announcements were sent following the transition to remote learning. The authors want to note that the act of clear, consistent, and frequent communication is not a negative, but the transition to remote learning exposed the lack of clear, consistent, and frequent communication in their pre-COVID-19 practice.

Increased cognitive load on students and instructors played a significant role in performance. The transition to remote learning was a demanding time for instructors and students alike. Instructors had to quickly pivot and adjust plans and learn new teaching modalities and technologies. Students faced learning new structures and course organization for as many as four to six different courses, and in some cases simultaneously having to secure housing, resources, and reliable internet to have a chance to complete their semester and their senior year. The ever-changing situation and the sudden isolation from support systems weighed heavily on all involved. Many students (and the instructors) reported not being able to focus on the tasks necessary of them to complete their projects or other coursework.

Students missed the interaction of in-person classes. Students often expressed to the instructors during their weekly team updates that they missed the in-person interaction of their courses. Many were grieving the loss of the end of their senior year. They eagerly anticipated completing their projects that they had spent months (really years) preparing for as a culminating experience to their formal engineering education. While the instructors worked tirelessly to give as similar an experience as possible, not being in person to complete the fabrication portion of the design or to work through design issues with the guidance of the instructors was a limiting factor for several teams. Some students also expressed gratitude for continuing to follow the pre-COVID-19 weekly schedule, which gave their days and weeks some structure and consistency.

How the COVID-19 pandemic has changed the approach moving forward

Teaching modality plans for the Fall 2020 semester were finalized in mid-July 2020, even though the situation remained fluid. While the instructors planned for an in-person modality, they also had to supply plans for accommodating students and instructors who needed to quarantine or isolate for a period, as well as practice physical distancing and wear masks when in the classroom. Each of these aspects incorporated a level of complexity to ensuring students were engaged and understanding course content, as well as able to collaborate in their teams and access departmental and campus resources.

Two pedagogical theories, as well as broad themes suggested by early surveys of faculty and administrator experience during the sudden transition to emergency remote teaching and learning [1, 2] set the foundation for many of the teaching strategies previously used and newly implemented in the 2020-2021 academic offering of BAE 402/403 Biosystems Engineering Design I/II. Prior to the COVID-19 pandemic, the implementation of the Senior Design courses

was supported by aspects of Constructivist pedagogical theories, where learning is built upon prior knowledge and students create their own understanding of the conceptual framework of engineering design by actively engaging in the design process [3, 4]. The instructors still wanted to provide an environment where students could explore topics and projects of interest within the restriction imposed by health and safety guidelines. Post-COVID-19 pandemic, viewing course design and implementation strategies for a course like Senior Design through the lens of trauma-informed pedagogical theories and educational practices may also prove beneficial moving forward. The authors would like to note that trauma-informed pedagogy is different from teaching trauma itself [5], and more about bringing an awareness and sensitivity in their approach to certain topics as students and instructors process the dramatic shifts in normalcy over the course of the last year. For example, projects related to COVID-19 were readily proposed for the 2020-21 academic offering. However, the instructors debated whether inclusion of COVID-19 related projects would be viewed favorably by students. Ultimately, the instructors concluded that students were already living in a very restrictive environment and did not want to unintentionally impose additional stressors and anxieties for an entire academic year on students by requiring they immerse themselves in more COVID-19 information. While the topic is extremely timely and of urgent concern, the instructors felt it would make it even more difficult for students to distance themselves from it and protect their individual mental health.

Course organization. The course LMS played a much more critical role in the course organization moving forward, which appears to coincide with faculty responses nationally. According to data from early surveys compiled in a report by Every Learner Everywhere, nearly 90% of faculty said they relied more heavily on their course LMS during the transition to remote learning, with first-time users highly likely to continue using their course LMS [1]. This favorable response nationally highlights the power of the course LMS as a digital tool when it is implemented well. For the 2020-2021 academic year, course content was developed and organized into modules on the course LMS, including treating some of the content more like new employee orientation or on-boarding procedures (Figure 2). For example, students were required to complete an orientation module, a lab safety training module, and a purchasing training module at the beginning of the second semester. Similar activities were also required for relevant information at the beginning of the first semester. For instance, the Orientation module provided guidance to students for organizing their work and other helpful tricks and tips for a successful Senior Design experience. Additional modules used across both semesters included a Final Deliverables module, a Resources module, and a FAQs module to group essential information in one common location. One benefit of presenting information in this manner was its accessibility to students for the duration of the course anytime they needed to reference it. These modules also added structure and organization to a course that can feel very unstructured at times for students.

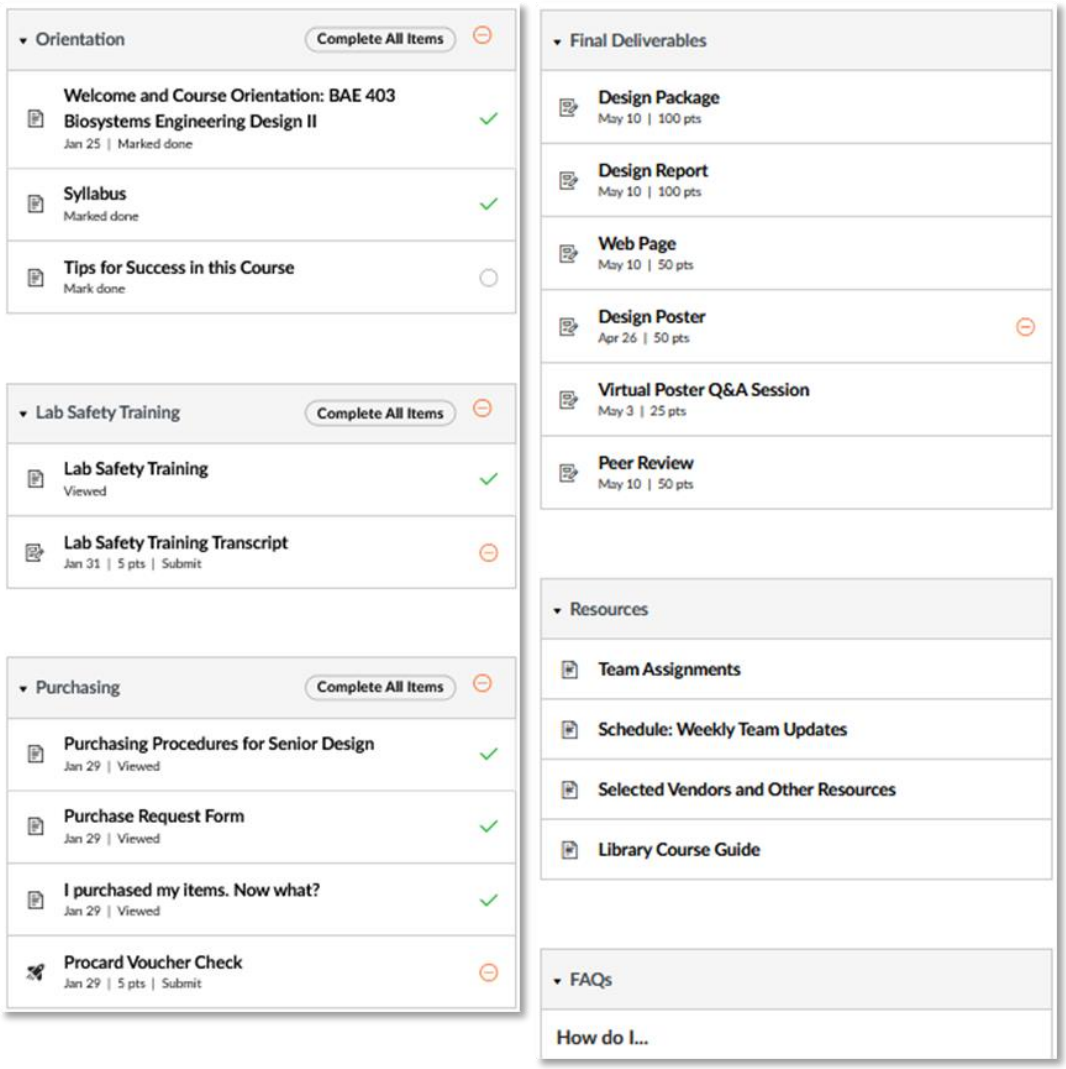

Figure 2. Orientation (left) and Resource (right) modules developed for second semester course of the senior design sequence posted on the Learning Management System (LMS) [6].

Project selection. Moving into the 2020-2021 academic year, the instructors cautiously accepted project proposals from collaborators. The instructors felt it was critical to have a selection of projects that could easily transition to remote work to accommodate students in the event the University of Kentucky returned to exclusively remote work, for students who were weary of attending in person classes and activities, or for anyone who needed to quarantine. Project topics, as mentioned previously, were also carefully selected to remain sensitive to student needs.

While project selection for the 2020-2021 academic year also took into consideration fabrication requirements, further discussion on the topic between the instructors led to the conclusion that implementing a remote fabrication model going forward may mimic a reality that many students could encounter in the workplace. It is reasonable to believe that developing a design and sending it out to be built is a valuable “real-world” experience for students, that also has the

added benefit of mitigating the inequities of limited access to resources that was observed in Spring 2020.

Digital, cloud-based resources. Use of an online, cloud-based CAD software program accessible by Mac and PC users across teams ensured all students would be able to access drawings from anywhere. While in theory, the use of cloud-based CAD software would address the primary issues with software access and sharing of models, lack of consistent hardware and network resources remained a significant bottleneck. The ability to share files improved communication among team members, as well as with the instructors. This change was another pre-emptive measure taken by the instructors to keep the teams functioning in case of widespread shutdowns or isolations, which seems to be in line with a majority of faculty nationally. Nearly 60% of faculty indicated they planned to adopt digital tools for fall 2020 courses [1].

The instructors also briefly considered transitioning to electronic design notebooks. However, the instructors decided to keep physical design notebooks for now and are continuing to investigate electronic options for future use.

Other communication tools for consideration. The instructors are still investigating other tools to ensure clear and consistent communication with teams. Currently, the course LMS is used for general announcements for the whole class. Gmail accounts are created, and project websites are developed with that Gmail account. The instructors also communicate with teams individually through their Gmail account. However, the instructors find that students do not regularly monitor those email accounts, so essential information can go unseen for extended periods. It also introduces yet another platform that students must monitor and use, adding to the confusion of which accounts to check. The instructors are considering other options like Microsoft Teams or apps like Slack to consolidate all lines of communication and act as a file sharing platform. It is likely that these skills represent a new reality in the workplace and changes in the capstone will better reflect the emerging distributed workplace.

Conclusion

For the instructors, this past year has been an exercise in being creative, thinking quickly but critically about the types of experiences the students deserved, and working collaboratively with students virtually and in person to ensure they still received a quality capstone experience. While no formal assessments have taken place of the changes implemented, the authors hope that these initial reflections will be a starting point to foster discussions more broadly with stakeholder and advisory groups about what the capstone experience could become at the University of Kentucky.

References

[1] K. Fox, G. Bryant, N. Lin, and N. Srinivasan, "Time for Class – COVID-19 Edition Part 1: A National Survey of Faculty during COVID-19.," *Tyton Partners and Every Learner Everywhere.*, 2020.

[2] N. Johnson, G. Veletsianos, and J. Seaman, "U.S. Faculty and Administrators' Experiences and Approaches in the Early Weeks of the COVID-19 Pandemic," *Online Learning*, vol. 24, no. 2, pp. 6-21, Jun 2020.

[3] A. Parmaxi and P. Zaphiris, "The Evolvement of Constructionism: An Overview of the Literature," in *Learning and Collaboration Technologies: Designing and Developing Novel Learning Experiences, Pt I*, vol. 8523, P. Zaphiris and A. Ioannou, Eds. (Lecture Notes in Computer Science, 2014, pp. 452-461.

[4] A. Weimer, *Learner-Centered Teaching: Five Key Changes to Practice*, Second ed. San Francisco, CA: Jossey-Bass, 2013, p. 287.

[5] J. Carello and L. D. Butler, "Practicing What We Teach: Trauma-Informed Educational Practice," *Journal of Teaching in Social Work*, vol. 35, no. 3, pp. 262-278, 2015.

[6] A. Modenbach and M. Peterson, "BAE 403 Biosystems Engineering Design II Orientation Modules," ed. University of Kentucky Canvas, 2021.