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Active Learning in Physics and Engineering Through UAV and Data Analytics

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Active Learning in Online Education for Engineering and Physics Through UAV and Data Analytics

1. Introduction

Research into the fields of unmanned aerial vehicles (UAVs), unmanned aircraft Systems (UAS), and remotely piloted aircraft (RPA) continues to steer the advancement in many related areas. In particular, the development of UAVs promotes research in composite-based additive manufacturing technologies and materials, more sophisticated means of communication for non-stationary devices, automation, advances in agricultural techniques and product supply chain. For example, NASA presented drone design improvements to entrepreneurs and businesses as a means to propel the field and create fuel efficient UAVs [NASA 2019]. In terms of manufacturing, the Department of Defense (DoD) is seeking to establish a domestic supply chain for the manufacturing of lightweight drones and continues to partner with universities, private companies and programs such as Manufacturing USA for the development of drone related technologies [DoD 2019, FCW 2019].

Developing manufacturing techniques for UAV production and producing a highly skilled workforce is a global concern, particularly for the US. It is estimated about 15% of the drones used by the Department of the Interior (DOI) are manufactured entirely by Shenzhen-based DJI, the world's largest supplier of drones, while the remainder are primarily constructed in China or contain Chinese-made components [Fortune 2019]. Investment into this area of research and manufacturing continues to attract companies such as Lockheed Martin, who is investing in the development of optionally-manned and unmanned systems. In 2015 DJI, received an investment of $75 million dollars, increasing its total valuation to $10 billion. Similarly, a report by the Congressional Research Service in September 2015 estimated that by 2025 worldwide production of unmanned aircraft systems would rise from $4 billion to $14 billion annually. [Global 2016] Hence, a capable workforce of designers, researchers and engineers are required as the field progresses forward.

Although, the U.S. Bureau of Labor Statistics (BLS) has yet to begin reporting the statistics for employment related to the production and piloting of drones and related components, companies in the sector see the need for a highly skilled workforce. The Federal Aviation Administration (FAA) predicted that in 2020 the market for UAV pilots would quadruple and further stated that there would be a need for over 300,000 more as demand increased. For example, industries not usually thought to be associated with advances in technology are being transformed by UAVs with related UAV employment opportunities arising: Real Estate, Construction and Mining, Filmmaking, Public Safety, Insurance, Agriculture, Energy, and Telecommunications.

Currently, the Amazon Corporation is developing a UAS and is seeking to implement UAVs into their supply chain. In 2016 a model of this system was created to address FAA regulations, drone design, logistics, and related factors to determine how Amazon would construct, initiate, and operate the drone system [Sudbury et al., 2016]. In their findings, Sudbury and Hutchinson concluded that such a venture would be feasible and that a UAS would cut current delivery cost by a third when compared to ground delivery cost while excluding the cost of research and development. Most recently, as a result of Covid-19 in June of 2020, it was reported by CNN and the Washington Post that the drone service Wing from Google's parent company Alphabet collaborated with a Virginia librarian to deliver library books to students in Christiansburg's Montgomery County Public School district using drones [Elassar 2020].

We make note of the work of M. H. Sadraey in his 2020 publication on UAV education [Sadraey 2020]. Sadraey outlines techniques and challenges he discovered while presenting construction techniques of UAVs in a traditional classroom setting. Here he states that, "The root cause for the lack of convergence between UAV education and practical application is the absence of experiential learning. The UAV experience requires students to develop skills such as … in data reduction, analysis, communication, and teamwork."

This paper presents the first phase of our experience with a two-phase project addressing the teaching, implementation, and assessment of online active learning modules in undergraduate introduction to engineering and physics courses designed to engross students in the process of advanced manufacturing principles and techniques for constructing and analyzing UAVs. Our courses guided students through producing working solutions by having them perform a series of virtual design, hands-on manufacturing and analysis exercises developed specifically to apply cutting-edge industry techniques with course modules.

2. Introduction to Engineering and Physics II

Engineering is a discipline dedicated to problem solving. It is the designing, testing, and building of machines, structures and processes using scientific principles with a more specific emphasis on particular areas of applied mathematics, applied science, and types of application. Whereas physics is a discipline that is concerned, to a lesser extent, with how such devices and structures based on experiments, measurements and mathematical analysis react to internal and external forces acting upon it by finding or applying quantitative physical laws.

Technology owes its practical successes to discoveries achieved by scientists with purely theoretical intentions, as in the case of many physicist. It is true that in other cases discoveries have arisen through scientific investigation of technical concrete problems. Thus, the creation or manufacturing of technology must develop through basic investigations in order to solve problems of application. Hence, there exists a continuous exchange between the sciences of physics and engineering [Morón et al., 2011].

Advanced manufacturing methods for UAVs include design analysis relating to the aerodynamic forces of thrust, drag, and lift. Utilizing data gained from applying Bernoulli's principle, the Coanda effect, and Newton's third law of motion, we acquire a more accurate view of the necessary processes involved with constructing designs that are efficient. In relation to efficient structure designs, the field continues to require lightweight composite materials that will need to be tested and provide insight as to the maximum weight and shapes with which UAVs can be used. In addition, the appropriate weather conditions which can be withstood is also a factor. Carbon fiber-reinforced polymers (CFRP) are the primary material used in the construction of the UAV frames. In comparison, a structure made of steel approximately weighs five times more than a CFRP structure with similar strength. The creation of new lightweight composites is already being applied to the design of other vehicles [Prucz et al., 2013].

In the supply chain for the manufacturing of UAVs there is also a need to ensure that the production is compliant with design specifications. We define the four stages of the (advanced) manufacturing process as such

1. Development
    a. Research
    b. Analysis
2. Baseline Systems
    a. Prototype
    b. Design
3. Production
    a. Planning
    b. Testing
4. Logistics
    a. Delivery
    b. Support

3. Introducing Advanced Manufacturing through UAV Construction and Analysis into Existing Undergraduate Introduction to Engineering Courses

We have introduced advanced manufacturing modules in undergraduate introduction to engineering and physics courses that focused on techniques for constructing and analyzing UAVs. During this project, a fucus on the development, baseline systems, and production stages of the manufacturing process was necessary to develop a cohesive flow between the two phases we outline. Emphasis was placed on the specific role each respective course plays within the process and stressed during the respective phases. The modules were introduced into our undergraduate course, *BME110 Introduction to Engineering,* during the 2020 academic year as part of Phase I and will be implemented into our *PHY211 General Physics II* during Phase II.

Given the transition to online (synchronous and asynchronous) and hybrid courses, the development of an online synchronous format was necessary for each course. Our undergraduate *BME110 Introduction to Engineering* course began with this as the core idea of its lecture and modules. As mentioned, in order to immerse students further into the process, the project consisted of two phases. In this, the first phase, students were provided with an introduction of basic engineering concepts through design, fabrication, and testing of economically produced quadcopters. The project provided students an opportunity to apply basic techniques already acquired or those closely related to topics outlined in the course syllabus.

Concepts were carefully disseminated into two parts: the theoretical and functional. Ideas behind the advanced manufacturing process under discussion were introduced in the first part of the module(s) as well as defining the relationship between engineering topics covered in the curriculum; whereas the active online experimentations were introduced in the second part of each module(s) focusing on preliminary engineering concepts and techniques such design and design rationale, durability, and other topics needed to build the UAVs. The students were advised to use SoildWorks or TinkerCad to make slight adjustments to the general design of their projects. The students could also use MATLAB to collect, store and analyze their data depending on the level of programing experience each student possessed, or MS Excel to a lesser extent.

We began by examining the curriculum for the *BME110 Introduction to Engineering* course to determine what concepts the students would be introduced to throughout the course and how various concepts could be naturally expanded upon within a discussion on advanced manufacturing by the use of UAVs. A pretest was presented prior to any discussion pertaining to advanced manufacturing and the construction or analysis of the UAVs.

Since Phase I involved an introductory course, students were beginning to understand key concepts of engineering and some were simultaneously enrolled in the materials course. We focused on the fundamentals of design, structure, and analysis of circuitry. This paired nicely with the development, baseline systems, and production stages of the manufacturing process. The majority of the class had recently completed the Calculus III and Differential Equations for Engineers course and had rudimentary knowledge of how differential equations could be utilized in the understanding of basic circuit components.

3.1. BME110 Introduction to Engineering

The following Advanced Manufacturing lectures and lab modules implemented into the existing introduction to engineering course: During the lecture, students received a brief review of the topics previously discussed during the semester that would be necessary for an understanding of the labs. This further provided a practical connection to understanding the Advance Manufacturing process. To begin, a formal definition of “Advanced Manufacturing” that best fit an engineering viewpoint was provided, the use of innovative technologies to create existing products and the creation of new products. Advanced manufacturing can include production activities that depend on information, automation, computation, software, sensing, and networking. Students were then provided with the definition of a UAV. Depending on the progression of the lecture a variety of topics were covered, beginning with composite and multiscale composite materials, frame design using a CAD based program, 3D printing, simple circuit board assembly coupled with soldering techniques and measuring voltage, resistance and current with a digital multi-meter (using a java applet(s)).

Each course received one lab and a discussion/results presentation period associated with the aspect of UAV manufacturing. The lab for the *BME110 Introduction to Engineering* course revolved around applying several of the design and building methods discussed during the lecture and included analysis of circuits and currents by employing Kirchhoff's second law on a prepared model and then compare those results to those observed using the multi-meter through simulation, given the online format of the course.

After being partitioned into groups, the students were allowed to work in virtual breakout rooms provided to them or allowed to arrange for themselves a virtual meeting through other means so that they could collaborate on the “take-home” project(s). They were asked to implement their designs and construct a 3D model of their UAV. The virtual meeting for presentation of each group’s model allowed for class discussion and analysis of their initial drone designs in an effort to construct more efficient UAVs. Students were allowed to design, and 3D print various components through their instructor.

During the discussion and review session, students would compare their devices and discuss open-ended questions related to the project and the manufacturing process. Preliminary questions were listed on the modules as, “Class questions for discussion.”

Students were evaluated based on the project rubric which contained the following categories for scoring: Technical (UAV design; Functionality; Durability/Robustness; Sufficient Justification for design), Preliminary design review, Evidence of teamwork, Design Notebook, Ethics Component, Presentation (Clarity; Appearance; Knowledge; Answered questions clearly and confidently), and Most Creative/Innovative (BONUS).

4. Results

From spring 2019 to spring 2021 semesters, Alabama State University faculty developed advanced manufacturing modules aimed at integrating theoretical concepts with those of application in a meaningful way for our students to engage and learn in a virtual environment utilizing current education and industry practices. These modules were implemented into the existing engineering courses and evaluated their effectiveness through pre- and post-tests. In addition, students in all offered classes were asked to complete a survey pertaining to their coursework, confidence in using advanced manufacturing modules in their classes, and strategies they use to learn in their *BME* courses.

4.1. Student Knowledge

The cohort for which the total results from both phases will be compared to in order to determine a modicum of student advancement, will be that of the benchmark which consisted of a total of 60 students who completed both the pre- and post-test. The data from pre- and post-test was used to accurately assess advances made by students after completing these modules. In the designated class, there were students that failed to complete the pre, post, or both tests. Based on earlier work, we conjectured that the scores on the pre-tests would average around 30% while their scores on post-test would be averaging around approximately 70% on the post-tests with a 95% confidence level.

P value and statistical significance:
The two-tailed P value is less than 0.0001
By conventional criteria, this difference is extremely statistically significant.

Confidence interval:
The mean of Pre-Test minus Post-Test equals -40.000
95% confidence interval of this difference: From -43.442 to -36.558
Intermediate values used in calculations:
t = 23.0142
df = 118
standard error of difference = 1.738

Data Summary:

Group	Mean	SD	SEM	N
Pre-Test	30.000	5.000	0.645	60
Post-Test	70.000	12.500	1.614	60

Figure-1: t-Test Results for Student Knowledge

4.2. Confidence in Using Advaned Manufacuring Modules in Class

In spring 2021, roughly 95% of the overall survey respondents from Phase I were either juniors or seniors. Of all the students 45% were enrolled in the *BME110 Introduction to Engineering* and 55% were enrolled in the Phase II course, *PHY211 General Physics II*, while the intersection of the two courses were found to be empty. Overall, Phase I contained a large number of students who self-identified as male (62.5%), and offered little diversity in terms of race, ethnicity, or disability. All students in Phase I identified as Black or African American (100%).
The results and demographics related with Phase II will be presented in a future publication.

Using a 5-point scale (1=little of no confidence…5=A great deal of confidence),

4.3. Student Academic Efficacy, Motivation and Learning Strategies in BME Courses

Finally, students were asked to respond to survey items pertaining to their level of academic efficacy, motivation and goals in learning course topics, and strategies that they use relating to their *BME* courses.

- <u>Academic Efficacy</u>: Students were asked to respond to five items related to their academic efficacy as it pertains to the BME class in which they were enrolled. When asked to assess their own academic abilities there existed a relative parity between all choices relating to confidence with the exception of one choice presented. Based on what students reported of their confidence in their own skill levels, a positive sign from this data was that no student(s) reported to have "little to no confidence" (on a 5-point scale). Where this denoted the lowest assessment of one's own skill level. Overall, students believed that they would learn if they tried, worked hard, and did not give up. They also believed that they could master the skills and figure out the most difficult class work.
- <u>Goals in BME</u>: Students felt that a number of goals were important to them, of which they felt that the most important was the ability to communicate course ideas to others. The second most important goal was equally split between wanting to satisfy degree requirements and learn new ways of thinking while considering specific procedures for problem solving related to course material. Although, important to them, students indicated that getting a good grade was the least important goal to them.
- <u>Preferred Learning Environments:</u> When asked to specify their preferred course format for leaning 50% of the students stated that a hybrid classroom model was preferred, a structure equally split between classroom and online instruction. Most notable was that none of the students indicated a preference for asynchronous (independent online) learning with 37.5% preferring traditional Face-to-face learning, and 12.5% of students favoring synchronous learning.

  When asked to indicate their perceptions of statements describing different learning environments, students reported the greatest agreement with "the instructor explains the solutions to problems" and collaborative thinking when "placed in groups to work on problems." Students also indicated situations in which they compared their BME knowledge to other students with the majority (75%) stating that they felt that their skills were "on par with others" or near. Students also stated that they studied their notes, explained ideas to others, and worked in small groups. Similar to the benchmark, students were less supportive of having the class critique their solutions, exams that prove their skills and group presentations.

- General Learning Strategies Used by Students: In general, students reported using a variety of strategies in their BME courses. When asked to indicate all that apply when based on their perceptions of statements describing different learning strategies they used. They overwhelmingly reported that collaborative strategies were most important, but "working with other students through platforms such as Group Chat" was the generally preferred strategy with 87.5% of students indicating this. Although, less supportive of finding their own ways of thinking and understanding, receiving guidance from a tutor, or guidance from an instructor, 50% of students considered at least one of these as a strategy they used. In comparison, students were more supportive of reviewing their work for mistakes or misconceptions. Strategies they also reported implementing were "checking their understanding of what a problem was asking", "studying on their own" and "using their intuition to determine what an answer should be."
- Motivation to learn BME - Task Value: Students reported high levels of task value, indicating their confidence in the importance and practicality of course content in their BME classes. Their understanding of BME topics and their motivation to learn BME related content were classified as very important. All students reported that they felt that the information provided by the BME course would be very important to their future career.
- Learning Strategy – Critical Thinking: In terms of learning BME related topics, students reported many strategies that require critical thinking. They reported that developing their own ideas based on course content and evaluating the evidence before accepting a theory or conclusion was preferred. They also reported questioning what they read or hear in class and thinking or possible alternatives.
- Learning Strategy – Self- Regulation: Students reported using many effective self-regulation strategies in their BME classes. Overall, students reported a desire to not give up when faced with a topic they found to be difficult or confusing. In particular, 50% of students indicated they pay "more attention than usual" to concepts that they find confusing and focus "more attention than usual" on studying and material they find challenging.

TABLE I. STUDENT ACADEMIC EFFICACY, MOTIVATION AND LEARNING

Measurement Scale	**Items**	**Reliability**	**Mean (SD)**
Academic Efficacy[a]	5	.493	3.7 (0.87)
Goals in *BME*[b]	10	.907	3.38 (0.97)
Preferred Learning Situations[c]	11	.513	3.14 (1.13)
Learning Strategies used in class (general)[d]	15	.888	4.33 (1.02)
MSLQ- Motivation - Task Value[e]	6	.857	3.27 (0.46)
MSLQ – Critical Thinking[e]	5	.755	4.55 (.83)
MSLQ – Self-Regulation[e]	11	.805	4.05 (1.05)
MSLQ – Time and Student Environment Management[e]	8	.944	3.22 (0.94)

a=5-point scale (1=Strongly Disagree…5=Strongly Agree)
b=5-point scale (1=Not at all important …5=Extremely important)
c=5-point scale (1=Strongly Disagree…5=Strongly Agree)
d=5-point scale (1=Very Seldom…5=Very Often)
e=5-point scale (1=Not True of Me…5=Very True of Me)

- Learning Strategy – Time and Study Environment Management: Students also reported on the management of their time and study environment. They reported attending class regularly, finding a place to study and keeping up with the weekly readings and assignments.

The reliability of these scales was generally supportive, with internal consistency estimates ranging from .493 to .944, with a median of .831. Student perceptions were in line with project projections. Below, a more detailed summary of items from these scales are shown in Table 1.

5. Acknowledgements

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6. Conclusions

This paper presents our experience with the teaching, implementation, and assessment of online active learning modules in undergraduate introduction to engineering courses designed to engross students in the process of advanced manufacturing through the principles and techniques for constructing and analyzing UAVs. The modules were aimed at integrating theoretical concepts with those of application in a meaningful way so that our students could engage and learn in a virtual environment utilizing current educational and industry practices. In each of these module(s) students were introduced to the advanced manufacturing process by employing techniques acquired from their engineering courses in order to better grasp how their classroom acquired skills overlap with the stages of the advanced manufacturing process. We do this by allowing the students to produce working solutions as groups to related tasks and allowing them to perform a series of computer aided design and analysis exercises developed specifically to apply cutting-edge industry techniques with course concepts.

Some observations we not anticipated but enriched the discussions. For example, students reported that project management, in a completely virtual environment, was initially challenging. However, some students reported that the virtual working environment required them to be more attentive to detail, particularly in presenting through a virtual meeting platform where traditional gestures and physical cues could not be utilized while explaining ideas.

References

1. Hall, Loura. 2019. “These New NASA UAV Designs Could Take Your Tech to the next Level.” NASA. December 11, 2019. https://www.nasa.gov/directorates/spacetech/techtransfer/new_uav_designs.
2. “Department of Defense and the Texas A&M University System Co-Sponsor Drone Venture Day To.” U.S. DEPARTMENT of DEFENSE. Nov. 14, 2019. https://www.defense.gov/Newsroom/Releases/Release/Article/2017216/department-of-defense-and-the-texas-am-university-system-co-sponsor-drone-ventu/.
3. Williams, Lauren C., 2019. “DOD Looks to Expand Drone Industrial Base amid Supply Chain Concerns -.” FCW. Aug 26, 2019. https://fcw.com/articles/2019/08/26/dji-drones-lord-dod-williams.aspx.
4. Barrett, Eamon. “The U.S. Interior Department Has Grounded Its Fleet of 800 Drones, Fearing Chinese Surveillance.” October 31, 2019. https://fortune.com/2019/10/31/doi-grounded-china-drone-fleet-surveillance/

5. Forshaw, Peter. "Drone Development in the Manufacturing Sector | Technology." Manufacturing Global. Jul 13, 2016. https://www.manufacturingglobal.com/technology/drone-development-manufacturing-sector.
6. Morón, C., E. Tremps, A. García, and J. A. Somolinos. 2011. "The physics and its relation with the engineering." INTED2011 Proceedings, 5929–34. https://library.iated.org/view/MORON2011THE.
7. Pruez, Jacky, Samir Shoukry, Gergis Williams, and Mark Shoukry. 2013. "Lightweight Composite Materials for Heavy Duty Vehicles." Www.osti.gov. August 31, 2013. https://www.osti.gov/servlets/purl/1116021.
8. Sudbury, Adrienne Welch, and E. Bruce Hutchinson. 2016. "A Cost Analysis of Amazon Prime Air (Drone Delivery)." Journal for Economic Educators 16 (1): 1–12. https://libjournals.mtsu.edu/index.php/jfee/article/view/1512.
9. Joye D. D., Hoffman A., Christie J., Brown M., Niemczyk J., Project-Based Learning in Education through an Undergraduate Lab Exercise, Chemical Engineering Education, Vol. 45, No. 1, pp 53-57, 2011
10. Austin R., Unmanned Aircraft Systems: UAVs Design, Development and Deployment, John Wiley & Sons, 2010
11. Sadraey, M. H. (2020, June), Unmanned Aerial Vehicles Design Education; Techniques and Challenges Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual Online. 10.18260/1-2—35433
12. Elassar, Alaa. "Google's Wing Drones Are Dropping off Books to Students in Virginia Who Can't Go to the Library because of the Coronavirus." CNN. June 6, 2020. https://www.cnn.com/2020/06/15/us/google-wing-library-books-drone-virginia-christiansburg-trnd/index.html.