Using the Entrepreneurial Mindset to Master Kinematics and Human Body Motion in a Biomechanics Course

Dr. Andrea T Kwaczala, Western New England University

Andrea Kwaczala is an assistant professor at Western New England University in the biomedical engineering department. She teaches Biomechanics, Product Development and Innovation, Senior Capstone Design and Prosthetic and Orthotic Devices. She focuses on hands-on labs centered on student engagement and project-based learning. She works in affiliation with Shriners Hospitals for Children where her research focuses in the design of assistive technologies to help people with limited mobility move and exercise so they can explore their world, independently. She has a husband and two young sons and they all love playing golf and adventuring outside together as a family.

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Abstract

Engineering analysis of the human body through kinematics and dynamic motion can be a challenging task that is daunting to undergraduate students. The mastery of dynamics in a biomedical engineering program starts by creating a framework of understanding in dynamics, kinematics, calculus and a strong understanding of anatomy and physiology. Most critically, is to develop a concrete knowledge of joint movement, kinesiology and gait, as well as current technologies used to analyze human body motion [1]. Students then must combine this knowledge with the comprehension of applied forces and muscle mechanics to understand how the body generates power to create locomotion [2]. The literature is significantly lacking opportunities to teach this content while also considering entrepreneurial mindset and applied applications of biomechanics. Educators should move towards a course structure that requires students to apply concepts to project-based learning and think innovatively in the field of biomechanics. Students will greatly benefit from using concepts in kinetics and kinematics in an application that also trains them on business planning, cost analysis of new biotechnology and market analysis. There is a need to introduce engineers to the entrepreneurial mindset which can help to engage students in the course material and become more curious about the world around them. This paper aims to demonstrate how a semester-long human body motion analysis project can teach innovation and business skills in the engineering classroom through the use of an entrepreneurially minded learning (EML) module.

Introduction

It is valuable to implement entrepreneurial mindset in the undergraduate engineering classroom. Often, entrepreneurship courses are taught by business programs and do not focus on engineering applications. This leads to a mismatch where the workforce is composed of business people who lack the technical knowledge combined with engineers without business acumen unable to translate these skills to their engineering domain [3]. Effective modules have been implemented in higher-level engineering courses such as in courses in thermodynamics [4] and aerospace engineering [5] but there are few business technology applications available in the field of biomechanics. Those that are published in the field of motion analysis for applied biomechanics [6] and motion capture design projects [7] could benefit from a more in-depth approach to business and entrepreneurial thinking and could be implemented through a semester long project.

Current teaching practices have demonstrated that project-based learning is more impactful than lecture, or passive instruction [8]. Over 6,000 students in a statics course were measured in active vs. passive learning environments and demonstrated that those exposed to an interactive learning environment performed better than those in traditional (lecture-based) learning environments [9]. Active learning can be uncomfortable for undergraduates because the responsibility of learning is placed on themselves. Students often complain of a sense of disorganization and lack of structure in the classroom due to the open-ended nature of projects and discussions. This is all despite demonstrated improvements in performance in these types of classrooms. Unfortunately, active learning is often linked with reduced student evaluations and lowers student perception of professor competence [10]. For tenure-track faculty some caution should be taken in new module development when considering these external factors. In order for a semester-long project to be implemented successfully, the instructor must provide organized content with clear rubrics, templates and schedules. Despite its challenges, active learning approaches can have major beneficial impact on student outcomes.

The project goals should align closely with course material and promote student engagement. An atmosphere of collaboration and active faculty role-modeling entrepreneurial activities needs to be implemented [11]. Careful analysis of student learning outcomes is required [12] [13], which can help to make connections between analytical data and experimentally acquired data. A project that provides hands-on learning can help to solidify core engineering principles and help students collect, interpret, and then synthesize biomechanical results. In this environment, students no longer learn by memorization or theoretical calculations, they learn through observation of their own body movement through testing and experimentation. This provides a rich environment for innovation as well as improved comprehension in the field of applied dynamics. Students need to be provided structured assignments and lab experiences early in the semester and gradually lead to independent learning to gain confidence in their knowledge base [14]. Technical feedback should be given often and throughout the semester, and can improve the quality of the final output.

For this module to work, a major key to student success was to allow them to choose their own topic of interest, and the freedom to plan the study based on their interpretation of best practices and crucial measures of human body performance. This allowed students to foster their curiosity and engage more genuinely with the content. This is a key principle in the entrepreneurial mindset because an open-ended experimental design project allows students to foster creativity. Students should be given ample opportunities to innovate through brainstorming techniques and applications. Team work allows creativity in troubleshooting and problem solving, as well as planning and executing student-led experimental design. Mavromatti et. al also demonstrated the importance of student-selected projects to help with motivation and personal interest with the subject matter [6]. In this module. student feedback demonstrated the importance of student-selected projects: "*I liked how we had freedom to decide what we wanted to do for our human performance project, it makes the work more fun and felt more like a personal success once it was done.*"

The integration of EML helped to broaden the focus of the project beyond the technical engineering application. This is becoming more feasible for faculty to deploy through shared resources via on-line modules from collaborative instructors with like-minded teaching goals. Well organized EML online-modules such as elevator pitch makes deployment easy to implement in the engineering classroom [15]. In this semester-long project, students were introduced to new engineering topics in lecture, they practiced techniques in mini labs, and then applied the knowledge to their project while considering the entrepreneurial mindset at every step. In this paper, we hypothesized that an EML module that utilized a project-based approach would improve student engagement, improve technical laboratory and writing skills and foster student's curiosity to learn about human body motion. This project led to a mastery in kinematics, kinetics and human body motion technology with a stronger understanding of the entrepreneurial mindset.

Course Structure and Module Implementation

The new EML module is a semester-long project that runs as part of a required 3-credit course titled Biomechanics II (BME 451) at Western New England University, a small undergraduate engineering school with class sizes between 20-30 students. The course is intended to educate senior-level biomedical engineering students on dynamics of the human body, kinematics, kinetics and anthropometry, with a strong emphasis on human physiology and locomotion. The course met 3x per week for 50 minutes per class. The Friday class was used primarily for project-related activities including mini labs to introduce lab equipment, troubleshooting and data analysis techniques. The Biomechanics II course is also supported with a 1-credit Biomedical Engineering Laboratory course with a 4-hour time block that meets 1x per week.

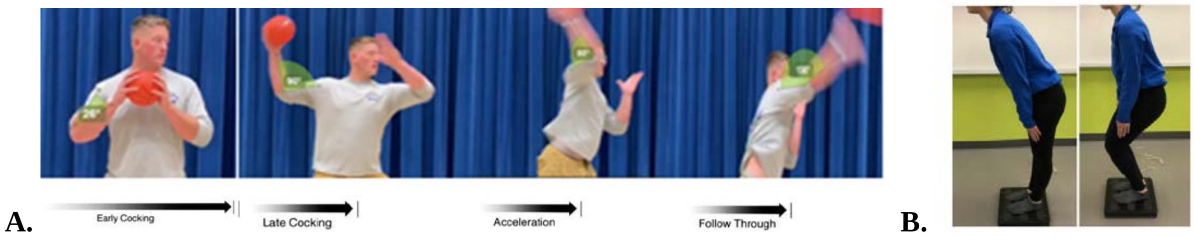

Figure 1. Impactful biomechanics projects teach kinematics of joints, kinetics and balance using motion analysis and force plates. A) Students utilized Kinovea to analyze the football throw for a typical 2-D dynamics using motion analysis software. B) Students learned kinetics and balance using force plates.

The EML module was designed to allow students the chance to design and execute a study in which they studied kinetics and kinematics of the human body in motion. They were introduced to motion analysis technology, sensors and data acquisition of physiological systems and experimental design for human subjects testing.

They used video analysis, force plates and digital goniometers to collect dynamic signals. Joint motion was recorded by digital goniometers (PowerLab and LabChart software, ADInstruments, Co, Colorado Springs CO) [16]. Video analysis was conducted using iPhones with Kinovea software (Open Source, Kinovea.org) [17]. Kinetics was incorporated using walking/running/balancing on force plates (PASCO, PS-2142, Roseville, CA) [18]. An example of a student experiment includes the dynamic analysis of the elbow joint during a football throw (Figure 1a). Project topics included sports biomechanics including throws (football, baseball, basketball), as well as landing mechanics and balance studies to predict lower limb instabilities in athletes. Clinical topics included simulations of the “Parkinson’s Shuffle”, Cerebral Palsy gait analysis and Multiple Sclerosis effects on balance (Figure 1b).

Lecture topics were required to prepare students. Topics included a review of position, velocity, and acceleration with an application-based lab module to measure joint angle motion (50 minute lab, Kinovea and goniometers) as well as measurement of energy consumption and body power and absorption (50 minute lab, force plate lab). Finally, a common theme throughout the class was to utilize biostatistics. Students were given thorough training and learning opportunities on proper data collection techniques. There was a strong emphasis on design of experiments, data analysis, data interpretation and effective data

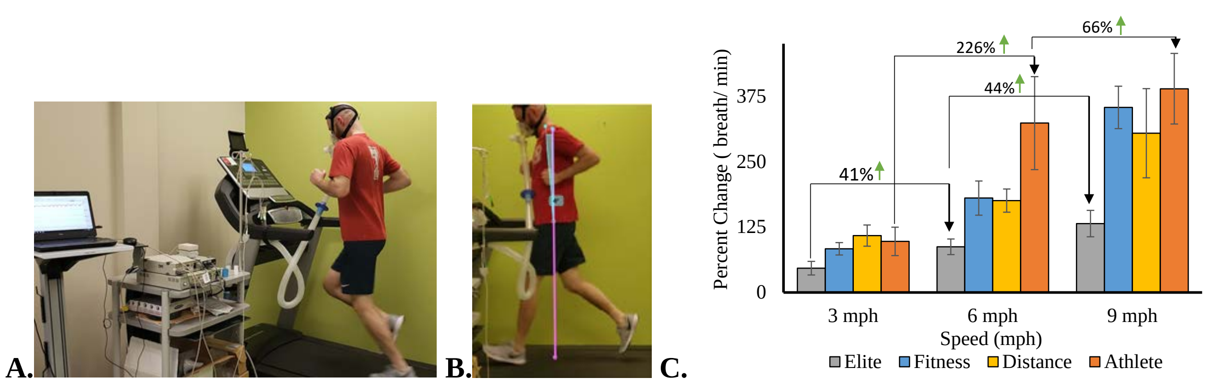

Figure 2. A student-developed research figure from a human performance running study. A) Experimental setup with data acquisition system, physiology respiration equipment (Spirometer) and treadmill. B) Kinovea anterior-posterior tilt analysis. C) Change in breathing rate versus speed. The change in breathing rate from resting breathing rate at three speeds 3 miles per hour (mph) 6 mph and 9 mph of four runners: fitness runner, athlete, elite and long distance runner, n=15 breaths/ trial/subject (Two-Way ANOVA: participant: $p<0.05$, speed: $p<0.05$, interaction: $p<0.05$)

presentations using high quality figures. This allowed students a chance to practice these scientific skills, but required several graded draft submissions with instructor feedback along the way. A sample of a high quality figure created by students is provided in Figure 2.

Business Skills in the Engineering Classroom

In addition to the technical content of the project, students were required to think entrepreneurially. Business content included a brief market analysis report (3-4 pages), and training on how to use scientific data to promote the value of a product through an elevator pitch to stakeholders. A continuous conversation on entrepreneurial thinking was embedded within the course. The instructor used personal examples from their own research endeavors in motion analysis technology to promote the mindset. Modeling entrepreneurial behavior and providing concrete examples of the applications was key to successful implementation for a topic that was relatively unknown to the students.

Students developed a reimbursement strategy and built a financial model to build a lucrative human body motion technology application. Transfer of biotechnology from clinical applications to sports biomechanics was demonstrated using the partnership model from Connecticut Children's Medical Center (CCMC). In the Motion Analysis Laboratory at CCMC, a clinical lab has been transformed to also allow utilization of equipment for sports performance testing. This gait lab is common in clinical practice, for instance to monitor orthotic treatment for Cerebral Palsy patients. In the typical use, the lab services are paid for through insurance reimbursement. The Biomedical Engineer, or Biomechanist, who is responsible for running that lab has implemented his own novel use of the technology and developed a new business opportunity for the hospital. The motion analysis lab now provides a pay-as-you-play sports biomechanics analysis for baseball pitchers and golfers to monitor sports performance, injury risk and prevention [19].

This business structure model was explained to the students and then applied to their own projects. Students were provided CCMC's business plan, and then conducted an independent online exploration of the business model from the lab's website (and other labs across the country) to better understand the cost analysis of the sports biomechanics application. The introduction of business lectures in a technical course provided an opportunity for engineers to learn how their research and innovation could integrate into a financially lucrative investment opportunity. Additionally, company valuation and market size were discussed for large companies that develop motion analysis technologies such as Fitbit, Vicon and Qualysis through in-class lectures. Students were educated on how to research information on the size, value and stock price of a company, and introduced to the assessment of its valuation in order to determine investment size, and return on investment from potential investors.

In conclusion, the students were required to write a 4-page business plan that summarized the market size, and the cost analysis of their proposed application. They wrote about a brief reimbursement strategy to recoup costs and create a sustainable revenue stream to support their novel biomechanics lab or analysis system. The timeline of the deliverables is described in Table 1.

Creativity and Innovation in Teams

Part of the entrepreneurial mindset is to provide opportunities for students to demonstrate curiosity about the changing world around them. Students selected projects based on an interest in the topic, and self-selected into teams of 3-4 students. This led to a stronger personal connection with the topic that facilitated learning biomechanics through a project-based approach. Students were given ample opportunities for creativity in the design process as they worked together to develop an experimental design, execute the experiment and troubleshoot laboratory equipment and to develop unique ways to promote their new technology. The project was open-ended, with the only requirement that students had to use the laboratory equipment to study the human body in motion.

Table 1 Timeline of course material, lab experiences and project deliverables for an Entrepreneurially Minded Learning (EML) module delivered in a 1-semester Biomechanics course.

Timeline (Week)	**Course Topic**	**Deliverables**
1	Dynamics Lessons	Lecture
2	Kinovea, Video Analysis: Joint Motion	1-page Report *
3	Kinematics	Lecture
4	Digital Goniometer: Joint Motion	1-page Report *
5	Kinetics	Lecture
6	Force plates and body power	1-page Report *
7	Design of Experiments (DOE) and Biostatistics	Lecture
8	Project Proposal	Scientific Proposal (3-pages) IRB, DOE, Preliminary data included
9	Elevator Pitch	Lecture, Pitch writing workshop
10	Market Analysis	Elevator Pitches – Technical and Business
11	Reimbursement Strategies	Lecture
12	Data Collection and Validation Testing	Preliminary Data Report*
13	Business Proposals	Final Elevator Pitches
14-16	Project Working Time	Final Report (4-6 pages, IEEE) Market Analysis Report (3-4 pages)

*Format: IEEE abstract

Additionally, the students were required to develop an engaging elevator pitch targeting 1) a scientific investor with a deep understanding of motion analysis technology: Biomechanist from local hospital and 2) a non-technical investor: Mark Cuban, a businessman with an interest in sports biomechanics and self-made billionaire. Students developed novel company slogans and hook statements to allure investors into their product. They were required to learn more about their potential investor and to think of creative ways to entice them to invest in their design ideas. The pitch module was successful by implementing an on-line learning module provided by New Haven University, a partner and collaborative institution [15]. The student performances were thoughtful, clever and memorable and required a high level of creativity.

This led to development of business plans that helped to distribute the technology to unique market spaces. For example, students worked to develop high school summer camp sports programs, and telehealth medicine apps to monitor aging patient populations from the comfort of their own home. Students conducted actual phone interviews with local sports teams and athletic directors to identify interest in diagnostic technologies. One student group contacted several local hospitals to determine if there was budget allocation for motion analysis technology within their organization.

Some of the most innovative discoveries were made during the technical troubleshooting phase of the project. Teams needed to work together and think creatively to solve complex problems. One student group watched videos to better understand and then to develop a biomechanical mimic of physiological behaviors for the “Parkinson’s Shuffle” which they implemented across a force plate. An innovative design solution was documented in the football study, where they struggled to analyze throwing videos because the arm velocity was too fast using the maximum frame rate available with cell phone cameras. This is a common problem in the best motion analysis technology platforms on the market, and needs to be optimized in a lab setting. These students now have firsthand experience with a real-world biomechanics challenge. To circumvent the problem, students captured all of their iPhone video recordings using the slow-motion setting on the phone in order to analyze relative velocities for each individual's football throw, an ingenious solution to solve a complex problem. Another team worked with Western New England University's baseball team to analyze pitching and independently got access to borrowed Rapsodo hardware [20] from the Athletic Department. They compared their engineering analysis project to characterize baseball pitch performance directly to commercially available technology. This represents just a couple of the project-specific student innovations that were realized throughout the course of the semester.

Engineering Education Assessment

The data collection tool was comprised of a student survey delivered before the start of the module and at the conclusion of the project. Surveys were approved by the Institutional Review Board (IRB) at Western New England University prior to the start of the study. To maintain confidentiality, students were randomly assigned a 6-digit code that was used to pair responses on the pre- and post-module surveys. The surveys consisted of three short answer questions: 1) understanding of a technical aspect of motion analysis data, 2) an opportunity to use motion analysis in a new market and 3) business acumen related to funding sources for early product development. The pre- and post-responses from these questions were scored by the professor using a 1-5 Likert-scale metric in terms of completeness and accuracy.

The survey was quantified by 5-choice Likert-scale questions that prompted students to rate their current level of knowledge regarding various EML skills (Table 2). The survey included questions across all measurement levels of the KEEN entrepreneurial mindset. KEEN is an organization that believes in developing a strong entrepreneurial mindset, and has been working towards improving engagement in undergraduate engineering education. The growing network of educational partners aims to increase the dissemination of teaching resources related to its mission [21].

Table 2 Entrepreneurially Minded Learning (EML) skills were assessed using pre- and post-module surveys. The EML's that were emphasized in this module were highlighted in bold.

#	Skill	0 Low	1	2 Medium	3	4 High
1	**Identify an opportunity**					
2	**Investigate the market**					
3	**Create a preliminary business model**					
4	**Evaluate technical feasibility, customer value, societal benefits, or economic feasibility**					
5	Test concepts quickly via customer engagement					
6	**Assess policy and regulatory issues**					
7	**Communicate an engineering solution in economic terms**					
8	**Communicate an engineering solution in terms of societal benefits**					
9	Validate market interest					
10	Develop partnerships and build a team					
11	**Identify supply chains distribution methods**					
12	Protect intellectual property					

Pre- and post-module responses to the write-in response questions and the EML skills were compared using a paired Two-Sample Student's t-test with a significance level, α=0.05. Student's response to their perception of the module were also included regarding what they learned, what they liked about the module, and what still needed improvement. Student responses were reported in raw form at the end of this paper.

The non-bolded items in Table 2, also represent a way to control for study outcomes. For instance, this project did not teach students about protecting intellectual property.

Results

The EML skills were assessed in the pre- and post-module surveys and compared between subjects. The module was run in the fall of 2018 and in the fall of 2019. In 2018, 22 out of 25 students, or 88%, completed both the pre- and post-module survey. In 2019, 21 out of 23 students, or 91%, completed both the pre- and post-module survey. All 43 students were pooled as all metrics changed similarly in both cohorts (Student's t-test: across cohorts, $p>0.05$).

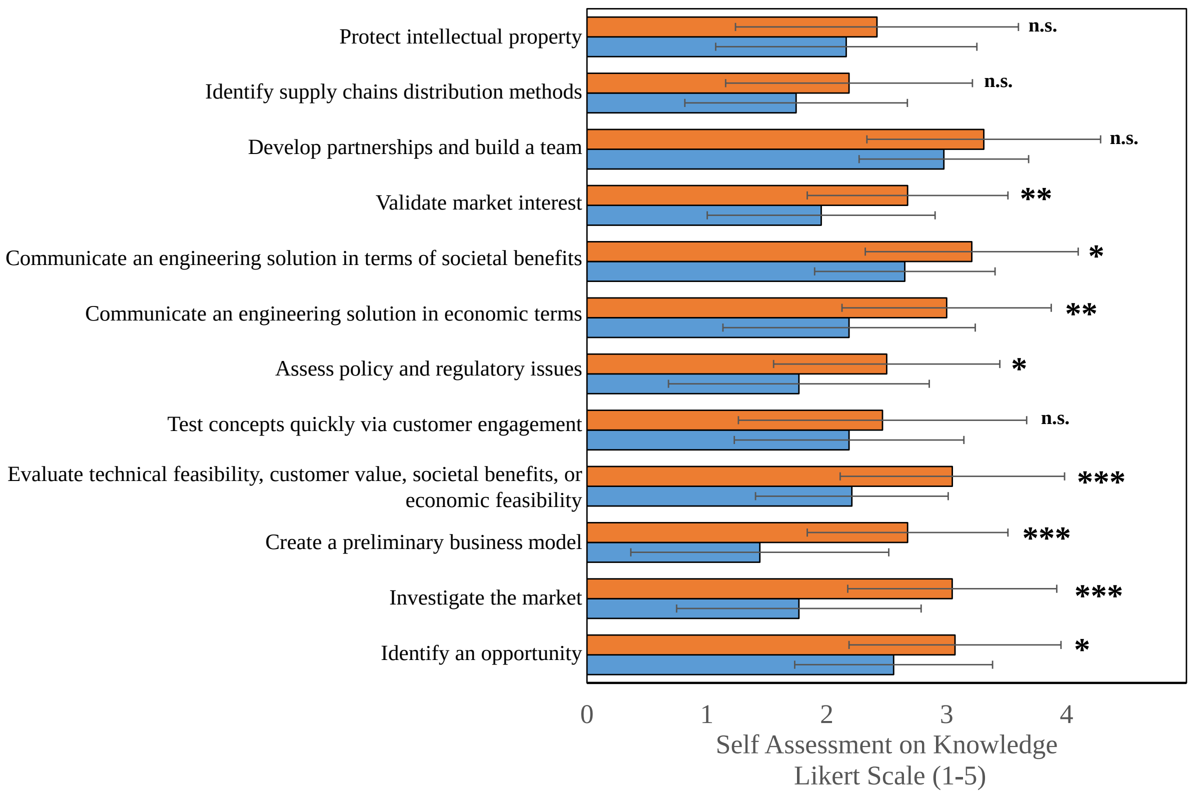

Figure 3. Self-Assessment on Entrepreneurial Minded Learning Skills. Data represents self-assessment scores on a Likert-scale from 1-5, 5-high, data is presented as means +/- standard deviation, for n=43 responses (Two-sample Student's t-test, pre- vs. post-response, *$p<0.05$, **$p<0.01$, ***$p<0.001$, n.s. = not significant).

The greatest improvement in student's self-assessment for entrepreneurial awareness were in investigating the market and creating a preliminary business model with 72%, and 85% increase on Likert-scale scores, respectively (paired Two-Sample Student's t-test, pre- vs. post- module surveys, $p<0.001$). Additionally, the student's sense of ability at evaluating the technical feasibility, customer value and societal benefits or economic feasibility increased by 38% ($p<0.001$). Students improved on their ability to communicate an engineering solution in economic terms and to validate market interest both by a 37% increase in Likert scores ($p<0.01$). Finally, improvements were also measured in ability to identify an opportunity with a 20% increase, assess policy and regulatory issues increased by 41% and communicate engineering solutions in terms of societal benefits increased by 21% ($p<0.05$, Figure 3). All four of the metrics that were not addressed (5, 9, 10 and 12) were not significantly changed and served as a study control (Table 2 non-bold items, Figure 3, n.s. not significant, $p>0.05$). In general, the project was well received by the students and demonstrated improved awareness and ability to think with an entrepreneurial mindset.

Students responded to three short answer questions related to: 1) understanding of a technical aspect of motion analysis data, 2) an opportunity to use motion analysis in a new market and 3) business acumen related to funding sources for early product development. Students demonstrated improvement in all three areas. The technical knowledge score increased by 89% and investor awareness increased by 41% (Student's t-test, $p<0.001$). Their ability to define a new opportunity for using motion analysis technology increased by 23% ($p<0.01$, Figure 4).

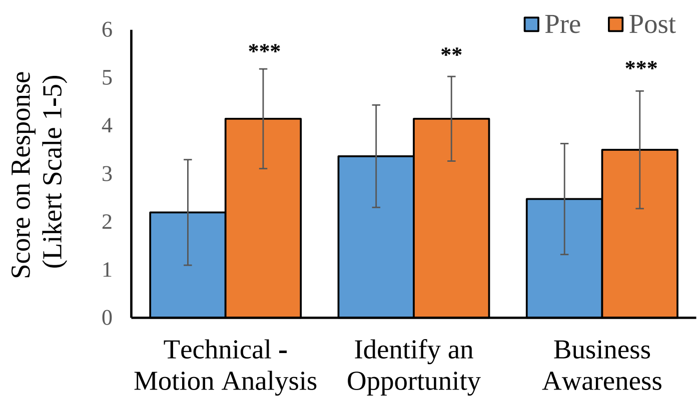

Figure 4. Students Response to Short-Answer Questions. Three specific questions related to a technical aspect of the project, new applications or opportunities for motion analysis and how to get novel technical applications funded were asked in a short-answer response. Student responses were scored on a Likert-scale in the pre-module survey (blue) and after the completion of the project in the post-module survey (red) using a 1-5 Likert-scale graded by the instructor. Data was presented as mean +/- standard deviation for n=41 responses (Two-sample Student's t-test, $^{**}p<0.01$, $^{***}p<0.001$).

Discussion

Keys to successful implementation of this module include providing a fast-paced curriculum in the first 6 weeks of class. Constant connections between the project and core course material needed to be highlighted throughout the semester. High level, and detailed feedback with clear project deliverables, rubrics and templates was provided. Concrete examples, such as the Motion Analysis Laboratory's business model at CCMC, helped to provide clear expectations for the students. In order to deliver in-depth technical instructor feedback to each student group, the faculty member needs to have experience in the field, or be willing to develop competency in research being conducted in sports performance metrics, injury biomechanics, and clinical assessments of typical and pathological gait. Routine project-specific feedback was required for design of experiments, statistical analysis, experimental setup and scientific writing.

The instructor recognized their own limitations at teaching business materials related to market research, cost analysis and valuation techniques. The student feedback identified this as a limitation to the module and improvements should be made by incorporating a business professor into the course in the future. However, this particular module did not have enough business related work to justify a cross-listed course to include business students for a semester-long project. Yet, the course could be improved with well-timed guest lectures from business professors with more knowledge on the topic areas. Additionally, allowing the engineers the opportunity to drive the business content without the dependence on business students.

Students appeared to be most knowledgeable about identifying opportunities in the market prior to completing this module. This was seen in the 3-question response (Figure 4). All faculty in the Biomedical Engineering department at Western New England University are engaged in Entrepreneurially Minded Learning modules in several undergraduate courses and students have previously been exposed to the teaching pedagogy. It is not surprising that compared to the technical knowledge in motion analysis, they had a 53% higher baseline for new market opportunities for a biomedical technology application. This may demonstrate future research opportunities for the department to study the crossover of the EML skills and concepts and how knowledge is transferred throughout the engineering curriculum.

To allow enough student-faculty interaction and data collection time, the project was run in conjunction with a 4-hour lab block that met weekly, with at least 5 weeks of open lab time reserved specifically for working on the project. Early deadlines were critical, and even with assigned documents due no less than 2 weeks apart, the feedback suggested that they were eager to start the project sooner, and would have benefited from earlier deadlines for the market analysis report and scientific proposal. The feedback: "*more dedicated lab time*" and "*Better timelines. Start earlier, emphasis on the time required to complete the project, and clear expectations with realistic time needed*" are important data points. This project and all of the deliverables and rubrics were introduced on the 3rd week of the semester with clear deadlines established in the course calendar.

This may be an indicator of the high expectations set by the professor for the outcomes on the project. This is a large portion of the work conducted in the class, and was given 40% of the weight of the final course grade. It stretches the limit of a typical undergraduate's capability to complete within a single semester. Working in teams was critical, fair division of labor across the group was essential, and this needed to be assessed through teaming evaluations. In conclusion, in the two years this module was run, no group was unable to complete the project by the end of the course. A simple solution to this is to execute the course earlier in the academic program, for instance spring of junior year when students are not also working on senior design projects. This would require major programmatic changes where the dynamics course is taught earlier in the curriculum. This is being considered in order for the comprehensive project to continue in its current form so that it does not interfere with senior design productivity.

It was critical to provide deadlines, grading rubrics, table of contents and templates for all documentation. Most important, was to get the teams collecting data early through a preliminary data submission as part of the scientific proposal due on Week 8 (Table 1). This allowed students the chance to troubleshoot and change direction if results were not attainable. It also allowed the instructor to provide timely feedback on the design of experiments, and feasibility of the completion of the project. Samples of student projects, rubrics, and templates can be seen in the instructor's Engineering Unleashed KEEN Card [22]. The students discussed discomfort and moderate confusion during the implementation of the project. This was most likely because they were learning skills in a style they had not been exposed to, such as trial by error, and open-ended project-specific data analysis. This agrees with others who have reported some of the challenges with negative student perceptions when implementing active learning modules [10].

Upon completion, students preferred the style of learning and found the project tremendously helpful in their synthesis of course topics. This work could serve as an example of how professors can implement entrepreneurially minded learning in a course while still maintaining a rigorous engineering curriculum. For successful implementation, the goal should be to set high expectations for senior-level students, and allow them to rise to the challenge in a project they become passionate about. Ultimately, the instructor needs to ensure students are well-supported, fully engaged in their teams, and encouraged to succeed throughout their active experience. This will ultimately lead to undergraduate students who can master kinematics and kinetics and develop an entrepreneurial mindset in the process.

Student's Open Response to the EML Module

Students open response to three questions related to their perception of the module are included regarding what they liked about the module and what still needs improvement.

Comment on your overall development during this module (e.g., what you have learned, skills you have developed, etc.):

- Learned how to go about new devices being invented and researching
- Was able to walk through the entire process from concept formulation, to designing experiments, market analysis, data acquisition, and analysis and reporting. This was an invaluable experience full of learning opportunities vital for the job market.
- I've learned more about market analysis and the business aspect of the field
- This module definitely improved my research skills about how to investigate a certain topic and what measurements to take, as well as improve technical writing skills
- I have never participated in market analyses or building a business plan, and that is a good skill to have for engineering. This project is what product development is like, or what it is kind of like in the real world
- The human performance project aka module was a good opportunity to learn how to design, run, and report research. There is a lot of work and it is difficult to complete everything on time, learned time management from complex projects
- I learned how to analyze the feasibility of a medical product
- I learned a lot about motion analysis equipment and studies
- How to investigate a market and address the market to benefit a product
- I knew nothing about market analysis at all but now I understand stakeholders and mission plans
- I learned mostly how to do a market analysis
- I learned about design of experiments
- I have learned to analyze human performance through motion analysis devices
- How to look at global impacts of a project
- I learned about motion analysis software and how to use it
- How to do effective testing
- Technical writing for a study performed in class, learned a lot about the struggle of medical staff and developers in dealing with insurance companies
- To work with a team and break down the design of a device and its influence on society, like market
- Understand market analysis/costs, apply prior studies to out data/testing
- I learned a lot about gait and motion analysis. Understand better the process to take data and set up an experiment
- So much exposure to MAC lab and technology. Understand the systems function and clinical component. Learned about CP and other conditions with geometric changes FMS, SFMA. So much clinical and professional development
- I struggled but I really learned about the biomechanics for sports
- My technical writing skills have improved so much plus I have a lot more skills regarding mechanics and body movement
- Feel very confident in using kinovea when looking at motion analysis
- I have definitely improved my technical writing and very good at formatting

- I learned a lot about important stakeholders and how to create and do good elevator pitches
- I think my skills in experimental design and documentation related to research have greatly improved during this semester
- Value proposition, exigency, customer needs
- Overall I have learned more about the engineering to market pathway
- I developed better elevator pitch presentation skills

Please comment on the things you liked about this module, if any, and why you liked them:

- Learning material more in depth than what was learned in class
- Doing the data collection
- Business stuff allows for a well-rounded engineer
- Cool to be able to choose our own research topic to study
- Freedom of choosing metrics to measure
- That we could design our own experiment, that we could pick who we worked with, and how we were very independent
- I liked the exposure to research project because it is different than typical classwork. Additionally working in teams was beneficial
- I liked that we looked at a medical product from different angles (i.e. economic, societal, etc.)
- I really liked how I learned to use kinovea and equipment
- Tying engineering work and business work
- I liked that we designed our own procedure and carried it out to the end
- Learning about biomechanics in reference to sports and how injuries can be calculated and predicted
- I enjoyed learning about how motion analysis can be useful in many scenarios
- I liked using Kinovea and the breakdown of each assignment in the project (i.e. market analysis, business model…)
- It was cool
- The project was interesting and realistic data collection process was good to experience
- Let's you reflect on what I've learned
- I liked the real world applications and going over data analysis techniques
- It was well rounded, showed another side to research
- I liked how we went through the whole process in regards to creating and running a study
- Benefited senior project exploration, technical writing and formatting skills
- Working on real world problems
- Project based class
- I liked how we had freedom to decide what we wanted to do for our human performance project, it make the work more fun and dealt more like a personal success once it was done
- I liked the hands on components that I took advantage of during the module
- We were able to do some motion analysis capture
- I liked having 2 tries for the elevator pitch, the liked the entrepreneurial aspects
- I think the human performance was also a great experience and carrying out a research study
- The idea of this module is fantastic, I like the structure concepts of making engineers more business, like learnt as a senior I think it is a bit late. The module would be more effective if we did this throughout my academic career in college
- I like that the module was hands on and more or less allowed us to move at our own pace
- I liked the project and how much time we had to work and not rush, it gives time to understand and learn techniques

Please comment on portions of the module, if any, that could be improved or changed:

- It's difficult, but more time allowed for creating experiment and gathering data
- Could probably add a portion for business model analysis or example

- Should have been done earlier
- Maybe divide classes for certain portions of the project (one class for data collection, another class for analysis, then writing, etc.)
- I felt a little rushed at the end, but not bad
- Better timelines. Start earlier, emphasis on the time required to complete the project, and clear expectations with realistic time needed
- More explanation on how to write a scientific proposal
- More time could be given. I could have done a much better job if I had more time
- How many different parts there were
- We could do more research into how to find a market, it was kind of guess work
- Data validation should be due sooner, everything should be bumped up in the semesters
- It was a cluster during but looking back it was good
- Better in class examples so there is less confusion
- Some of the due dates got lost in the mix of other things which made for some frantic last minute finishes
- Better defined overall goals of the module
- The length could be shortened and the module could be modified to align with the material more
- I think lectures should be less tense so that the material is better understood by the students
- Clearer instruction, depths of market analysis, ways to do other type of research, techniques to speak less technical especially for senior engineers (4 years of technical words).
- More dedicated lab time

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