Methodology and Development of Open-Source Lecture Nuggets that create Hands-on Engineering and Discussion Spaces

Abstract—**This discussion focuses on one approach and methodology for developing openly available (e.g. Youtube) short lecture nuggets enabling in-class discussions and hands-on learning experiences (e.g. experimental measurements). These video nuggets give space for interactive student learning in the available faculty-student classroom time. From developing lecture nuggets and using these nuggets in multiple ECE classes over the last five years, classroom time can transform toward focused on interactive faculty and student conversations as well as creating space for interactive hands-on laboratory experiments and related opportunities. This discussion focuses on this author's experience, strategies, and methodology developing open-source lecture nuggets for a wide range of nominally ECE courses.**

No longer is the primary value of university education is simply the delivery of content from an expert to a student. Although traditional faculty lectures were focused on delivering content to students in the classroom (Fig. 1), technical content is becoming more and more available in formats openly available to everyone. This discussion focuses on one approach and methodology for developing openly available (e.g. Youtube) short lecture nuggets enabling in-class discussions (e.g. inverted classroom) and hands-on learning experiences (e.g. experimental measurements).

The goals of developing asynchronous lecture materials has shifted over the last two decades. These video nuggets give space for interactive student learning in the available faculty-student classroom time. Our previous video development (2000-2006) using 20-25 minute or longer recorded lectures as student reference material (50 minute lecture = 20 minute recorded lecture) started enabling class time for other learning opportunities. Multiple videos have been considered in many areas of education [1], [2], [3], [4], [5], [6], [7]. The explosion of internet videos over the last 1.5 decades on a range of platforms (e.g. Youtube starting in 2005) have changed student expectations of video content and video length.

Initial experimentation of short lecture nugget videos before the worldwide Covid pandemic in 2019-2022 provided an opportunity for further creativity during the pandemic. Openly available lecture nuggets (open-source, e.g. Youtube) at a typical consumed video length of 4-8 minutes (e.g. [8], [9]) makes course lectures through a medium that students routinely utilize that matches their typical experiences. Simply recording traditional lectures that students watch at 2x speed seems to miss the available opportunity.

Using Lecture Nuggets watched before class transforms classroom time to be focused on interactive faculty and student conversations (Fig. 1). These approaches enable a range of flipped classroom opportunities [10], [11], [12], [13], [14], [15], [16], opportunities enabling interactive discussions and

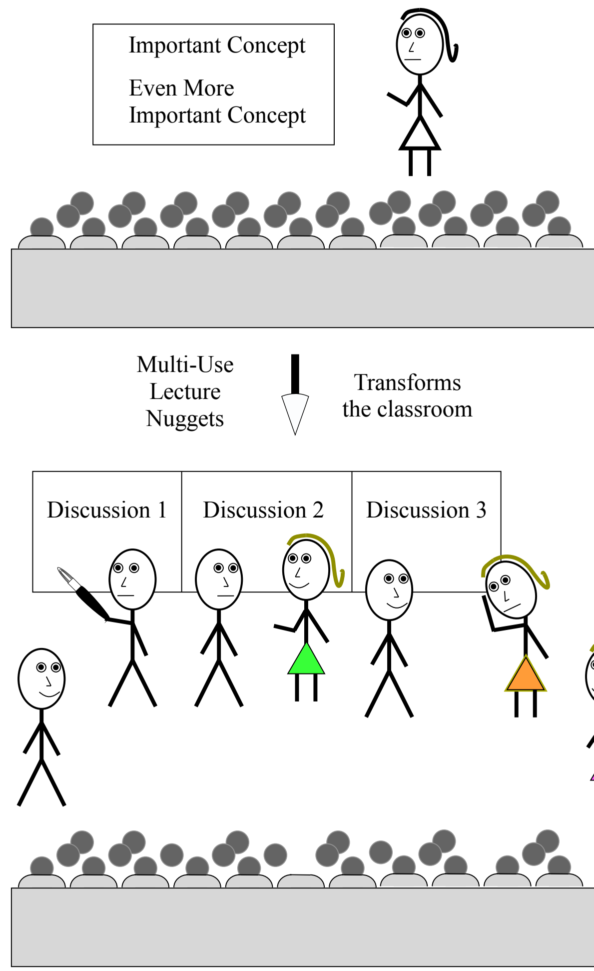

Fig. 1. On-Line lecture nuggets enable transofrming a classroom from conveying information to interactive discussion spaces. Using on-line lecture nuggets, in this case open-source lecture nuggets, to convey information frees up the available lecture time for an interactive class discussion or for experimental hands-on student interactions.

resulting active learning. The question is how best to utilize these contact hours, these face to face interactions. Classroom lecture time can become a free-flow and interactive problem solving session (Fig. 1), where the students perceive they have agency in conversations. Classroom lecture time can be transformed to enable hands-on efforts include efforts, such as in second-year core linear circuit and a first signal-processing ECE courses, as well as senior level and graduate level design and experimental measurements.

This discussion works through our multi-year efforts developing on-line, open-source, course development, its result-

2023 IEEE Frontiers in Education Conference (FIE) | 979-8-3503-3642-9/23/$31.00 ©2023 IEEE | DOI: 10.1109/FIE58773.2023.10342930

Stage 0	Stage 1: Curr Videos	Stage 2: Example Videos	Stage 3: Connecting Videos	Stage 4
Course Development	Start taping lectures Start shifting class	Nuggets = Solved Problems Occasional Traditional Lecture	Meta Lecture Nuggets	Maintance Have Online?

Course	# offered	Short Description	Stage
Undergrad ML	Su ’23	Initial Offering (2nd-3rd year students)	0 to 1 (0.5)
ECE 6550	F ’22	Linear Control Systems	1 to 2 (1.5)
ECE 2040	Sp ’19, F ’20	Linear Circuits	2
ECE 2026	F ’22, Su ’23	First Signal Processing	2 (→ 3 after Su ’23)
ECE 6435	Sp ’16, ’18, ’20, ’22	Analog VLSI / Neuromorphic Circuits	2 to 3 (2.5)
ECE 4430	F ’15, ’17, ’19, ’21	First Analog IC Design	3

Fig. 2. Stages of Course Development with on-line lecture nuggets. Stage 1 requires involves translate typical lectures into short lecture nuggets and starting to use the classroom time for additional interactive opportunities. Stage 2 is focused towards moving problem solving to on-line lecture nuggets, both problems being solved in class that are later recorded as well as translating exam and other measure solutions also into lecture nuggets. Stage 3 shows the addition of higher-level guiding lectures, effectively Meta lectures, that guide students through the material. Stage 4 is a maintance mode for the course as well as a range of next opportunities using this course (e.g. other on-line deployments). Each stage could occur within a semester, multiple phases in a single semester, or developed over multiple semesters. The course levels at GT are 1xxx and 2xxx are first and second year courses, 3xxx and 4xxx are third and fourth year courses, and 6xxx are graduate courses open to senior undergraduate students.

ing structure, and our experience building and implementing interactive educational techniques. We have developed over 250 YouTube lecture nuggets for classroom experiences that were developed near or during the offering of multiple ECE courses. We describe our interactive teaching approach enabled by lecture nuggets, empowering learning where the faculty member is often teaching from the side (Fig. 1) rather than in front of the class. Creating a new course with video content requires four main stages that include course curriculum development (Stage 0, Course Development), video nuggets communicating core curriculum content (Stage 1, Curriculum Videos), video nuggets solving example problems (Stage 2, Video Examples), and higher-level overviews such as unit summaries that connect the individual blocks into specific groups (Stage 3, Connecting Videos). The discussion starts with the foundation of these lecture nuggets to enable hands-on classroom space (Sec. I) with the approach and methodology for developing short lecture nuggets (Sec. II), using video nuggets to enable in-class discussions & hands-on learning experiments(Sec. III), developing open-source nuggets with built in hardware (Sec. IV).

I. Nuggets enabling Hands-on Classroom

These video techniques were initially developed to open classroom time for hands-on experimental measurements. These efforts use in-class interaction to build confidence in hands-on tools in joint student–faculty discussions. In many cases, the students, having access to technical material, or having their own equipment, have attempted the experiments before class starts. The students are motivated by the availability of time to work through technical issues as a community with their design system physically present; students who do not come prepared realize they will spend far more time solving their issues individually. The group solution of technical issues builds everyone’s confidence in using their system tools, from IC layout tools, to MATLAB tools for signal processing, to hardware measurements for linear and nonlinear circuits. Previous efforts utilize hardware-based class projects using research tools starting at the graduate level integrated circuit measurements (e.g. [17], [18]) that moved into core undergraduate transistor circuit courses [19]. An integrated-circuit layout design course utilizing short lecture nuggets provided lecture time for multiple hands-on design sessions to build student confidence in their design projects [20]. The approach showed both increased student capability and student confidence for developing system design at a higher level than experienced in graduate level circuits courses. Our recent effort using open-source lecture nuggets for a graduate-level integrated circuit measurement course (Sp 2022) transformed class time almost entirely as a hands-on laboratory experience with discussion time around difficult technical areas. This effort expands these discussions to a wider range of ECE courses, from signal processing (ECE 2026), control systems (ECE 6550), and Machine Learning.

II. Multi-Use Video Nuggets Development Stages

Development of a curriculum of multi-use open-source on-line nuggets requires multiple development stages as well as planning over multiple courses. Creating a new course with video content requires course curriculum development (Course Development), video nuggets communicating core curriculum content (Curriculum Videos), video nuggets solving example problems (Video Examples), and higher-level overviews such as unit summaries that connect the individual blocks into specific groups (Connecting Videos). As the author developed or redeveloping courses, the pattern of starting a new course follows these categories. These videos are often developed while offering one or more semester / quarter course offerings, where the student feedback through the development refines the content. One rarely creates these videos all together without some initial interaction. The following paragraphs describe the four main stages (Stage 0, 1, 2, 3) in developing open-source on-line videos (Fig. 2), where a stage occurs during a single semester, part of a semester, or over multiple semesters.

Stage 0: *Course Development.* This stage involves Course Development as the initial development of the course material, initial lectures and materials that the particular professor injects their expertise and experience into the course. Some

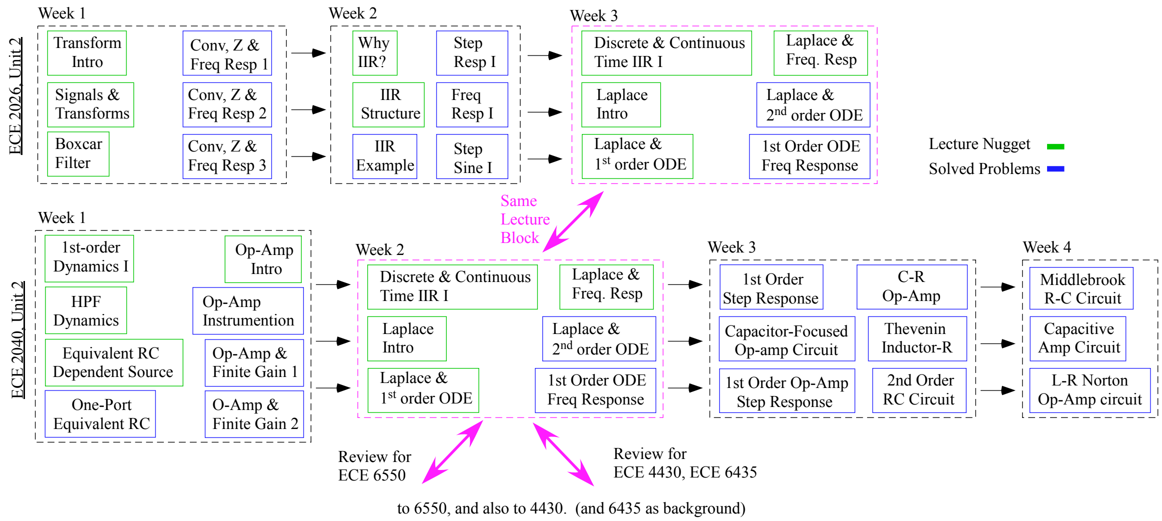

Fig. 3. A detailed lecture nugget map for the second Unit for ECE 2026 (First Signal Processing) and ECE 2040 (Linear Circuits), showing the both the items covered as well as the overlap of multiple video lectures between these two courses. Lecture nuggets can be reused in multiple course flows assuming the nugget is not tied to a particular place, course, or time. These lecture nuggets also become review for further courses on controls (e.g. ECE 6500) and review for further courses in circuits (ECE 4430, 6435).

initial materials might get developed, such as initial slides to be used in lecture that could be taped in the future with modification from the class experience.

Stage 1: *Curriculum Videos*. This stage develops the online lecture nuggets for creating Curriculum Videos. In-class course content and material needs to be translated into initial course nuggets. A typical semester course (40-45 contact hours) tends to be 60-80 short videos of 4-8 minutes in length, roughly two for each class. Initial lectures recorded from other classes, whether by the professor or from another source, can be incorporated into this structure. Open lecture materials developed by others can be incorporated into the course depending on the taste of a particular course. Many of these videos get created at the beginning or early weeks of the semester (or quarter). Experience shows that the video development decreases with the increasing semester pressures. One starts generating some of the Video Examples from the course by recording example problems used in class as well as recording some solutions for exam problems. Typically this stage requires the largest amount of faculty energy time and effort even with this staged approach.

Stage 2: *Video Examples*. This stage develops problem solving lectures based on in-class problem solving or other class solutions (e.g. exams). Classes are structured with an explicit focus on making problems, enabling a wide range of interactive student in-class lessons. These lectures become available for the next semester. Some development likely starts in Stage 1 and yet, becomes fully implemented during this stage. Typically 60-90 example problems are created in a single semester, providing a large base of recorded nuggets for that semester and following semesters.

Stage 3: *Connecting Videos*. This stage adds a focus on high-level overview lectures for a particular grouping of lecture nuggets while still continuing the previous stages in the class format. These high-level overviews can stil be used in multiple places if the lectures do not include specific class or time information. The particular connecting videos are typically only clear after multiple offerings of a course, as these are developed in the initial in-class overviews, and usually benefit from more creative nugget development.

This approach utilizes many bottom-up development approaches, something far easier for faculty with significant teaching loads to incorporate into their teaching efforts. One can try a top-down approach, although that requires significant amount of time and a heavy lift for a faculty member.

Our techniques developed in a number of courses (Fig. 2) before and after the pandemic. This methodology crystalized at the beginning of the pandemic, being developed for both 2^{nd} and 4^{th} year undergraduate courses, as well as graduate courses. Our development of a Lecture Nugget class initially in a systematic way with senior-level analog integrated circuits (ECE 4430) built upon experimental earlier cases (ECE 6435). These techniques expanded into teaching earlier undergraduate courses (ECE 2040, 2026) as well as other graduate courses.

III. Multi-course Video Nuggets enabling Classroom Discussion

Utilizing lecture nuggets to open classroom time for discussion and hands-on development requires both developing course material as well as encouraging students to watch these videos before the class session. This author's develops in-class sessions that are interactive learning experiences that students both see the value in watching the lectures ahead of time, as well as realizing their cost in terms of class effort if they are not able to watch the lectures ahead of time. This approach avoids quizes to encourage students to watch the videos, building community trust, as well as students perceive this flipped classroom as more than additional assignments. The short lecture time increases the probability of lectures being watched.

Each nugget roughly stands alone. A nugget can be used by multiple courses. An introduction to Laplace transforms (Fig. 3) shows up as core material in linear circuits (e.g. ECE 2040), important material in signal processing introduction

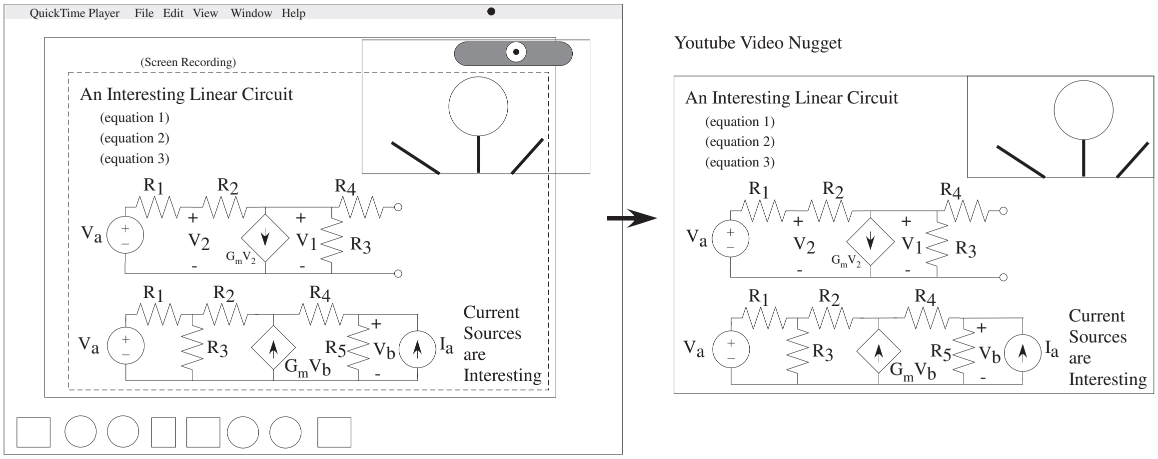

Fig. 4. Computer on-screen setup for the author's taped lecture development. Starting from a screen image (typically a pdf page), the videos are set up in MAC OS using built-in QuickTime Player. The video recording option is used (but not recording) in the upper right or upper left corner of the video to for the conversation. The screen image is blank over the region of the speaker; typically this region is optimized for each video recording. A selected screen recording gathers only the desired image space for the recording. The resulting video has nothing of the original MAC OS background (right).

(e.g. ECE 2026), and background material in upper level and graduate courses (e.g. ECE 4430, ECE 6550). As one can use and reuse some videos in different places and different times (Fig. 3), each nugget must not identify with any particular class, a particular semester, or identify with a particular date of recording. Videos need to be designed to last through many years of potential use. Recording of such videos and their open-source deployment requires careful control of individuals in the video, particularly if other than the instructor (unless explicit permission is given). Open-source enables course material everywhere, providing both easy access for students to access the course material whether currently taking the particular course, as well as enabling individuals from nearly any background to have access to a wide range of materials. Multiple class video lectures are openly available (e.g. MIT OpenCourseWare [21]) or at low cost (e.g. Mooc [22]) as well as other on-line opportunities from other academic individuals (e.g. [23]). These resources makes world-class engineering education knowledge accessible to a wide audience, and likely increases the accessibility of these courses. Using on-line courses enables lower-cost availability of traditional courses and resulting engineering resources. Openly available videos can raise STEM & engineering knowledge worldwide increasing opportunities to many individuals.

IV. Videos with built-in computer software

Developing open-source nuggets leverages the current techniques for recording videos using widely available computing techniques. The goal is to develop 4-8 minute length video lecture nuggets to be openly available (e.g. Youtube), corresponding to the length of many typical Youtube videos. Our experience shows that the most common format for a 4-8 lecture often uses a single background picture with multiple concepts with the speaker image. Some cases one will want longer lecture videos, likely as an overview video or something that has dual research use (e.g. conference presentation). Significant motion and animation helps to hold an audience for a lecture longer than 4-8 minutes. Different video formats change some of these constraints. The above techniques can be modified for multislide approaches with the speaker image present, although requires a few additional steps (e.g. an *esc* from recording that still records but allows screen commands for advancing pdf images).

Creating open-source video nuggets does not require significant infrastructure, often only requiring a typical laptop with built-in or open-source software and careful selection of the recording environment. The author's video recording uses a Mac laptop with built-in software. The figures, equations, and graphs are all generated onto a single .pdf page with space not used in the upper right-hand or upper left-hand corner (Fig. 4). The short video recording does not require changing the .pdf page during the recording. That includes the built-in QuickTime Player function, getting images the from camera (*Movie Recording*, but not doing any recording) and from screen (*Screen Recording*, recording) at the same time. If one is creating open-source videos, the creator needs to be mindful of using specific university faculty taping resources.

Choosing the video and acoustic environment is essential for any taped lecture. The video framing and resulting background typically is a clean blank white wall, and care is taken to have clothing that does not clash with the wall unless that is the desired effect. The acoustic background should be clear of any external noises or background sounds unless one is illustrating such effects. Shorter videos minimize the potential undesired sound coming into the recording. These small steps make sharp videos that are useful for many years.

V. Summary

This discussion focused on one approach and methodology for developing openly available short lecture nuggets enabling in-class discussions. These video nuggets provide space for interactive student learning in the available faculty-student classroom time. From our experiences developing lecture nuggets and using these nuggets in multiple ECE classes over the last several years, we envision classroom time becoming focused on interactive faculty and student conversations as well as creating space for interactive hands-on laboratory experiments and related opportunities.

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