Using Guidelines from Cognitive Load Theory with Applications in the Traditional/Online Flipped Classroom Approach and Entrepreneurial-Minded Learning (EML)

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***Abstract*— Using guidelines from Cognitive Load Theory (CLT), the College of Engineering (CoE) used a flipped classroom approach in two courses: (1) a freshman-level course entitled, Introduction to Engineering (EE110) for both the Electrical Engineering and Computer Engineering and (2) a senior-level course entitled, Communication Systems II (EE 463) with a focus on entrepreneurial-minded learning (EML) activities using the framework developed by the Kern Entrepreneurial Engineering Network (KEEN). The paper summarizes CLT's key principles and guidelines. Key principles are illustrated with examples from EE110 and EE463.**

INTRODUCTION

For the Face-to-Face (F2F) classroom, the flipped learning approach has been successfully implemented with EE 110 during the past few years [1] [2]. The labs in EE110 were identified as a challenge when the course will be delivered online [3]. Using interactive video and Google Docs were effective means in delivering the content [4] [5]. Although the creation and delivery of multimedia content was based on the years of teaching experience by CoE, research studies provide a theoretical basis for the design, development and instructional delivery of the content.

Specifically, research based on Cognitive Load Theory (CLT) appears to be consistent with the CoE's F2F teaching approach and experience. The paper shows how the instructional delivery of the EE110 content compares with some guidelines offered by CLT. For the senior-level course in digital communications, EE463, discussion boards were used to implement a flipped-classroom approach in preparation for a research paper and presentation. This course will be presented after discussing results from EE110. The CLT suggests evidence-based teachings for designing and delivering the instruction to account for the limited capacity of working memory [6] [7]. The CLT also models the student's cognitive learning process and architecture for efficient learning.

I. COE'S ADULT LEARNERS AND TEACHING EXPERIENCE OF FULL-TIME FACULTY

The student body in the CoE consists mostly of adult learners who have family and are working full-time. Most of the evening students take classes at night between 5 p.m. to 11 p.m. To meet student and employer needs, the college successfully developed and implemented a program curriculum involving day and night classes in electrical engineering and computer engineering. The curriculum program consists of 11-week courses and allows a flexible schedule for students to successfully complete an ABET-accredited degree in either BSEE or BSCE. During 2017, CoE proudly received an ABET re-accreditation for six years with no required interim reports.

In 2015, the University tasked CoE to develop a strategic plan in delivering online undergraduate and graduate engineering courses. Starting in April 2015, the college embraced a flipped learning approach for future and online delivery of undergraduate engineering courses. One reason for adopting flipped learning concerns the amount of time during a synchronous session when students and instructor are online together. The full-time faculty, consisting of four professors, determined that there is little time to deliver synchronous lectures online. However, when engineering content is delivered during an online synchronous session, CoE anticipates that more time is needed to address student questions on the multimedia content, assigned readings, homework and weekly lab experiments. The engineering faculty also wanted to have students practice on problem-solving techniques during the online synchronous session.

Another reason for adopting the flipped classroom is based on one of the authors' years of acquired experience in developing interactive and multimedia content suitable for e-books and online delivery. Multimedia content turns out to be a key component to the flipped classroom when students work individually on their own. The teaching approach attempts to leverage numerous technologies to translate the traditional ground or F2F teaching philosophy to one suited for the online classroom environment.

It should be noted that after developing the initial content during 2015 and refining the flipped learning content and delivery, the University postponed delivery of the EE 110

Week #	Lab Assignments
Week01	Circuits Laboratory Introduction
Week03	Digital I/O Circuits
Week04	Basic Gates Verification
Week05	Digital Simplification
Week06	Ohms Law
Week07	Complex Circuit Analysis
Week08	RC Circuits Multisim Simulation
Week09	Function Generator Assembly
Week10	Function Generator Testing

Table 1. EE110 Lab Schedule

online course due to limited resources for the next two years. The time and effort of the full-time faculty was focused on preparing for the ABET visit during 2017. Plans and implementation for the delivery of a sequence of online engineering courses resumed in 2018.

A. Description of EE110

EE110 consists of basic electronics and weekly lab assignments. The introductory course attempts to prepare students who will be entering either the electrical or computer engineering programs. Table 1 shows the deployment of weekly F2F lab assignments.

The College of Engineering recognized online lab assignments will be the challenging part of the program curriculum [3]. This insight was verified and validated during a pilot program when the flipped classroom was implemented to mimic the online synchronous chat sessions. In this case, when students met in the classroom, it simulated the online chat session in two areas: (1) one chat session addressed student questions on the multimedia content, readings, and homework problems; and (2) the other chat session addressed lab questions. Instructors observed how students conducted their labs experiments providing guidance on how to go through the troubleshooting process. The instructors also observed that students collaborated with each other when troubleshooting their circuits.

If the College of Engineering (COE) can effectively deliver the lab content with this first course to meet student outcomes, then the engineering faculty can expect the development of future electrical engineering courses involving lab activities to go much smoother.

Although the full-time engineering faculty has extensive experience teaching adult learners in F2F classroom, the faculty had no experience in developing and delivering a complete engineering course fully online in 2015. Because the engineering faculty has its primary focus on teaching, a full-time instructor carries a typical workload of four courses per quarter. Consequently, each instructor has taught between thirty to forty different engineering courses including math and physics during their time in the CoE. During the development of EE110, the instructors have been downloaded to two to three classes for one year to focus on content creation and instructional delivery for the online environment.

B. F2F Teaching Philosophy

Typical engineering courses taught at the CoE are two to three hours long meeting twice a week in a physical classroom. The teaching pedagogy uses a student-centered approach. Students actively participate in their learning as opposed to listening to several passive one-hour lectures in class.

Based on the authors' experience, providing a one-hour lectures is inefficient, especially when it comes to the student body at the CoE. With most of the students who are working adults with family and kids, they usually work during the whole day and come to school at night. A two or three-hour lecture during the evening class will lead them to becoming disengaged and in extreme cases, fall asleep. It was found that short five to fifteen-minute lectures followed by short exercises completed by the students achieve better learning outcomes with a more engaging learning experience.

For example, one approach of instruction involves solving numerous engineering problems such as circuit analysis or signals and systems. In this context, the teaching approach entails the following steps:

- Step 1. Introduce an engineering topic for 5 minutes. Motivate why this topic is important and relevant…keeping it short and sweet. Show how information will benefit students or tell an appropriate 'war story' based on industry experience.
- Step 2. Solve and work out an example analytical problem. The activity usually takes 5 to 15 minutes depending on the complexity of the problem.
- Step 3. Have students struggle with another similar problem for 10-15 minutes, either individually or in pairs.
- Step 4. Solve problem together (10-15 minutes). An instructor can have one of the students solve the problem on the whiteboard and appropriately guide the student to unravel the problem requesting feedback from other students as well.
- Step 5. Take a break for 5-15 minutes and repeat for the next hour.

The above approach is not set in stone. The instructor can adapt the delivery of the material while addressing any student questions or reinforcing concepts for the next hour. For example, an instructor may have a short lab or hands-on exercise using Matlab/Simulink or PSPICE to emphasize the concept taught during the first hour. The CoE's pedagogy is consistent with past teaching philosophies [8] [9] [10].

So how does one translate, the F2F teaching that proved successful in the past to one that is suitable for online delivery? One approach leverages available technologies to emulate the successful active and student-centered learning philosophy found in the F2F classroom. In addition, the content developed for flipped learning can be used to transition from F2F course to a fully online version. Once the online content becomes suitable for the F2F flipped learning, then the content would be suitable for the online environment supplemented with frequent online synchronous sessions and other online learning activities.

C. Flipped Learning

In the digital and internet marketing world, "Content is King," as written by Bill Gates in 1996. And with the flipped classroom approach, this is no exception. Engaging and interactive multimedia content serves as a key component for the flipped classroom. The authors believe that this is especially true if a student decides to pursue an undergraduate degree that is delivered fully online for several years.

For an optimum learning experience, there must be a tight and integrated link with work done by students at home and work they do in class [11] [12]. This idea applies to a synchronous and online group session. For the F2F flipped learning, a professor must maintain alignment when there is a blend of online and in-class activities for a specific learning activity. That is, both activities are supplementary and not complementary. The authors see the online activities tailored for individual work as preparation for the group activities conducted through either the F2F or online synchronous meetings. During the group activity, the most complex or deep learning tasks can take place [12].

To set up the group activity, the professor can start off with a review to connect concepts studied that took place during the individual space online (e.g. viewing videos and taking frequent quizzes). Another alternative is to ask a challenging question to prepare the student's frame of mind for group activity.

Finally, an important point is to build individual accountability for each student. For example, students may be asked to view a YouTube video as an individual activity. To provide student accountability, each student must summarize on what they viewed and then post their reflective comments on an online discussion board as discussed later for EE 463. For even greater accountability, each student is then asked to formulate a discussion question and be prepared to lead a 10-15 minute in-class group discussion. This approach was successfully used in a senior-level course on digital communications [11]. The accountability requires student reflection to provide a productive learning experience when the students meet in a group setting. The professor can then randomly select or solicit a student volunteer to lead the discussion.

The F2F learning is a more expensive mode of communication when compared to online communication. F2F learning requires both instructor and students to be physically together. In a F2F environment, learners must work together at the same time and place, to reach a common understanding of what is to be learned. In an online environment that is asynchronous, learners do not have the constraints of time and place. By leveraging online technologies, student learning should be designed with transfer of same information to all learners. For the freshman student, online learning is most suitable for factual type learning or less challenging learning activities [12].

F2F would be recommended for intensively and challenging learning activities with high benefits. For example, the hands-on laboratory experiments in EE110 solidify key concepts learned from the multimedia content: online videos, text readings, assigned homework and frequent online quizzes. Through peer collaboration, students can help each other work through the labs as well as learning how to troubleshoot their circuits with instructor guidance.

Another consideration when using the flipped learning philosophy is student workload. The online activities should not provide additional work found in a traditional F2F classroom. To account for student workload, the online activities performed individually should be well integrated with the F2F group activity or the online synchronous group session [12].

Flipped learning combines active problem-solving activities and direct instruction/mastery learning activities. These core activities provide a coherent and meaningful learning experience [12]. However, the professor needs to address student's potential fear or resistance to the new method. This point may have not been emphasized to students for EE110 during 2016 when the course was flipped and is a lesson learned for the authors. Based on the EE110 experience, not only do professors need a variety of teaching instruments to evaluate higher-order thinking skills, like: critical and creative thinking skills, problem-solving, and content mastery, they also need to be aware of Cognitive Load Theory (CLT).

II. KEY CONCEPTS IN COGNITIVE LOAD THEORY (CLT)

The professor's teaching can use CLT by accounting for the student's cognitive architecture. Knowing how a student processes information, can enhance the learning experience whether the course content or instruction is delivered either by means of online multimedia and social-media learning or F2F group learning.

In CLT, there are two types of memory, long-term memory and short-term (or working) memory. Long-term memory has unlimited capacity while working memory has very limited capacity. Working memory is limited when holding and processing new information. In working memory, five to nine chunks of information appear to be its holding capacity before it becomes overloaded. Also, working memory has a limited lifetime for retention (e.g. thirty seconds to two minutes). [12]

The three main concepts of CLT are: schemas, types of cognitive load, and dual processing channels (i.e. audio and visual channels).

Schemas. So how does learning takes place as information is transferred into long-term memory? The learner must create connections between new information found in short-term or working memory and existing information stored in long-term memory to build upon a schema or create a new schema. Schemas are complex patterns of information stored in long-term memory. Schemas are basically mental structures to organize knowledge. In addition, long-term memory can hold vast amount of complex data organized through an infinite number of stored schemas. The student can automatically retrieve the schema from long-term memory necessary to accomplish a given task. A student knows a concept and learned its content when the corresponding schema is stored in long-term memory.

For example, one schema concerns an individual driving a car when traveling from one familiar place to another, such as, weekly driving to work from an individual's home residence. The individual does not need an instruction manual or a map to get to work. In fact, the individual may be attentive enough to listen to the radio while safely driving to the destination. However, if the destination is unfamiliar, the driver turns off the radio and focuses more attentively on where the driver needs to go, resulting in developing a new schema. Another example is when a student can solve numerous engineering problems automatically and with relative ease. In this case, the student has acquired numerous schemas to become an expert in an engineering topic.

When a large schema is retrieved from long-term memory, the schema is treated as a single element in working memory. And when a large schema is treated as a single element, the faster the student can perform a given learning task. New information in working memory can be transferred and stored in long-term memory. The stored information can be later retrieved when needed. When the capacity of working memory is not exceeded, greater transfer of information can be stored into long-term memory.

Real learning takes place by altering the learner's schematic structure. When this change occurs, learners can grasp the information and process it within their working memory, and finally commit it to long-term memory. That is, they build upon previously learned information to expand their knowledge base.

Building schemas applies to both F2F and online learning environments. For example, Talbert relates CLT with flipped learning describing the pedagogy for both F2F and online environments [12]. On the other hand, Pappas [13], Hendricks [14], and Guyon [15] describe and apply CLT concepts focused for e-learners in corporate environments.

When cognitive overload occurs, learners will make more errors, become not fully engage and provide poor effort overall. The needed change in the schematic structures and pathways will not occur. Why? Simply because the learner did not have enough time or cannot process the information being offered within the lesson. Therefore, from an instructional design point of view, courses should be created in such a way that reduces the student's cognitive load. This reduction will give students' time and opportunity to process what is being taught more effectively and more easily.

In summary, the professor must design the content as well as its delivery to transfer the course content into the student's long-term memory through the development of schemas. Schema theory says that the student's expertise in any area is equivalent to the acquisition of schemas. In this case, knowledge and skills become automatic. Applying CLT allows the professor to design its course by building upon the student's informal knowledge, using existing schemas stored in student's long-term memory. If previous knowledge is not there, homework or other learning activities can be used to build the necessary knowledge in working memory that can be transferred into long-term memory as schemas [12].

A. Types of Cognitive Load.

To efficiently design the delivery of content resulting in efficient learning, the professor needs to account for three types of cognitive load in working memory: extraneous cognitive load, intrinsic cognitive load and germane cognitive load [6] [7]. Knowing these types of load allows the professor to make optimal use of the student's working memory.

The first type is extraneous cognitive load. This load involves how the content (e.g. exam or question) is presented. You can reduce the load by using diagrams with text or using worked-out examples to show a student on how to solve a question. The extraneous cognitive load is a burden caused by unnecessary items that are not relevant to the learning experience but occupies working memory. Unnecessary information requiring extra mental processing includes: decorative pictures, animations, background music and others that are not relevant or add value to the learning experience.

Intrinsic cognitive load is the second type of cognitive load which deals with the built-in complexity of the material. The professor can reduce this type of load by splitting the task and using previous informal knowledge. Some tasks are more complex than others resulting in different levels of intrinsic cognitive load. The professor may not reduce the built-in complexity of the material, but what is important is how the course material is presented.

The last type of cognitive load is germane cognitive load requiring the learner to invest in time and effort. In this case, germane cognitive load builds new and automates new schemas. The more you can reduce extraneous and intrinsic load, the more resources are available for germane cognitive load in working memory to process the information and move into long-term memory. In other words, retention goes up by reducing extraneous and intrinsic load.

Audio and Visual Processing Channels [6] [7]. To help students learn efficiently by transferring information from working memory into their long-term memory, the professor must present the information by reducing non-relevant items (extraneous cognitive load). Built on CLT, efficient learning requiring significant cognitive processing can take place through the processing channels for verbal and visual material (or dual channels).

One experiment for the reader to show that two processors are needed for efficient learning is to find a narrated video and ask the following questions: Does the visual content make sense without the narration? Does the narration make sense without the visual content? Does the narrated video make sense resulting in more efficient learning? Hopefully, the last question is yes. If not, then one of the processors is redundant increasing cognitive load and making inefficient use of resources in working memory.

In summary, before CoE was aware of CLT, the creation and delivery of multimedia content for EE110 was based primarily on the CoE teaching experience. However, CLT appears to be consistent with the F2F and online teaching philosophy by the CoE. The authors agree that CLT provides evidence-based guidelines for designing and delivering instructions while accounting for the limited capacity of working memory [6]. CLT also leverages the learning process and cognitive architecture for efficient learning [6].

With CLT, there are numerous ways to use working memory for long-term storage and numerous ways to reduce cognitive load. By taking these factors into account, the student has more space in working memory. Consequently, the ease of learning can take place.

B. Reducing Cognitive Load for EE110

What are some load reducing techniques? Examples of cognitive load reduction include the following [16]:

- Use symbols instead of photographs
- Use simple text on the screen
- Add sound effects to support on-screen animation
- Use a voice-over instead of text
- Frame video using the rule of thirds

The above examples can be explained by CLT principles. Discussed next are some principles developed by Clark, et al [6] [7], and Mayer [15] [17] to manage cognitive load. These learning principles include: modality principle, learner control, split attention, reversal effect, redundancy effect, and self-explanation/mental rehearsal (weekly quizzes and lab activities).

Modal Principle. Divide and spread the information so visual and audio channels are used to avoid overloading each channel. For example, if all the course content is visual with text, pictures, or animations, the visual channel becomes overloaded. The delivery of engineering content should offer some data verbally and other data visually to avoid exceeding the capacity of working memory. This will allow the learner to absorb information using different processing methods, which will reduce cognitive overload. Visual content with narration spreads the load between the two channels improving the processing capacity. This allows students to absorb information using different processing methods while reducing cognitive overload.

Given that CLT says that efficient learning takes place when both visual and audio processors in working memory is used, narrated videos were obviously developed. EE110 leveraged the modality principle by having over seventy YouTube short videos, totaling about nine hours. This averages about less than one hour of video instruction is needed for each week. A series of short videos were used throughout the 11-week course of instruction. These videos include both visual and audio narration providing efficient use of resources in working memory while allowing students to learn and process the content more efficiently. Most of the seventy-plus videos in EE110 are less than ten minutes.

The reader may ask, 'what happen to the rest of the forty hours found in a traditional classroom?' The rest of the time is focused on learning activities to transfer and automate their understanding into long-term memory. These activities include: homework problems, quizzes and lab experiments. A series of short videos followed up with short assessment activities (e.g. quizzes) provided a means to avoid overloading working memory. In EE110, short videos were the norm to minimize the amount of extraneous cognitive load that is not of immediate interest to the learner and to make optimal use of working memory. A Harvard Study [18] shows that short videos are not enough. Students' attention will wander even for a short video. The professor needs to include assessment activities to keep students mind from wandering. In EE110, weekly practice quizzes and weekly final quizzes were used to help transfer knowledge from working memory into long-term memory. The videos and quizzes prepared students to perform weekly lab experiments promoting the development and automation of schemas.

When investigating on how to produce engaging videos back in 2008, Professor Santiago learned that entrepreneurs who are using videos to promote internet marketing or other affiliate products have been using Camtasia, produced by TechSmith. During 2015 when developing content for EE 110, the full-time faculty learned how to use Camtasia, a video capture and editing software tool for creating multi-media content. Camtasia has many features to cue and engage the student on important areas on the video. For example, a professor can use callouts to highlight areas on the video where students should focus their attention. Callouts are handy during the editing process when the professor forgets to use its mouse for highlighting areas within the video.

When the learning objective is competency in a technical task, it may be best to make a screencast where Camtasia excels [19]. The tool became one of the first and must-have video creation and video editing tool for the authors. Recently, other popular video editing software began incorporating this screen capture feature as well. However, Camtasia was originally targeted for the educational marketplace. Camtasia evolved from being a program for software demonstrations back in 2005 to a full-featured educational tool in 2015. Despite the large number of current features, its learning curve is manageable based on faculty use of Camtasia. Table 2 lists key educational benefits & features of Camtasia.

Camtasia Feature	Description	Educational Benefit
a	Hot Spots	Students can choose a particular learning path and interact with video by clicking on buttons or characters. Create attractive PowerPoint slides and import with Camtasia. Allows anything to be clickable so learner can move seamlessly to a new screen or even outside the video to additional learning materials.
b	Add-in to PowerPoint	Screen Capture of PowerPoint Presentation delivered in a micro-learning fashion and combined with cursor highlighter to keep learner attentive.
c	Ability to Collect and Report Test Scores	Create Quiz and Collect Results via email. Organizes them and sends a daily report of how students are doing,
d	Multiple video Windows or Tracks	Keep Learners attentive. Display screen recording inside one window, presenter talking in another and an animation to go along with the screen recording in the third.
e	Green-screen removal	Overlay videos to create interesting learning scenarios. Need to avoid too many moving parts that will distract the learner
f	Call-outs	Can be used to call attention to the learner on a key concept or call-to-action. Like calling attention to the learner on an area on the video
g	Cursor highlighter	Can be used to keep interest to follow the animation of a hand-written sketch or text similarly found in a whiteboard presentation…has potential for a Dopamine effect.
h	Pan and Zoom	Use to highlight an area of interest in the screen and to create variety in what's being displayed and keep learner attentive
i	Markers	Use to create a table of contents of portions of a long video

Table 2. List of Key Features in Camtasia & Educational Use

The features enable the instructional designer to keep the learner attentive that includes establishing an interchange of actions between the student and the video. Screen capture with Camtasia has the advantage of requiring a relatively small initial capital investment and logistics when compared to a video recording studio. Based on the experience of Professor Santiago to teaching the laboratory content of EE110, he believes that more videos may be needed to provide additional help for students [3]. For online delivery, a problematic issue is helping students troubleshoot their circuits [3]. Hangouts, Skype or video chat sessions with either the instructors or with other students are possible solutions. Another means is the development of a troubleshooting checklist for students to follow before requesting instructor help.

Learner Control Principle. Breaking the content into smaller chunks allows the student to control their learning pace. Students must have enough time to process the information efficiently when the content is getting progressively complex. This will ensure students do not overload their working memory and can effectively move the information into long-term memory. Once students grasp the content, they should be encouraged to move on to the next segment. To retain the learners' attention, the online lecture should be less than twenty minutes as given by most TED talks and even less than ten minutes if it is a static screencast that does not show the instructor's face such as those YouTube videos found in Khan Academy.

Allowing the learner to control the pace of learning increases student engagement. Using video, students can pause or rewind if the content didn't make initial sense. The professor can simulate question and answer approach in a F2F classroom in an online environment by using interactive video. Student feedback showed that interactive video experimented during 2016 provides a more engaging experience and documented elsewhere by the authors [4].

Because watching a video is mostly a passive experience, the authors wanted students to have more interaction with the videos to increase engagement. In EE 110 for example, embedded questions were posted on top of the videos to simulate a Q&A conversation with students. Interactions were added without redoing the 9 hours of 70-plus videos using web software, called H5P, described later in the paper. Questions can be randomly embedded in time throughout the video. The authors found that this random feature of embedded questions while having variety of content, adds an element of anticipation to engage the user to be attentive.

Positive results from the use of interactive video and Google Docs were received. Student surveys were encouraging using both interactive video and Google Docs in delivering the multimedia content. The interactive video was used in EE110 to engage and allow learners to control pacing and content. Further details on these two implementations are documented in [4] and [5] by the authors.

Figure 1 provides an example of what is meant by an interactive video. The left screenshot shows the display of an interactive video before a student presses a knowledge check button. When a knowledge check activity appears on the video, the video automatically pauses. The pause cues or signals the student to act. As shown on the bottom of the left screenshot, the knowledge checks appear throughout the video at various times. This feature provides the student a level of suspense drawing attention to the media content.

The right illustration of Figure 1 shows the display after the student clicks on the button. The student must respond to the learning activity. After answering the question, the e-learner gets feedback. Also, the answers shown here are randomize in terms of the order. For example, 1.33A shown on the top of the choices may appear on the bottom 0.75A the next time the video is played. This random feature forces the learner to pay attention if the student decides to replay the video for review. The interactive video includes clickable, clear and concise e-learning questions. In terms of mental rehearsal, several and short practice quizzes are given each week in preparation for weekly final quizzes and lab experiments.

Tips on Using Interactive Videos. Christopher Pappas [13] outlined some key tips when using interactive videos that are summarized below appropriate for the academic environment:

- Keep the interactive videos bite-sized so they are easily digestible and focused on a specific sub-topic
- Keep the focus on the speaker and avoid busy backgrounds and other distractions.
- Include clickable, clear and concise eLearning questions
- Try to include captions while giving complete control to learners so they can pause, rewind and adjust the volume
- Create an online companion guide and avoid computer-type manuals

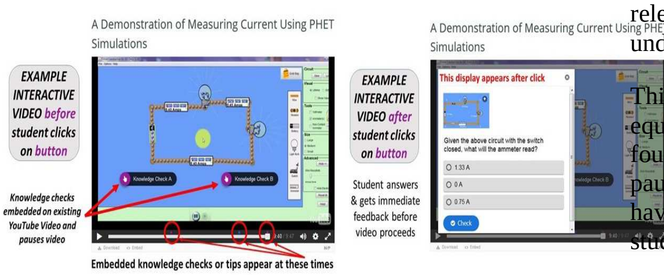

Figure 1. Example of interactive video of screenshots before and after student clicks on knowledge check button

The reader will notice that the above bullets has elements of CLT. The last bullet helps reduce the effects of split attention, discussed in detail later in the paper. The online companion guide was not implemented for EE110 since students did not raise this as an issue. Pandey also outlined similar points to include: hotspots, drag-n-drop and fill-in-the-blanks [20] [21]. In addition, the above tips are consistent with extensive and comprehensive studies on multimedia e-learning [6] [7].

Interactive videos provide visual cues for the student learner when a different topic or activity begins or ends. This approach helps avoid overloading working memory.

Coherence Principle. Keep the content as simple as possible. Remove background music, animated backgrounds, decorative graphics and non-essential content that does not support the instructional goal. These elements may appear to make the learning more interesting but it increases the processing and extraneous load. Irrelevant content can distract the student as well.

As a general rule of thumb, stick to one audio channel and one visual for optimal learning [19]. When recording a lesson on your computer, keep a plain background on your desktop and avoid a busy wallpaper image. A cluttered work space can draw attention away from the important content intended for the student. These tips were used in EE110. When recording a computer screen with Camtasia, authors closed or removed all nonessential applications, browser toolbars, and desktop icons. Also, busy animated backgrounds were avoided in the video to follow the coherence principle. When installing Camtasia, an add-in is embedded within PowerPoint allowing direct use of Camtasia to eliminate extraneous background from the desktop when recording with PowerPoint.

However, green-screen techniques can cue the learner on important portions of the video or cue an important summary of the content that was previously presented [1]. The important point, is that the animations need to add value to the student's learning experience.

The animations in recorded videos of PhET simulations have been effectively used in EE110. As long as the multimedia content with animations and simulations are relevant, then they can add value to the student's understanding of the content.

This technique can be used as you animate a series of equations to derive a mathematical result. The authors found that animating a long series of equations with pauses and explaining what each equation means or having the students interpret what it means can increase student engagement and understanding of the material.

During 2008, before CoE developed EE110, Professor Santiago recorded videos to assess the instructional and online delivery of advanced and abstract engineering concepts. Results appear promising to develop future engineering courses using the instructional techniques found in this sample of videos. The experience gathered after 2008 in creating these videos was used to develop the multimedia content in EE110. These survey results appear to verify and validate the flipped learning approach or philosophy during the past few years.

The videos developed can be enhanced to further engage the student by embedding questions using: (1) interactive video or (2) highlight and cue relevant areas on the videos by Camtasia's video editing capabilities and educational features found in Table 2. The encouraging results, evidenced by a large proportion of likes versus dislikes on YouTube, increase Professor Santiago's confidence, since there appears to be 'buy-in' from viewers allowing to proceed in pursuing the multimedia approach.

The narrated videos provides variety to engage the viewer including: (1) a highlighted cursor to engage the viewer, (2) animated equations in PowerPoints, (3) recorded animated PhET simulations and (4) experimentation of whiteboard animations. Providing a variety of presented content will help engage the viewer or e-learner. An animation records an artist drawing of a creative storyboard on a whiteboard provides engagement. The whiteboard animation often has an audio lecture or speech. A professor who has an audio recording can create a video using whiteboard animation [18]. Like the videos in Khan Academy, Professor Santiago has use Camtasia since 2008 to hand-write and derive equations on a writing tablet to emulate whiteboard animation.

When producing professional videos, the professor needs to practice, practice, and practice [19]. The professor needs to practice correctly moving the cursor or opening applications so they appear appropriately in the recording area. To get the proper screen recording, the professor needs to practice on positioning of browser windows and other applications [19].

YouTube provides a means to make the video the same size or Professor Santiago's YouTube Channel. These considerations are highlighted as well by TechSmith, maker of Camtasia [19].

Split Attention Principle. The instruction should keep diagram/charts and detailed explanations on same page or screen within a short video. To improve information transfer, place text close to the corresponding graphic. Do not force the learner to visually scan the screen to match the text with the graphic since requires additional resources for mental processing. You can use cueing techniques to highlight key pieces of content. The professor can cue the student by highlighting important details. In a circuit schematic, the instructor can emphasize on the diagram by circling the component or provide an arrow of a key component.

Composition and video editing software, like Camtasia, has many features to draw attention to key portions of the video. For example, the left figure of Figure 1 has a yellow semi-transparent circle following mouse movements. The student can then keep track of verbal explanations corresponding to highlighted areas from cursor movements on the video.

To minimize split-attention, CoE used other methods to help focus and engage the student in EE110. For example, before using interactive video, CoE used Google docs to provide a straightforward layout of a series of short videos and assessment quizzes so that students do not have to frequently jump back and forth between YouTube videos and assessment quizzes on word. The layout of YouTube videos and assessment quizzes is shown in Figure 2. Initial attempts used links to YouTube videos and links to word documents which can result in split attention. The authors have experimented with PowerPoint to embed YouTube videos followed with assessment quizzes. The authors have also experimented with embedding interactive videos within PowerPoint. The recording of student actions and collating results from quizzes gathered from interactive videos embedded in PowerPoint is work in progress. This is the primary reason to use the Google Docs approach which helps reduce the administrative burden for the authors associated with weekly assessments. Google Docs allow to easily collect weekly quiz results and export the results to an Excel spreadsheet.

Redundancy Principle. Do not narrate on-screen text. Audio and text duplication impedes learning and should not be confused with rehearsal which aids in automation [6] [7]. When the same information is processed through audio and visual channels, the learner is forced to process the same redundant information. However, narration of on-screen text appears appropriate when summarizing the content [6] [7].

Students learn best with graphics and narration better than with both graphics and on-screen text. Reading a lot of text with graphics on a single slide or screen is unsuitable for the student. Reading an extensive amount of text and understanding the graphics can lead to overloading working memory. If reading text is necessary, try not to have the student look for the essential text on a computer screen for example. Cue or highlight the essential text.

Videos for EE110 did not have instructors reading text on the videos and comments on student surveys show reading on-screen text was not an issue. If fact, student comments from surveys reveal that there was a good mix of video and text in the multimedia course content.

Reversal Effect. In terms of reversal effect, freshman need worked examples while experts (e.g. seniors) may need less worked-out examples [6] [7]. To account for learner's prior knowledge, the proposed use of PowerPoint for adaptive learning is explained elsewhere [22].

As mentioned earlier, EE110 required intensive development of multimedia content and four full-time instructors. This freshman-level course required over seventy YouTube short videos, totaling about nine hours. Weekly online quizzes and weekly labs were performed in class to assess student understanding. For future development of traditional/online courses, CLT will be used for improving instructional design and delivery.

CoE anticipates that less intensive development of multimedia content will be needed as students' progress through the program curriculum. For example, less videos may be needed for graduate level or senior undergraduate courses while more reflection type of learning activities may be required.

Self-Explanation/ Mental Rehearsal. During the last two years in EE110, the in-class and weekly lab experiments as well as weekly practice quizzes prepared for the final quizzes and labs. And these quizzes and labs proved effective to help transfer new knowledge and skills for long-term retention. As mentioned earlier with CLT principles, interactive video and Google Docs has been effectively used.

When students can perform hands-on lab experiments in class with instructor assistance in the troubleshooting process, the authors are confident that the multimedia content consisting of videos, text readings, homework and other assessment activities prepared the students to apply the learned content with hands-on lab experiments.

The online videos and quizzes provided individual space for students to reflect on the content. Providing students with enough time to process the multimedia content prepared students to perform the weekly lab experiments.

Group activities include students helping each other collaborate and address lab procedures. Based on this observation, students performing the labs at home will be a challenge. The CoE plans to have a chat session to address questions about the conduct of the lab experiments. In terms of accountability for an online environment, CoE plans to have each student record short videos on their lab findings to verify and validate their understanding. Developing a concise and short video, takes a significant time for students to reflect on their weekly laboratory experience. In the F2F environment, students already give group presentations on selected labs in various engineering courses.

Students need to provide a short lab report on their findings to further internalize what they learned. Of course, full-blown lab reports will be expected on circuits and electronic courses after students have taken EE110.

Discussion boards can easily provide individual student reflection and mental rehearsal. The techniques for reflective learning have been successfully used in a senior digital communications course [11]. Discussion boards for EE110 were also used but are complementary to the labs which were resulted in increased student workload. Recently, the discussion boards lacked participation in the discussion when adjuncts taught EE110 for the first time during the past year. The discussion boards will need to be investigated in the future in terms of reducing the amount of student workload.

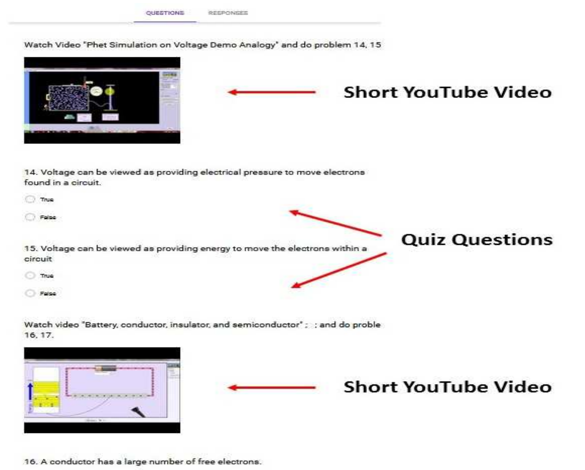

Figure 2. Screenshot of example Google Docs with embedded YouTube videos and quiz questions.

It was mentioned earlier that interactive videos were used to engage students. The authoring suite used to engage students with variety of learning activities is called H5P. The authors intend to use the other H5P widgets to provide more reflective and self-explanation learning activities.

The H5P authoring suite is a free and easy-to use. H5P includes numerous widgets to allow students to reflect on what they viewed and what they learned. H5P widgets provides techniques allowing for self-explanation and mental rehearsal. The widgets intend to improve student engagement with the course material. For mobile learning, H5P uses HTML 5 and supports numerous mobile devices [23].

Table 3 lists the various interactive multi-media content found in H5P. Although not as versatile as other tools, it eliminates the cost for experimentation. A YouTube video can be enhanced with a variety of questions, text, pop-ups, and quizzes. Similar H5P services from other companies and used by some leading universities can cost at about $65,400 per year for a platform version.

In addition to interactive video, H5P has numerous other content types to deliver interactive course material [23]. Using the numerous H5P widgets makes the interactive content more engaging for students. The H5P authoring tool has been designed so that the content can be shared and reused. The types of content include widgets such as: games, multimedia, questions and social media. One widget is "course presentation". An instructor creates slides that are interactive on a webpage. Here, the educator can add text, audio, video and more. The instructor can even add gamification such as a board game. In this case, the user answers quiz questions to complete each level. The instructor can develop a question set. The question set can be a sequence of tasks engaging the user with multiple choice, drag and drop and fill in the blanks. Flash cards are also valuable for mental rehearsal so that learners can insert text corresponding to an image [17]. These content types provide a variety of interactive teaching modules to maintain student interest.

Multimedia Content Type	Description
Interactive Video	Create videos enhanced with interactions
Course Presentation	Produce interactive slides engaging students to act
Image Hotspots	Overlay an image with multiple hotspots to provide info
Timeline	Create a timeline of events with multimedia
Find the Hotspot	Create hotspots for students to find
I frame Embedder	Embed a URL or a set of files
Appear.in	Add a video chat to a web page
Chart	Generate bar and pie charts
Impressive Presentation	Create a slideshow with parallax effects
Collage	Create a collage of multiple images

Table 3. Samples of Multimedia Content Widgets in H5P [23]

Summary of CLT guidelines. Based on student comments from several end-of-course surveys, the delivered content for EE110 followed key principles associated with CLT. Table 4 summarizes key principles and guidelines based on CLT [6] [7]. EE110 attempts to provide a positive learning experience for the freshman student. The above CLT principles found in Table 4 explain the instructional design for the course. To implement the flipped classroom approach, the authors have used a number of Camtasia's visual features to cue learners on important portions of a complex visual screen as well as using an e-learning authoring suite H5P to increase user engagement. The use of Camtasia, H5P widgets, YouTube social component, and Google Docs provided variety of ways to deliver the content and assess student understanding. This approach attempts to reduce student boredom for the same mode of instruction.

Principle	Guidelines
Modality	• Working memory uses separate processing of visual and audio information (dual encoding) • Use Visual and Audio Narration for Efficient Use of Resources in Working Memory
Learner Control	• Allow learners to control pacing and content • Teach in segments and modules allowing for repetition or skipping as desired • Teach support knowledge separately • Teach Components before full systems
Split Attention	• Keep diagram/charts and detail explanation on same page to help student focus attention (avoids split attention) • Use visual cues and signals when content is complex • Provide content summaries • Avoid computer manuals
Redundancy Effect	• Avoid narration of slide text (audio and text duplication impede learning) • Not to be confused with rehearsal or repetition aiding automation
Reversal Effect	• Need to consider learner's expertise • Experts need less external instructional support • Novices need worked examples while experts do not
Self-Explanation/ Mental Rehearsal	• Learning activities to transfer new knowledge and skills for long-term retention • Mental processing of examples requiring clarification and elaboration • Rehearsal for maintenance or elaboration on problem solving instruction • Worked example/problem pairs more efficient than all-practice lessons

Table 4. Some Key Principles and Guidelines of Cognitive Load Theory (CLT) [6] [7]

Summary of Results Using the Flipped Classroom Approach for Winter 2016 to Fall 2017

Table 5 shows the results of the grade distribution for the flipped classroom when compared to the traditional F2F classroom for course offerings of EE110. The left column shows the grade distribution, average percentage grade for the class, number of instructors, and delivery method. The grades were averaged for with and without including students who received an F. Instructor 1 (one of the authors) taught all the flipped classrooms during 2016 and F2F (or ground) course during Fall 2014 quarter.

During 2014 and 2015, adjunct instructors taught the ground sections shown in the last three columns while the full-time faculty developed and refined the course content. The percentage grades found in the last three columns served as a comparison with the flipped classroom.

Table 5 also shows the average percentage grade (highlighted in yellow) when removing students with F-grades. For students who passed the course, the results show that the flipped learning approach was effective. The results from the 2016 Fall Quarter are comparable with the 2014 Fall Quarter results. Based on successful student feedback, the multimedia and interactive content appear to be satisfactory in preparing students to conduct the labs.

	Fall2014	Win2016	Sum2016	Fall2016	Win2017	Fall2017		Fall2014	Spr2015	Fall2015
A	5	3	1	3	2	3		1	2	3
B	2	1	2	1	3	2		4	2	5
C	1	1	1	1				4	1	
D		1	1		2					
F	1	3	2	2						
w/o F	*90.6*	*85.5*	*83.0*	*88.8*	*82.1*	*90.8*		82.7	*88.1*	[illegible]
w/F	*85.2*	*66.7*	*67.0*	70.7	*82.1*	*90.8*				
Instructor	1	1	1	1	5	4		2	3	4
DELIVERY	Ground	Flip	Flip	Flip	Flip	Flip		Ground	Ground	Ground

Table 5. Summary of Grade Percentages from 2014 Fall Quarter to 2016 Fall Quarter

Instructor 1 taught one traditional (ground or F2F) and the F2F flipped classroom simulating an online environment. With the flipped classroom approach, there is an increase in the number of Fs when compared to the ground courses. Instructor 4 has taught the traditional and recently the F2F flipped learning approach. Although the student sample size is small, both approaches appear comparable in terms of grade outcomes. The intent is not to show which delivery method is better, but to see if the delivery of the flipped learning and its implementation as described by this paper can meet course outcomes.

The adjuncts (instructors 4 and 5 of Table 5) who taught EE110 using the F2F flipped classroom during 2017 were comfortable with the course content and that the flipped learning approach met the course outcomes. However, the online discussion boards did not have much student participation according to the adjuncts. They commented that the discussion boards required extensive time and needs to be relooked. The authors agree that the online discussion boards did not support with the in-class lab and group activities. The authors plan to either eliminate or reduce the amount of student workload required to complete the discussion boards.

III. POOR PERFORMING STUDENTS AND NEXT STEPS

The student receiving Fs resulted primarily from non-attendance in class and lack of submitted work. The authors further investigated the increase in the number of students receiving Fs summarized in Table 6. The poor performing students did not like the flipped classroom. The flipped classroom requires the student to take on more responsibility, including: (1) viewing the multi-media content and completing assigned homework, (2) taking the weekly practice and final quizzes and (3) performing weekly hands-on experiments. Students who are more comfortable with the traditional F2F instruction may not be prepared for these responsibilities.

Attendance	% Grade	Comments
20.0	7.6	lack of attendance
47.6	12.4	lack of attendance and large number of assignment receiving a grade of 0 points
50.0	37.0	large number of assignments receiving a grade of 0 points
60.0	23.7	large number of assignments receiving a grade of 0 points
70.0	34.1	large number of assignments receiving a grade of 0 points
71.4	38.6	large number of assignments receiving a grade of 0 points
80.0	36.1	large number of assignments receiving a grade of 0 points

Table 6. Attendance and percentage grades from students who received an F

For students who performed the assigned tasks, the multimedia content and assessment activities prepared them to do the weekly lab experiments. These activities are intended to develop and automate their schemas as they progress through program curriculum. In addition, weekly quizzes were given to assess their understanding and recorded through Google Docs.

During 2016 Fall Quarter, results from the use of interactive video and Google Docs are shown in Table 7 in the column labelled ‘Fall2016’. Student surveys were positive about the use of interactive video as well as the delivery of multimedia content using Google Docs.

In terms of addressing poor performance by some students, CoE intends to look at Self-Determination Theory (SDT). Research suggests that people are more motivated to do something if the learning experience satisfy their needs for autonomy *(degree of independence, choice and control of self-knowledge)*, competence *(degree of mastery of subject material)*, and relatedness *(sense of belonging)* [12]. How can professors support those individuals to enhance the student’s learning experience?

- Feedback: When providing student feedback, make the poor students feel respected who are capable of drawing the right conclusion. It may be that the poor students need more instantaneous feedback to address their wrong choice. The CoE briefly experimented with H5P when it comes to instant feedback which needs to be further implemented with text narrative in the future, especially when the course is delivered fully online. The assessment activities will help student become independent and give confidence to progress through the content with *autonomy*.

- Information: Student feedback show that the conscientious students do pull the information they need when they need it. This concept helps support their autonomy and lets them build *competence* at their pace. Professors need to provide resources for students to pull. All of the provided content need not be pushed to the students during the F2F or online learning environment. However, students need to be aware that the resources are available.

- "Voice" in learning. How can CoE make self-paced online activities feel more "human" to help people feel relatedness? One solution may be that interactive video and synchronous chat sessions will make the students feel more engaged in the learning activity. To promote *relatedness*, interactive video with narrative feedback can allow the learner to make the best choice. When the student sees a happy result (indicating *competence and mastery of the material*), narrative feedback can explain why it was the best choice and what was wrong with all the other choices. Due to time constraints in EE110, very little feedback in terms of text narrative was given in either interactive video or Google Docs when a student makes the wrong choice. The simulated chat session is intended to answer questions from the multimedia content and assessment activities. For online delivery, CoE intends to have two weekly chat sessions per week to address the questions from the multimedia content and the lab experiments. Student accountability will be important when instructor and students meet online synchronously.

Applying CLT to the Integration of Entrepreneurial-Minded Learning (EML) Activities in Communication Systems II (EE 463)

In following sections, the paper will now focus on the entrepreneurial-minded learning (EML) activities and results for a digital communications course, identified as EE 463, Communication Systems II. 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 senior students did not have any exposure to the entrepreneurial mindset in their previous engineering courses, the intent of the EML activities in this course is to have them develop their entrepreneurial mindset from KEEN's framework, discussed in [11]. 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.).

One concern by the authors is student workload given the amount of required technical deliverables plus the EML activities during the 11-week course. 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 technical concepts. In addition, the authors wanted to retain the technical rigor of the content while adding EML activities. Table 7 shows the percentage of student deliverables before and after integrating the EML activities. Grade percentage weight of EML modules increased from 0% to 24%.

In Table 7, 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.

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 7. EE 463 Before and After Percentages of Student Deliverables

EE 463: Discussion Boards for Reducing Cognitive Load in Preparation for the Research Paper and Presentation

Students were tasked to deliver a professional research paper and presentation for EE 463. Before applying CLT using a flipped teaching approach, students selected their research 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 activities. These learning 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 uses guidelines from CLT. Specifically, there are three guidelines intended to reduce cognitive load as shown in Table 4:

(1) *learner control* to allow learners to control pacing and content while teaching segments and modules allowing for repetition as well as teaching components before the full systems;

(2) *reversal effect* where the instructor needs to consider learner's expertise since these students are seniors where they need less external instructional support and need less worked examples and;

(3) *self-explanation/mental* rehearsal where learning activities transfer new knowledge and skills for long-term retention.

The new instructions for the research paper and presentation are given in Figure 3 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, described in [11]. 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. Students then performed learning various tasks in the modules to foster an entrepreneurial mindset.

The authors realize that the propose research paper and presentation, as describe in Figure 3, may be overwhelming for most students at first. More instructor guidance and instructional design 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 and CoE have used it develop learning activities based on the Kern Entrepreneurial Engineering Network (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 4 came from the Institute of Electrical and Electronics Engineering (IEEE) Communication Society website [25]. Discussion boards are intended to apply CLT 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 8 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.

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.

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 – Internet of Things (IoT)

– Driverless Everything – Security, Privacy

– Distributed Ledgers (bitcoin, block chain etc.) – Deep Learning/Artificial Intelligence

– Smart Everything: City, Grid, Cars – Molecular Communication (nanobots)

– Light Fidelity (LiFi) – Spectrum Allocation (MIMO, 1000x),

– Next Generation 911 – 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 3. New Instructions for EML-centered Research Paper and Presentation

Figure 4 shows an example of an EML discussion topic for ‘the Internet of Things’. In Figure 4, 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 5 is an example student response to the discussion board about the internet of things (IoT). In Figure 5, 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.

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 8. 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 4. Example of Instructions for a Discussion Board Topic: Internet of Things.

The response in Figure 5 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. 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.

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 area 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 5. Example of Student Response to Internet of Things Discussion Board Topic

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.

IV. 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 was 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 6 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 Santiago 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 involve: 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.

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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 6. Student Feedback of EML modules/activities.

In Figure 6, 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.

V. NEXT STEPS IN EML ACTIVITIES

Fall 2017 was the first quarter to apply the newly developed entrepreneurial activities to account for cognitive load. The data sample is small and the results are preliminary. Using guidelines from CLT, the authors will continue appropriately integrating these entrepreneurial activities while applying the flipped classroom approach in other engineering course sequences. These courses include subjects in: circuit design, communication systems, and digital electronics.

Using CLT 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.

CONCLUSION

Using CLT and leveraging CoE's teaching experience using the flipped instruction approach, the authors are attempting to find the best ways to help students store and retrieve information through either a F2F or online environment. In terms of future development of online courses, the authors will leverage experience from flipped learning and apply CLT to improve the design both the instructional content and its delivery. The e-learning principles include: modality principle, split attention, self-explanation/mental rehearsal (lab activities), and learner control. CLT provides guidelines for better module design for efficient learning for either the online and F2F instruction.

Based on student comments, the delivered content for EE 110 followed principles and guidelines associated with CLT. Student feedback showed the use of Google Docs and interactive video are effective means to implement the flipped learning philosophy for either online or F2F teaching. The suite of tools provided by H5P requires further investigation to provide variety in delivering important engineering content in numerous ways. CoE anticipates the need for variety of content in engaging ways when future students do decide to pursue an undergraduate engineering program for several years in an online environment.

To address students who have received F grades from this study, Talbot [12] identified CLT, self-determination theory (SDT) and Self-Regulated Learning (SRL) to serve as frameworks for flipped learning. The authors will investigate these frameworks to help reduce or minimize the number of students having poor performance. In the short-term, one simpler approach is to educate students on the flipped learning approach and its philosophy. Another consideration is to incrementally transition future courses to the flipped classroom on selected topics and on selected courses as students familiarize with the flipped learning concept.

Using CLT in EE 463, the EML activities appear to be successfully integrated while maintaining the technical rigor. 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.

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