Developing an Entrepreneurial Mindset Using the KEEN Framework for a Digital Communication System Course

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Professor John Santiago has been a technical engineer, manager, and executive with more than 26 years of leadership positions in technical program management, acquisition development and operation research support while in the United States Air Force. He currently has over 16 years of teaching experience at the university level and taught over 40 different graduate and undergraduate courses in electrical engineering, systems engineering, physics and mathematics. He has over 30 published papers and/or technical presentations while spearheading over 40 international scientific and engineering conferences/workshops as a steering committee member while assigned in Europe. Professor Santiago has experience in many engineering disciplines and missions including: control and modeling of large flexible space structures, communications system, electro-optics, high-energy lasers, missile seekers/sensors for precision guided munitions, image processing/recognition, information technologies, space, air and missile warning, missile defense, and homeland defense.

His interests includes: interactive multimedia for e-books, interactive video learning, and 3D/2D animation. Professor Santiago recently published a book entitled, "Circuit Analysis for Dummies" in 2013 after being discovered on YouTube. Professor Santiago received several teaching awards from the United States Air Force Academy and CTU. In 2015, he was awarded CTU's Faculty of the Year for Teaching Innovations. Professor Santiago has been a 12-time invited speaker in celebration of Asian-Pacific American Heritage Month giving multi-media presentations on leadership, diversity and opportunity at various military installations in Colorado and Wyoming.

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Abstract

The College of Engineering (CoE) is using the Kern Entrepreneurship Education Network (KEEN) model to develop an entrepreneurial mindset while meeting technical objectives in a digital communication course. The authors attended a three and one-half day meeting called the Integrating Curriculum with Entrepreneurial-Mindset (ICE) Workshop to help students develop an entrepreneurial mindset. [1] During the workshop, the authors developed a set of learning modules focused using KEEN's model. The student must deliver a presentation and a written report focused on the entrepreneurial mindset for a digital communication course, identified as EE 463. Several Entrepreneurial-Minded Learning (EML) activities prepared students for the research project and report. Although the senior and adult students were exposed for the first-time to the KEEN framework, they performed tasks to foster an entrepreneurial mindset based on the following topics covered in six of the eleven weeks: Internet of Things, Light Fidelity (LiFi), Deep Learning/Artificial Intelligence, Smart Everything (Smart Cities, Smart/Driverless Cars, etc.), Bitcoin/Block Chain Technology, and 5G and Enabling Technologies. Each student must summarize their findings in a discussion board for the assigned topic and make at least one connection of a communication system concept studied in class. Their discussion must also include either a business opportunity/business model, economic or social implication. Each student was asked to develop a discussion question to lead a 10-15 minute discussion for the next lesson. The discussion boards are intended to prepare the students for doing the research paper and presentation. An end of course survey and student feedback are presented.

Introduction and Course Description

The College of Engineering (CoE) seeks opportunities to enhance its program curriculum helping students become more successful after graduation. As of October 2017, the CoE's mission is as follows:

"The mission of the College of Engineering is to develop team-oriented engineering professionals from diverse backgrounds who are prepared to ethically apply industry-current real-world skills to achieve value-added solutions in a dynamic world."

During 2017, CoE successfully received an ABET re-accreditation with no interim reports for six years for the BSEE and BSCE undergraduate programs. During the accreditation process, one issue ABET visitors posed a question to CoE paraphrased as: where does the CoE see their students after three to five years beyond graduation? To better address this question for another ABET visit in six years, CoE intends to enrich its program curriculum and equip students with additional skills by incorporating an entrepreneurial mindset.

In September 2017, the College of Engineering (CoE) decided to embed entrepreneurial skills in engineering learning activities for a number of courses throughout the program curriculum, requiring an efficient and integrated process. By incorporating EML in different course sequences such as circuits, electronic design, and communications systems, students will have the opportunity to develop and build up their entrepreneurial mindset.

The CoE already offers elements of systems thinking for complex problems in the capstone courses for undergraduate and graduate programs [2]. However, the engineering students will not only have the technical "know how" when they graduate but will further augment their technical skills with "the why" mindset. CoE intends to incorporate the entrepreneurial mindset in engineering problem solving within the engineering curriculum.

In summary, CoE also intends to address ABET's question about graduates three to five years beyond graduation. CoE's a long-term vision is to graduate students who are inventive engineers providing innovative solutions having economic and societal benefits. With students having an entrepreneurial mindset coupled with their technical skillsets, CoE aims to graduate strategic thinkers creating value for themselves, for their employers, and for society.

To get started, the authors decided to develop two courses for the 2017 Fall Quarter to begin incorporating the entrepreneurial mindset. One of these courses is a digital communication course and the other is an electronics course. This paper will focus on the final course of a three-course communications system sequence.

The course represents a continuation of basic communications theory with emphasis in digital communications. Representations of digital signals are studied along with techniques for digital modulation and multiplexing. The course presents coding theory principles and introduces spread spectrum system fundamentals. Students perform three Matlab experiments for system modeling and simulation of communication system concepts. The technical objectives for the course are given as follows:

- Determine the sampling rate for a continuous-time signal, the spectrum of the sampled signal, and identify any aliasing effects
- Identify and explain the components and functions of a basic Pulse Code Modulation (PCM) system.
- Demonstrate the effects and tradeoffs of Delta Modulation and other variants of a PCM system.
- Explain Intersymbol Interference (ISI) in baseband transmission and explain methods to minimize these effects.
- Demonstrate the tradeoff/performance of basic bandpass modulation systems (ASK, PSK, and FSK) in a noisy environment.
- Explain the fundamentals of spread spectrum techniques.
- Demonstrate error coding techniques in digital transmission methods.
- Apply software design tools to demonstrate the above concepts.

Before describing the changes to foster an entrepreneurial mindset in the digital communication course, the next two sections provides a comprehensive review of entrepreneurial minded learning (EML) from other universities and a description of the Kern Entrepreneurial Engineering Network (KEEN) framework to help students develop an entrepreneurial mindset.

Support for and Review of Entrepreneurial Minded Learning (EML) in Engineering Education

In the past, a curriculum of entrepreneurship education was most likely be found in business schools. With the rapid changes in the world and the globalization in the engineering area, more higher-education institutions worldwide saw the benefits of adopting the entrepreneurial skills into their engineering curriculum. According to Byers, "…beyond technical expertise, today's engineers must possess an entrepreneurial mindset in order to be the innovators of tomorrow." [3]

Engineers need to solve challenging, complex real-world problems. In the article "Engineering the Future", the authors stated that training engineers to take on the challenges of the future and solve complex real problems are the most important contributions that colleges and universities make to advance the human condition [4]. To bring technical solutions to life, students need help to become master learners with an outcome-oriented mindset.

Kern Engineering Entrepreneurship Network (KEEN) lists the following title at their website: "Engineers with an Entrepreneurial Mindset Transform the World". [5] Engineers equipped with an entrepreneurial mindset will understand the bigger picture, recognize opportunities, evaluate markets, and learn from mistakes to create value for themselves, for their employers and for society. KEEN is a 33-plus network of universities and colleges and has continued to grow [5].

Recently, more universities and faculty are engaged to include an entrepreneurial minded learning (EML) into the engineering curriculum. Several universities involved with KEEN developed detailed four-year plan to implement EML in their curriculum. Although not every student will become an entrepreneur after they graduate, having an entrepreneurial mindset will help them become creative and valuable engineers. "EML is not about start-ups, it is about thinking creatively and creating value for society" [6]. However, it is not easy for students to build up entrepreneurial skills within one course or a couple of courses in an already crowded engineering program. Welker, et, al [6] summarized the classes with EML in the four-year Civil Engineering Curriculum at Villanova University. University of New Haven created short, self-paced, e-learning modules into courses spanning all four years of all engineering and computer science programs. They used a flipped classroom instructional model to integrate the modules into courses [7].

More and more universities in the U.S. are trying to incorporate EML into students' learning. Some universities have their own Entrepreneurship Center. For example, MIT has several departments, labs, centers, and over 40 student clubs and initiatives to foster entrepreneurship and innovation. Their educational efforts in this area resulted in having an impressive impact at local, regional, and global levels. "A 2015 report suggested that 30,000 companies founded by MIT alumni were active as of 2014, employing 4.6 million people and producing annual revenues of $1.9 trillion, equivalent to the world's 10th largest economy." [8]

In addition, there is an entrepreneurship center in the Stanford's School of Engineering. The Stanford Technology Ventures Program (STVP) targets to accelerate entrepreneurship education at their university and around the world [9].

Santa Clara University has an aggressive extracurricular program complementing elements of the EML program. Each quarter, they have activities including: seminars, lunch with an entrepreneur events, business and law primer presentations. One highlight of this program is an EML challenge in which teams of students develop ideas based on opportunities they identify in order to validate a market and assess the creation of value. The winner is often offered a "contract" to produce the product for university purposes [10] .

Some schools integrated EML in their course projects. The authors of the paper "Entrepreneurial Mindset and the University Curriculum" applied technology based on dynamic live case study with color graphics animated computer simulation in their entrepreneurial course [11]. The live case study involves multiple student visits to existing companies. Students construct a company supply chain under the professor's guidance. Bilen, et al suggested to provide students with multiple exposures to what it means to have an entrepreneurial mindset [12].

Chasaki described a seven-week mini-project "Cyber Crime Scene Investigation" they reserved in their new course for EML activity [13]. The author found that freshman year is a great time to introduce EML concepts. EML objectives are introduced at the beginning of the mini-project. Students form two groups "hackers" and the "defenders", and rotate roles during the term. Students need to understand what value their business idea brings to table, and how it fits customer's need. Wang introduced how they incorporated entrepreneurial mindset materials in a 10-week and open-ended design project in a first-year Introduction to Engineering Course at Arizona State University. Students list pain points that bother themselves or others, and select their design project. They used a decision matrix with criteria "societal importance, general interest, market need, engineering related problem, number of current solutions, and solution benefit" to help students identify opportunity [14].

Schools applied different technologies when adopting EML. Tabrizi [15] fostered an entrepreneurial mindset in "digital systems" class through a jigsaw-puzzle model. In each lab assignment, they provide students with some components or puzzle pieces as well as the user guide of a digital system. The main EML objective include to "stimulate students' curiosity, instill a feeling of value creation in students, and encourage teamwork, collaboration, and connection." Hoffman [16] introduced how they applied an entrepreneurial approach to a senior design course. In order to simulate the workplace, the entire design class functions as a startup company addressing an instructor generated problem for development of a new product. The University of Florida College of Engineering offers an entrepreneurship course which mimics the real-world experiences of enterprise formation and growth in an academic environment [17].

Universities outside the U.S. also noticed the importance of building an entrepreneurial mindset in their higher education systems. In a paper from Romania, the author mentioned the worry about the country's scores in terms of innovation capability. They are trying to find solutions from promoting technological entrepreneurship through sustainable engineering education. The

paper summarized the top 10 technical and personal qualities of an ideal entrepreneurial engineer. These 10 qualities are: "analytical skills, rigor, communication skills, creativity, logical skills, technical knowledge, economic knowledge, managerial knowledge, reliability and integrity" [18]. There has been a growing concern in Malaysia that the technical students prefer to become job seekers and to be employed rather than job creators. The Ministry of Education aspires to instill an entrepreneurial mindset throughout Malaysia's higher education system. [19].

The KEEN Framework

Following the successful ABET re-accreditation, the authors attended a technical meeting entitled, Innovating Curriculum with Entrepreneurial (ICE) Workshop 9-12 August 2017 [1]. The workshop was held in collaboration with the Kern Family Foundation and Lawrence Technological University.

The main goal of the workshop is to promote student engagement in "the three Cs: Curiosity, Connections, and Creating Value" [20]. Kern Engineering Entrepreneurship Network (KEEN) published the framework at their website as shown in Figure 1. The entrepreneurial mindset plus engineering skillset has been used to develop educational outcomes for several engineering courses.

The text highlighted in yellow are focused on the entrepreneurial skills and the ones with shades of blue are focused on the technical skills (also in white background under the heading 'design').

CoE has already incorporated elements of Active Collaborative Learning (ACL) and Problem – Based Learning (PBL) into its program curriculum with emphasis on the system engineering process and system thinking for either the laboratory-centered or capstone courses [2] [21] [22]. However, adding new Entrepreneurial-Minded Learning (EML) courses in an already packed undergraduate curriculum is a challenge. The authors decided to carefully integrate EML modules in numerous courses as part of the long-term strategic planning to enhance its program curriculum.

"The three Cs: Curiosity, Connections, and Creating Value [20]" found in the KEEN framework are added as course outcomes. CoE included several EML activities to prepare doing the research and presentation. For example, the projects help students investigate the market and communicate technical solutions in economic and societal terms. The paper will provide preliminary results from these activities combining both technical skills and elements of the entrepreneurial mindset.

The EML outcomes are taken directly from the KEEN framework of Figure 1 and given below for the reader's convenience.

CURIOSITY

- DEMONSTRATE constant curiosity about our changing world
- EXPLORE a contrarian view

CONNECTIONS

- INTEGRATE information from many sources to gain insight

- ASSESS and MANAGE risk

CREATING VALUE

- IDENTIFY unexpected opportunities to create extraordinary value
- PERSIST through and learn from failure

The above outcomes were included in each EML assignment module.

For discussion board topics, described later, the KEEN student outcomes that are to be addressed include: (1) demonstrate constant curiosity about the changing world, (2) integrate information from many sources to gain insight, and (3) identify unexpected opportunities to create value.

The entrepreneurial skills from the EML activities (for example: discussion boards, research paper and research presentation, group discussion on priorities, technology rankings and resource allocation) include: communicate an engineering solution in economic terms, communicate an engineering solution in terms of societal benefits, investigate the market, identify an opportunity, evaluate technical feasibility, evaluate customer value, and assess policy and regulatory issues.

Following the experience from the ICE workshop, the authors began to embed their proposed EML modules in several courses for strategic planning purposes starting in September 2017 for the Fall quarter. EE463 Communication Systems II is one course among them.

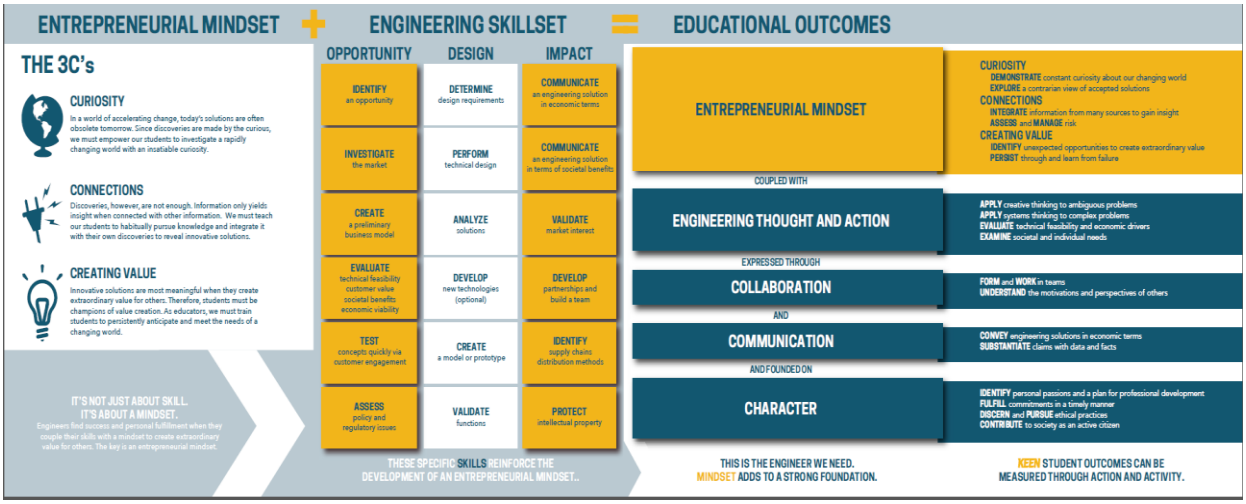

Figure 1. KEEN Framework [23]

Integration of EML Modules in Digital Communications (EE 463)

One month following the ICE workshop, the authors began to integrate and embed their proposed EML modules into their courses in September 2017 for the Fall quarter. This paper will focus on the EML modules and results for a digital communications course, identified as EE 463. EE 463 is the final course of a three-course sequence in communications systems. Student feedback on the EML activities for this course will be given in the paper.

Since these students did not have any exposure to the entrepreneurial mindset in their previous engineering courses, the intent of the EML modules in this course is to have them develop their

entrepreneurial mindset from KEEN's framework. In the EML activities, the intended skills found in the KEEN framework and the 3C's include:

- Address economic viability and drivers
- Creating customer value
- Identifying individual and societal needs and benefits
- Communicating engineering solutions in terms of economic value and societal benefits
- Understanding perspectives and motivations of others (stakeholders, customers, peers, senior leadership, etc.).

Integration of EML Activities and Student Workload Considerations

One concern by the authors is student workload given the amount of required technical deliverables plus the EML activities during the 11-week course. The typical CoE student are adults who have family and work full-time. Most of the evening students take classes at night between 5 p.m. to 11 p.m. In addition, the digital communications course has numerous abstract concepts that are new to students, supplemented with three experiments or projects using Matlab and homework to reinforce learning the concepts. In addition, the authors wanted to retain the technical rigor of the content while adding EML activities. Table 1 shows the percentage of student deliverables before and after integrating the EML activities. Grade percentage weight of EML modules increased from 0% to 24%.

BEFORE		**AFTER**	
Homework/Quiz	10%	Homework/Quiz	10%
3 Exams	60%	3 Exams	51%
3 Matlab Projects	15%	3 Matlab Projects	15%
Research Paper	10%	**Discussion Boards (6 EML modules)**	**9%**
Research Presentation	5%	**Research Paper (EML Module)**	**10%**
EML Modules (none)	**0%**	**Research Presentation (EML Module)**	**5%**
TOTAL	**100%**	***TOTAL***	**100%**
		Note: **Total Percentage of EML Modules:**	**24%**

Table 1. EE 463 Before and After Percentages of Student Deliverables

In Table 1, the reduction of percentage weight of nine percent in the three exams provided room for six discussion boards. Each discussion board is worth 1.5 percent. The reasons for online discussion boards are described later in the paper.

Prior to incorporating the EML modules, students were tasked to deliver a professional research paper and presentation. Students can be based on a topic of their choice to include common communications system or techniques, such as: GPS, Wi-Fi, Satellite Radio, Bluetooth, DSL, Cable TV, and others. However, based on the authors' experience, students usually start their research project one or two weeks before the end of the quarter.

The past pattern of student behavior to procrastinate their research project provided an opportunity for a more structured approach to include EML modules. These EML activities will guide the student to embrace a more challenging open-ended project. What is meant by an open-ended project is that there is no 'school solution' when the research paper is completed.

The new instructions for the research paper project and presentation are given in Figure 2 and these deliverables are due during the last week of the quarter. The text narration in the new instructions came mostly from the KEEN framework, depicted in Figure 1. The narrative was adapted to fit the course description and content of EE 463. The research project intends to increase students' development of entrepreneurial skills to further their career in engineering while understanding research trends in communications.

Research Paper and Presentation Based on Author's Air Force Experience

The idea of the project was based the one of the author's Air Force experience during his twenty-six years in managing technology and acquisition programs. In anticipation of budget cuts throughout the Air Force, technology programs needed to be ranked with appropriate allocation of monetary resources. Due to time constraints from short-notice actions to perform budget cuts, technology programs were usually and equally cut percentage-wise (metaphorically known as a 'peanut butter' cut). For example, if there is a budget cut of 20%, then all programs will be equally cut by 20%. However, this approach to budget cuts may cause the 'promising technology programs' to suffer. Hence, an alternative response to budgets cut is needed. In this case, a prioritization scheme was developed when responding to short-notice budget cuts. When a specific amount of budget cuts was given, then the low-priority programs were appropriately cancelled.

The above 'war story' on budget cuts was explained to students four to five weeks before the end of the quarter and provided additional realism to the research project. In addition, seven of the eight students were either military veterans or active-duty military. They are very acquainted with the phrase: "doing more with less".

The students were briefly introduced on how financial uncertainty impacts capital and technology investments. And hence the prioritization scheme by the students near the end of the quarter is just based on the collective assessment of the organization when anticipating budget cuts. Another way to define risk is in terms of systems thinking or system engineering. In this case, risk can be interpreted when considering the probability of occurrence and its consequence. For example, the engineer would do more system engineering when human lives are involved such as Air Force fighter systems and do less system engineering if a given file becomes lost in a workstation These simple examples is one concept of risk. In the future, the concept or further explanation of risk can be implemented in this course as well as other courses.

The primary objective of the research paper and presentation is to start practicing and learning the entrepreneurial mindset as described in Figure 1 but can be adapted to focus more on assessing and managing risk.

Discussion Boards as EML Practice Space for the Research Paper and Presentation

The authors realize that the propose research paper and presentation, as describe in Figure 2, may be overwhelming for most students at first. More instructor guidance is needed for students to incorporate some of the technical content taught in class and address elements of the entrepreneurial mindset into their research paper and presentation.

To guide students in meeting the requirements of the research paper, discussion boards were added. These discussion boards serve as a bridge and practice space in developing the students' entrepreneurial mindset. Professor Bosman have used discussion boards to incorporate the KEEN framework [24]. The CoE agrees with Professor Bosman that creating, deploying and managing online discussions require relatively minor investment for the instructor in terms of preparation work and resources.

Most of the research and discussion board topics listed in Figure 2 came from the Institute of Electrical and Electronics Engineering (IEEE) Communication Society website [25]. Discussion boards are intended to build interest in the research project, increase development of entrepreneurial skills found in of KEEN's framework and prepare students to conduct the research paper and presentation. In addition, discussion boards are meant to minimize student procrastination when writing their research paper, gathering ideas from many sources and leveraging other student perspectives. The deployment schedule is given in Table 2 for delivering the EML Modules (discussion boards, research presentation and research paper). The discussion boards allow students to have time to reflect more on the topics while serving to build students' interest on developing their entrepreneurial mindset. The discussion boards prepare students for group discussion in class while understanding the motivations and perspectives of their classmates before meeting in class.

In Figure 2, the word 'aware' found in the introductory description will be deleted and the sentence will focus on the development on entrepreneurial skills. Students will have more familiarity with the entrepreneurial mindset in other courses. The word 'aware' was first used since this entrepreneurial approach was presented to the senior students for the first time. Students then performed learning various tasks in the modules to foster an entrepreneurial mindset.

The EML schedule allows for some flexibility when circumstances dictate to do so, such as thoroughly covering and reviewing the technical content based on student questions or when weather conditions make it unsafe for students to travel resulting in class cancellation. Figure 3 shows an example of an EML discussion topic for 'the Internet of Things'. In Figure 3, each student needs to complete the assigned tasks for each online discussion board: (1) consume the content provided by the professor; (2) provide a technical summary (3) provide a paragraph of an entrepreneurial skill: business opportunity/model, economic impact, or societal benefit (4) provide an additional reference; and (5) provide a discussion question for the next group session. These tasks must be completed before discussing the topic as a group.

Figure 4 is an example student response to the discussion board about the internet of things (IoT). In Figure 4, the 'Turnitin' verification score is 0% and does not sense *plagiarism*.

However, the verification score does assist in verifying the overall integrity of the material delivered by the student. Usually, the authors would like to see the score below 20% which occurred in most of the students' response. Some verification scores ranged from 20% to 35% and is a result when students provide a list of references.

INTRODUCTION

In a world of accelerating change, today's solutions are often obsolete tomorrow. Since discoveries are made by the curious, you must empower yourselves to investigate a rapidly changing world with an insatiable curiosity. Discoveries are not enough. Information only yields insight when connected with other information. You must habitually pursue knowledge and integrate it with your own discoveries to reveal innovative solutions. Innovative solutions are most meaningful when they create extraordinary value for others. Therefore, you must be champions of value creation. Be aware that this course and associated activities are intended to allow you to persistently anticipate and meet the needs of a changing world.

5G has many implications and applications that have societal benefits and economic value:

- 5G
- Driverless Everything
- Distributed Ledgers (bitcoin, block chain etc.)
- Smart Everything: City, Grid, Cars
- Light Fidelity (LiFi)
- Next Generation 911
- Internet of Things (IoT)
- Security, Privacy
- Deep Learning/Artificial Intelligence
- Molecular Communication (nanobots)
- Spectrum Allocation (MIMO, 1000x),
- Other applications/technologies items you may discover

PROJECT: HOGGING THE BANDWIDTH…NOT…BUT AT WHAT PRICE

An angel investor of communication technologies gave your company $500 million to make 5G and its applications a reality in the next five years. You are the lead engineer. Your KEEN and KIND boss assigns you to:

- Describe some key limitations and lessons learned of past communication systems
- Identify the operating frequencies of previous and proposed frequencies for communication systems
- Investigate economic value and societal benefits of 5G and its applications
- Prioritize at least 7 items (Internet of Things, LiFi, Deep Learning/Artificial Intelligence, Smart Everything, Bitcoin/Block Chain Technology, 5G and Enabling Technologies, plus one more of your choice) with allocated monetary costs of the applications researched in this class. Provide your reasoning of prioritization.

  - Your paper should identify any opportunities that create value for others
  - Your paper should communicate your findings in terms of market interest and customer value,
  - Your paper should communicate your findings in economic terms and societal benefits.

CONNECTIONS: The project should tie some key concepts in the course on digital communication system. The research project should include one or more of the course objectives and should include some analysis using equations and if possible a Matlab simulation. As a reminder, the course objectives are:

- Determine the sampling rate for a continuous-time signal, the spectrum of the sampled signal, and identify any aliasing effects
- Identify and explain the components and functions of a basic Pulse Code Modulation (PCM) system.
- Demonstrate the effects and tradeoffs of Delta Modulation and other variants of a PCM system.
- Explain Intersymbol Interference (ISI) in baseband transmission and explain methods to minimize these effects.
- Demonstrate the tradeoff/performance of basic bandpass modulation systems (ASK, PSK, and FSK) in a noisy environment
- Demonstrate error coding techniques in digital transmission methods.
- Apply software design tools to demonstrate the above concepts.

EML Objectives (showing relevance of analytical techniques)

- Lessons learned of previous systems used to improve proposed implementations of 5G and applications
- Contrarian views for one of the proposed 5G implementation schemes

Your research paper should be 5-7 pages in IEEE format.

Figure 2. New Instructions for EML-centered Research Paper and Presentation

The response in Figure 4 shows the student's critical thinking on IoT's impact to society. The opportunity described in the response concerns improved efficiencies in the health care industry but mentions how IoT and 5G will impact the human body as higher frequencies are needed to increase the data throughput.

The response also implied regulatory policies and issues based on the questions about standardization of proposed IoT products. Privacy issues are another concerned addressed in the student response. Overall, the discussion boards and the student responses in the discussion boards showed increased development of entrepreneurial skills found in KEEN's 3Cs and framework.

Week (Planned)	Week (Actual)	EML Modules
2	2	DB 1: Internet of Things
3	4	DB 2: Light Fidelity (Li-Fi)
4	6	DB 3: Deep Learning / Artificial Intelligence
5	7	DB 4: Smart Everything (cities, car, power grid, health, etc.)
6	10	DB 5: Bitcoin/Block Chain Technologies
7	10	DB 6: 5G and Enabling Technologies
11	11	Research Presentation and Poker Chip Voting
11	11	Research Paper

Table 2. Planned and Actual Deployment Schedule of EML activities (DB: Discussion Board and Student-led, In-class Discussion)

Discussion Topic: Internet of Things

1. Please watch or read the following content:

a. How It Works: Internet of Things: https://www.youtube.com/watch?v=QSIPNhOiMoE (IBM Think Academy)
b. Top 5 Facts about the Internet of Things: https://www.youtube.com/watch?v=c-Ekz2kK7J4 (watchmojo.com)
c. Unlocking the potential of the Internet of Things: http://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/the-internet-of-things-the-value-of-digitizing-the-physical-world

2. Write at least two technical paragraphs with a topic sentence and supporting paragraphs. Make at least one connection of a concept studied in class (you can include EE443 or EE 463 communication concepts or do additional research as well).

3. Write at least one paragraph of either a business opportunity/business model, economic or social implication for the discussion topic.

4. Include at least one additional reference.

5. Write one discussion question for a 10-15-minute on the next lesson. The instructor will randomly select one student or ask for a volunteer to lead the discussion and other students are expected to participate.

Figure 3. Example of Instructions for a Discussion Board Topic: Internet of Things.

A face-to-face group discussion, led by one of the students, intends to provide a more in-depth dialog of the topic. After posting their online comments, students are then randomly selected to lead a group discussion in the class session.

Based on the experience with the discussion boards during the Fall 2017 quarter, the authors intend to make one change. The authors will modify the online discussion boards by having a student write a one paragraph summary of the additional reference provided by each student. Students simply cited the reference with no discussion about the additional reference. This change aims to promote additional curiosity of the discussion topic to include identifying an opportunity with market interest as well as societal and economic implications.

The Internet of Things (IoT) is a construct in which multiple devices are connected via wireless communications. Each device transmits relevant information that contribute to improving efficiency within a functional areas such as retail, healthcare, transportation, energy etc. Much like how computers rely on the relay of information to perform certain task in order to complete the next task, wireless communication at like the bus of a computer. While many people may think too much information or micromanaging is useless or annoying, IoT aims to filter and disseminate information to enhance processes and procedures.

In order to pass the high amount of data IoT will require faster wireless speeds. This is where the next generation of wireless communication or 5G will need to be established. IoT rides on wireless communications which is founded on digital signals transformed to analog then back to digital. The establishment of 5G may require expanding the current commercial frequency bands available to the public. Additionally, the more business that implement IoT will mean the more congested, contested and limited the electromagnetic spectrum will be. This can lead to more oversight by the ITU of frequency management.

As we continue to expand technology at an ever rapid rate, it's vital that we also understand the implication of our actions. IoT may create efficiency within the healthcare industry but do we know the impacts IoT will have on the human body? What are the biological effects of constant exposure to 5G? Another aspect to consider is privacy, will IoT have the option to be turned off? Not everyone will have the finances to afford a device which is IoT or want a device that is IoT.

Who will establish the protocols for each product and how will they all be compatible among each other?

Internet of Things (IOT). (n.d.). Retrieved October 11, 2017, from https://www.sas.com/en_us/insights/big-data/internet-of-things.html

Originality Verification Report (0%)

Figure 4. Example of Student Response to Internet of Things Discussion Board Topic

Student Presentations on Technology Rankings and Resource Allocation

The students' 'shark tank'-like presentations were a two-lesson activity during the Fall 2017 quarter: five speakers for the first session and three speakers for the next lesson. During one of the first-day presentation, Professor xxx asked the following question: "if you just suffered a $100 million cut, what would you do?" Other students began discussing among themselves on how to address the issue since they were not prepared for this question. The question is intended to review their priorities and to 'assess and manage risks' given in the KEEN framework under the theme, 'Connections'.

The intent of the 'budget-cut' question is having students think about the entrepreneurial mindset when it comes to managing risks. This question was not asked again to the other speakers. However, on the next class session, one student had a slide with a $100 million budget cut. The student's budget cut resulted in having equal allocation in all technologies which posed other questions on priorities.

As mentioned in the paper, the authors aimed to give students an idea and consideration about financial risks. Students will have taken program management courses and was not emphasized in this course. However, since the students all did not anticipate the "budget-cut" question raised

during the one of the student presentations, the question got the students to start thinking about risk and its impact when it comes to financial uncertainty.

Another question that was presented during the talk was: 'What products and services are you going to provide and how do you know that it has market interest?' Just like the first question, the question got students to start thinking more about the market interest and recognizing opportunities. Overall, the research presentations demonstrated the students' development and increased practice of the entrepreneurial skills and mindset based on the KEEN framework. The results of the technology rankings and resource allocation are presented in Tables 3 and 4, respectfully.

Technology Rankings. The students remarked on the diverse views and approaches of technology rankings and assumptions from their classmates. Assumptions include the level of technology maturity and approach in how to make 5G happen in the next five years. After compiling and showing the results shown in Table 3, the students were asked to take a look at the top three technologies that the group should focus and invest. The students also talked about alternative technologies that were presented in Table 3. These technology topics were added by students not specifically assigned as discussion board topic. Group discussion centered on technology maturity, interrelationships among the technologies and security issues. After some discussion, the students agreed with the following top three technologies: (1) 5G and enabling technologies, (2) Security and (3) the Internet of Things. It should be noted that 'Security' was not specifically assigned as a discussion topic but was frequently mentioned on previous discussion boards.

Topic\Student	1	2	3	4	5	6	7	8	Total
Internet of Things	2	3	3	3	4	7	3	3	28
Light Fidelity	7	1	7	8	6	5	4	7	45
Deep Learning/AI	1	5	6	1	5	6	6	4	34
Smart Everything	3	2	5	8	8	4	1	2	33
Bitcoin/Blockchain Technology	0	4	4	2	7	8	7	5	37
5G & Enabling Technologies	6	6	1	5	1	2	2	6	29
Other									
- Security			2		2				
- Molecular				4					
- Spectrum Allocation					3				
- Quantum Computing							5		
- Electronics						1			
- Artificial Leaf Tech								1	
-Security/Privacy	5								
-Driverless	4								

Table 3. Technology Rankings and Prioritization by Students

The group approach to rank technology programs was actually implemented by one of the authors about twenty years ago during an off-site to prioritize the Air Force's technology programs in precision-guided munitions. The votes to rank technology programs came from three groups or sections in the branch organization, totaling 30-35 engineers and scientists. The three groups were asked to rank their programs when compared to the total list of branch programs. After all the technology programs were ranked, low priority programs were cut for a specific amount of budget cuts.

Resource Allocation. In terms of resource allocation, three students presented significant allocation to other technologies not specifically assigned as a discussion topic: two students allocated significant resources in Security ($175 million and $100 million) and another student allocated $200 million for Artificial Leaf Technology. Security was discussed earlier in previous class topic discussions like: internet of things, bitcoin/blockchain technology and smart everything. From the group discussion, students agreed that security and privacy is a major issue.

Student 8 presented 'Artificial Leaf Technology'. Although Artificial Leaf Technology was 'neat' technology to generate energy as part of the discussion, students quickly noted that this technology did not meet the requirements of the research project related to 5G. This was verified and validated with the Poker-Chip Voting. The student who introduced Artificial Leaf Technology received the lowest score in the Poker-Chip voting.

Topic\Student	1	2	3	4	5	6	7	8
Internet of Things	100	50	75	100	30	75	100	50
Light Fidelity	10	200	25	0	12	75	30	50
Deep Learning/AI	200	50	50	200	18	50	150	50
Smart Everything	50	100	50	0	5	50	20	50
Bitcoin/Blockchain Technology		50	75	25	5	75	100	50
5G & Enabling Technologies	25	50	125		215	100		50
Other								
- Security			100		175			
- Molecular				50				
- Spectrum Allocation								
- Quantum Computing							50	
- Electronics						75		
- Artifical Leaf								200
- Security/Privacy	40							
- Driverless	75							

Table 4. Resource Allocations by Students (numbers in millions)

Poker Chip Voting

Each student presented their case and answered questions from the other students. Then, they were asked to vote for the best presentations. While students were casting their votes, Professor xxx compiled their results from the technology rankings and resource allocations shown earlier in Tables 3 and 4. Figure 5 shows the low-cost but functional voting apparatus. Students placed their poker chips in small containers labeled with student names.

Each student was given four poker chips valued at $100 (black chip), $50 (blue chip), $25 (green chip) and $5 (white chip). Each student must vote for their top four presenters. When each student placed their four poker chips, only one chip per student can be dropped into the container. Before the student voting, Professor xxx deposited a $50 chip for each student to minimize the effects of a "sympathy vote" when a student noticed that there was an empty container. This voting behavior was evident based on the Professor xxx experience during the ICE workshop.

Figure 5. Low-cost Voting Booth for Students to Cast Vote for Best Presentations

Figure 6 shows the results of the poker chip voting. Professor xxx agreed with the student voting, especially with the top two presenters which occurred during the first day of presentations. Professor xxx could have made it more dramatic by opening a sealed envelope of his top two picks after the student voting. The voting results verified and validated his assessment of the best presenters during the first session. The voting results also show the students practiced and developed their EML thinking and judgment. The top two presenters received a bag of 'PayDay' candy bars. As expected, the winners passed out the candy bars to the other students so that each student has a 'PayDay' reward.

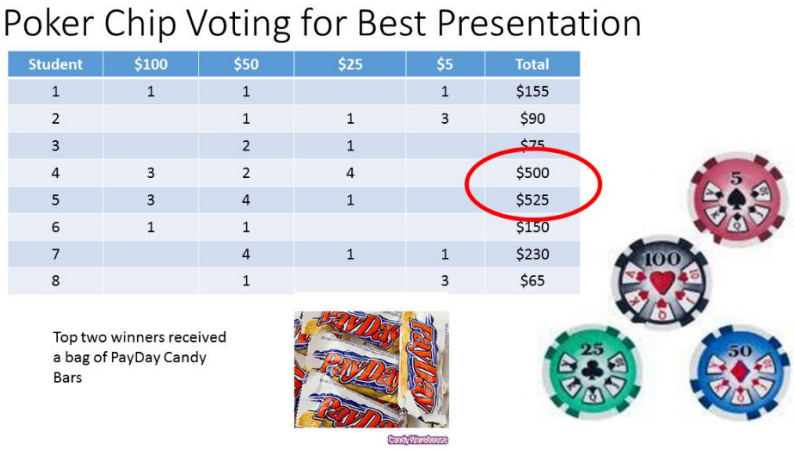

Figure 6. Results from Poker Chip Voting

In summary, the EML individual and group exercises consisting of: (1) technology rankings, (2) resource allocations and (3) poker-chip voting successfully showed different motivations and perspectives of classmates while increasing development, practice and promotion of an entrepreneurial mindset.

Student Feedback on EML Survey

Initial research on potential survey questions were based on the author's expectations of behaviors from the EML activities as well as reviewing the work by Professor David Jamison IV [26]. The format of questions were tailored from the KEEN framework and customized based on

student experience with the entrepreneurial mindset. Since this is the students' first-time revelation to the entrepreneurial mindset, the survey questions were selected based on the authors expected outcomes from the KEEN framework through the discussion boards, the research paper and presentation.

The senior and adult students have demonstrated system thinking skills found in the KEEN framework and its 3C's (curiosity, connections and creating value). Overall, the students did very well to incorporate numerous skills but not all the skills were intended to be developed in this single course.

After the group discussions and presentations, students were asked to complete an EML survey. Figure 7 shows the overall student feedback from the EML modules. During the quarter, the authors agree that the students enjoyed the in-class discussions led by the students and EML activities. They were actively engaged in the discussion topic spinning off ideas about social and economic implications of the technologies. Most responses to the questions were either agree or strongly agree. Three of the four neutrals came from one student.

Question 3 of Figure 6, 'formulated questions and generated own inquiries', had the second highest number of 'strongly agree'. One student commented that the EML modules "got all students to discuss many other questions" and another "definitely made me do research and learn new material". The survey indicates that the EML activities increased development of KEENs 3Cs with student comments on promoting "curiosity". In terms of 'curiosity', the authors also noted that student research papers had more references than previous research papers. One student commented that the EML modules 'definitely stimulated curiosity'.

Question 4 of Figure 6, 'explored alternative or encouraged contrarian views of accepted solutions', had the highest number of 'strongly agree'. In this case, Professor xxx emphasized during the second half of the quarter that there is no 'school solution' for this project.

One student commented that the 5G and its applications were conceptual and were not really used. The authors did not intend to go in-depth technically for each application in the discussion board since they did not have the technical skills at that time. The intent is to look at future trends of communication technologies and attempt to make connections between the concepts taught in class and their research on the discussion topics.

The student deliverables and instructor observation for the discussion board, research paper and presentation involves: student self-reflection and discussion, observation with regards to curiosity like number of questions raised, identified any opportunities contrarian views and other observed skills and degree of participation from all participants. In addition, discussion went beyond the allocated time of 10-15 minutes to 20-30 minutes. The authors had to cut off the discussion to cover the technical material.

Survey on the Entrepreneurial-Minded Learning (EML) Activities for EE 463 – Communication Systems II

Given the EML/thinking activities (e.g. discussion boards for reflection, in-class student-led discussions and the research project/presentation) and in comparison, to other courses, the EML course activities emphasized the following?

Topics/Questions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. Applied learning in new contexts			2	**3**	**2**
Comments: *1. Definitely made me research and learn new material. 2. Applications were not really used, more conceptual.*					
2. Furthered learning beyond the course content curriculum				**5**	**2**
Comments: *Encourages you to look outside at the scope of the course*					
3. Formulated questions and generated own inquiries				**2**	**5**
Comments: *Got all students to discuss many other questions*					
4. Explored alternatives or encouraged forming contrarian views of accepted solutions				**1**	**6**
Comments: **(Professor emphasized to students that there is no "school solution")**					
5. Supported diverse perspectives				**3**	**4**
Comments: *EML allowed students to further expand their interests within the curriculum.*					
6. ***Increased awareness of the Entrepreneurial Mindset along with the Technical Skillset***			1	**4**	**2**
a. Stimulated ***Curiosity*** about the changing world				**3**	**4**
b. Encouraged *making* ***Connections*** to integrate knowledge to everyday life				**4**	**3**
c. Fostered to think about ***Creating Value*** for yourself or society			1	**4**	**2**
Comments: *1. Definitely stimulated curiosity. 2. Enjoyed it.*					
7. Suggestions for Improvements or other comments: 1. None.					

Figure 7. Student Feedback of EML modules/activities.

The survey has the word 'awareness' in question 6 which should read 'practice and development' for the next iteration of the survey. As mentioned earlier, the intent of the series of EML modules is to practice and increase students' use of KEENs 3Cs and their development of an entrepreneurial mindset.

Next Steps

Fall 2017 was the first quarter to apply the newly developed EML lab modules. The data sample is small and the results are preliminary. The authors will continue integrating EML in other

engineering course sequences, including subjects in circuit design, communication systems, and digital electronics. The capstone courses in undergraduate curriculum at the CoE have elements of systems thinking but the KEEN framework provides an important reference in developing more entrepreneurial skills for students. The authors intend to include a similar set of EML modules to another graduate-level digital communications course for the 2018 Spring Quarter.

To develop an entrepreneurial mindset is not a one-time affair but a process of discovering, evaluating and exploiting opportunities. Students need frequent practice throughout the engineering curriculum so that the entrepreneurial mindset becomes a habit. Since each of the full-time faculty, including the authors, have taught over 40 different courses in the BSEE, BSCE, MSEE, MSCE and MSSE (System Engineering) programs, these courses will include numerous elements of KEEN's entrepreneurial skills over a period of time. This approach serves as a strategic plan during the next several years. With more EML activities embedded in the courses, the students' mindset will become a habit.

For example, the authors have introduced the KEEN framework in the following undergraduate and graduate courses in the Fall 2017 and Winter 2018 quarters, including:

- Circuit Analysis I
- Signals and Systems
- Electronics Design I
- Product Design I
- Impact of Global Issues on Design
- Advanced Communication System Design
- Computer Engineering Capstone
- Digital Signal Processing

The CoE intends to cooperate with other universities in the KEEN network to develop more engineering activities having EML, share information and resources, and grow together while incrementally enhancing the curriculum.

Rubrics and an updated student survey focused on key entrepreneurial skills found in the KEEN framework will be developed for the above courses.

Conclusions

The EML activities appear to be successfully integrated while maintaining the technical rigor of the course. The EML modules fostered the development for the subset of skills found in the KEEN framework. Student feedback on the integrated EML activities were encouraging and positive. There were no student complaints of the increased or perceived workload. The success was due to the careful integration of EML activities to manage student behavior for the research paper and presentation while using discussion boards as practice space in developing their entrepreneurial skills in the KEEN framework. The discussion boards and research provided realistic individual reflection while in-class discussion and research presentations provided group space activities for deeper thinking and alternative perspectives from classmates into the research topics.

References

[1] K. E. E. N. (KEEN), "Get Connected Through These Upcoming Events," 2018. [Online]. Available: https://keenwarehouse.blob.core.windows.net/keen-downloads/KEEN_events.pdf. [Accessed 2016].

[2] Santiago, John and Jing Guo, "A System Engineering Approach for Implementing An Electrical or Computer Engineering Master's Capstone Course," in *ASEE Rocky Mountain Section Conference*, Cedar City, Utah, 2016.

[3] T. S. Tom Byers, "The Future of Entrepreneurship in Engineering," 5 July 2013. [Online]. Available: http://stvp.stanford.edu/blog/the-future-of-entrepreneurship-in-engineering . [Accessed 1 12 2017].

[4] M. Crow and L. Leshin, "Engineering the Future," *University Business* , vol. 19, no. 4, p. 48, 2016.

[5] KEEN, "Engineers With an Entrepreneurial Mindset Transform the World," [Online]. Available: https://engineeringunleashed.com/.

[6] K. M. S.-L. J. R. Y. Andrea L. Welker, "Weaving Entrepreneurially Minded Learning Throughout a Civil Engineering Curriculum," in *ASEE Annual Conference and Exposition*, Columbus, Ohio, 2017.

[7] R. S. H. J. N.-G. C. Q. L. M.-I. C. Nadiye O. Erdil, "Impact of Integrated e-Learning Modules in Developing an Entrepreneurial Mindset based on Deployment at 25 Institutions," in *124th Annual Conference & Exposition*, Columbus, Ohio, 2017.

[8] "Entrepreneurship and Innovation http://web.mit.edu/facts/entrepreneurship.html," MIT FACTS,, 2017. [Online]. Available: http://web.mit.edu/facts/entrepreneurship.html.

[9] "http://stvp.stanfor.edu," The Stanford Technology Ventures Program website, [Online]. Available: http://stvp.stanfor.edu. [Accessed 2018].

[10] A. M. Christopher Kitts, in *124th Annual Conference & Exposition*, Columbus, Ohio, 2017.

[11] B. D. I. K. Dennis Ridley, "Entrepreneurial Mindset and the University Curriculum," *Journal of Higher Education Theory and Practice* , vol. 17, no. 2, pp. 79-100, 2017.

[12] S. K. E. C. R. S. E. &. W. J. Bilen, "Developing and assessing students' entrepreneurial skills and mind-set," *Journal of Engineering Education*, vol. 94, no. 2, pp. 233-243, 2005.

[13] D. Chasaki, "Entrepreneurial-Minded Learning in a Freshman Mini-project in Computing," in *124th Annual Conference & Exposition*, Columbus, Ohio, 2017.

[14] C. Wang, "Teaching Entrepreneurial Mindset in a First Year Introduction to Engineering Course," in *124th Annual Conference & Exposition*, Columbus, Ohio, , 2017.

[15] N. Tabrizi, "Fostering an Entrepreneurial Mindset in "Digital Systems" Class through a Jigsaw-Puzzle Model," in *2017 IEEE Frontiers in Education Conference (FIE)* , 2017.

[16] A. H. Hoffman, "An entrepreneurial approach to a senior design course," in *2017 IEEE Frontiers in Education Conference (FIE)* , 2017.

[17] E. Sander, "ENGINEERING ENTREPRENEURSHIP: LEARNING BY DOING," 2011. [Online]. Available: https://www.asee.org/public/conferences/1/papers/819/download. [Accessed March 2018].

[18] M. D.C, "Promoting Technological Entrepreneurship through Sustainable Engineering Education," *Procedia Technology, Elsevie*, vol. 22C, no. ISSN: 2212-0173, pp. 1129-1134, 2016.

[19] M. S.A., "Entrepreneurship Education In An Engineering Curriculum," *Procedia Economics and Finance* , vol. 35, p. 379 – 387, 201.

[20] "The 3C's of Entrepreneurial Mindset," KEEN, [Online]. Available: https://engineeringunleashed.com/mindset-matters.aspx.

[21] Santiago, John & Kasley Kathy, "Design & Development of a 3D-Printed Quadcopter Using A System Engineering Approach in an Electrical Engineering Master's Capstone Course," in *ASEE Annual Conference and Exposition*, Columbus, OH, 2017.

[22] Guo, Jing & John Santiago, "Using Survey and Assessment to Improve Engineering Students' Teamwork and Collaboration Skills," in *ASEE Zone IV Conference*, Boulder, CO, 2018.

[23] KEEN, "Educational Outcomes," KEEN , [Online]. Available: https://keenwarehouse.blob.core.windows.net/keen-downloads/KEEN_Framework_spread.pdf. [Accessed 12 1 2018].

[24] Bosman, Lisa and B.rookseK. Mayer"Promoting Entrepreneurially Minded Learning through Online Discussions," in *ASEE Annual Conference and Exposition*, Columbus, OH, 2017.

[25] "Top 10 Communications Technology Trends in 2017," 2017. [Online]. Available: https://www.comsoc.org/blog/top-10-communications-technology-trends-2017. [Accessed August 2017].

[26] D. Jamison IV, "Framework for Integrating Entrepreneurially Minded Learning in Upper," in *2017 ASEE Annual Conference and Exposition*, Columbus, OH, 2017.