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# Board 82: Remote, Hands-on ECE Teaching: Project RECET

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Project RECET - **R**emote **ECE T**eaching

**Abstract:** RECET (Remote Electrical and Computer Engineering Teaching) is a pilot project developed by the Electrical and Computer Engineering Department Heads Association (ECEDHA) to help provide quality ECE education even when fully online and explore issues associated with blended online and in-person instruction for the future. The COVID-19 pandemic forced most ECE programs in the US to rapidly go online. Departments found this transition quite challenging if they had not previously developed materials and infrastructure for online delivery. Online compatible techniques for teaching have been developed and researched for years, but prior to COVID-19 they were not widely deployed across ECE Departments in the US. The extraordinary push to online learning forced programs to look to experienced instructors at other academic institutions and educational hardware and software engineers in industry for help. ECEDHA and IEC offered online meetings to facilitate communication between faculty and teaching support staff from their member programs, but missing was a searchable, curated, content repository, especially for remote hands-on learning. Project RECET is working to fill this void by enabling active sharing of course content with other institutions and industry.

RECET, while still a pilot, has passed through several revisions to improve the user experience. RECET visitors are greeted by a diagram that shows its basic structure as seen by content users or providers. Content is tagged by topic, course level and hardware and/or software platform. Content presently available is generally limited to circuits and electronics, where the need during COVID-19 was the greatest. A communication channel between industry and the academy has been created and a process is under development by which the learning products can be created, maintained, socialized, and owned to promote a new trans-institutional culture to increase the impact of engineering education research on ECE education.

The RECET website is now being used to promote and collect feedback from potential content users and providers, to systematically improve the repository impact and to prepare for its eventual scale-up. The vision of RECET to enable more effective collaboration between ECE programs for educational delivery has been socialized throughout the communities served by ECEDHA and IEC. There have been articles in online newsletters and presentations at online and in-person meetings, with a particular emphasis on regional meetings of department heads. Unfortunately, interest in a repository like RECET has waned since COVID-19 restrictions on ECE educational delivery have been eliminated. Many programs have gone to a new normal, but they have done so by almost entirely addressing their remote delivery issues locally. ECE departmental leadership largely considers the issues their programs had to deal with during COVID-19 as solved and the forces for change gone. Based on ideas that have been received from the ECE community, RECET is now in the process of pivoting so that the lessons learned during the pandemic can eventually lead to a true new normal.

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## Introduction

Online and online compatible techniques for teaching Electrical and Computer Engineering (ECE) at the undergraduate and continuing education levels have been developed and researched for years [1], but prior to COVID-19 they were not widely deployed across ECE Departments in the US. This was also the case more generally for applying the results from Discipline Based Education Research (DBER) [2]. The COVID-19 pandemic forced virtually every ECE program in the US to go online within a short period of time during the spring 2020 semester. Some departments found this transition more challenging than others, depending on the extent of materials and infrastructure for online delivery already developed in the department. In many departments the implementations were improvised by necessity.

Given continuing uncertainty about the duration of the pandemic, the availability of vaccines, the need to maintain social distancing and isolation of sick and at-risk students and faculty, most universities continued some level of remote activity at least throughout the 2020-2021 academic year. As ECE educators and students became more experienced with remote education, they learned that the choice between face-to-face and online instruction is not an either-or proposition. That academic year helped them to see the value of what has, possibly, been the most common thread found in work described in the DBER report and papers presented at the ASEE Annual Conference - blended learning strategies. Nearly all ECE programs have offered students, in at least some of their courses, the opportunity to experience live/synchronous instruction while located in campus classrooms and/or at home. Instructors and/or institutions have come to realize that what COVID has required them to do should become at least part of *the new normal*, continuing in the future to realize the best possible learning environment for their students. (This characterization of the impact of COVID is from a study of minority serving ECE programs. [3])

For over three decades, since Benjamin Bloom's original publication on the *2 Sigma Problem* [4], we have known that personalized, tutored instruction using a *mastery learning* approach [5] has a two-standard-deviations better chance of enabling students to equitably reach their maximum learning potential than conventional instruction (e.g., in-class lecturing, weekly homework assignments, and two or three high stakes exams). One of the historical challenges to providing such personalized instruction has been the prohibitively high person-hours required, especially with large enrollment classes, when added to course delivery and administrative tasks such as lecturing and grading.  Another challenge has been the persistent limited knowledge and understanding of higher education teachers, especially, but not only in engineering, about instructional methods other than the lecture-based model that they experienced during their undergraduate years. At the dawn of the 21$^{st}$ century, however, digital education technologies began to emerge with the ability to enable conventional classrooms to more closely approximate individualized tutoring. The quarantining and distancing forced by COVID spurred an explosion of enhancements to online instructional support infrastructure such as improved and more generally available learning management systems (LMS), video-conferencing meeting software, and internet bandwidth upgrades, as well as innovative, affordable hardware (or hardware-software) products for hands-on learning *at home*. Consequently, we now have an unprecedented opportunity for technology to solve at least some—perhaps most—of the logistical barriers to personalized learning. There was an important *tipping point* opportunity to leverage the COVID-driven investments in online instructional tools to foster a post-pandemic environment—a *new normal*—where *blended* and *hybrid* instructional modes are broadly accepted as the gold standard for teaching and learning. [6]

ECE is particularly well-suited for leveraging electronic and digital technologies to achieve the best outcomes from hybrid and blended teaching and learning. This is due to two unique factors: (1) ECE students have inherently self-selected—and thus, already anticipated—a curriculum that expects them to master electronic and digital devices and environments, and (2) many hands-on, active-learning laboratory activities in ECE involve measurements with instruments now available in miniaturized, mobile, low-cost realizations. Therefore, in the *new normal*, combinations of online, face-to-face, asynchronous, and synchronous instruction can elevate student learning by:

- Using online tech to deliver basic knowledge content (instead of live lectures), freeing up more instructor time to provide personalized coaching with individual students.
- Transferring low-value-added, time-consuming tasks (e.g., delivering, collecting, and grading assignments and exams) to online LMS, freeing up more instructor's time for high-value-added personalized instruction and building meaningful student relationships.
- Leveraging online video meeting technologies to allow synchronous remote and in-person instruction [7] so that students or instructors facing temporary life challenges that force them to be remote can continue to teach and learn with high quality, personalized, synchronous interactions. These include situations when students are called away from campus for an emergency for a period of time and yet can't afford to drop the course, or students in study-abroad programs who desire to take the course remotely but wish to maintain the value of synchronous access to the instructor and other students taking the course, or students who *need* the course this semester but waitlists exceeded course capacity so they enroll in an online section running in parallel with the face-to-face section, or students taking the course online during the summer while also participating in critically important summer internships.

The new normal is not limited to education. Industry needs similar hybrid or remote working skills; employees who are self-directed, self-managed; have high self-motivation; and, at the same time, can work as an effective part of a physically dispersed team. Knowing when to ask for help, and when to troubleshoot systems by yourself becomes more critical as employees are working remotely. Software companies like Facebook, Twitter, and Square are among the many early adopter companies to announce they would permanently extend their fully remote work policies, announcing employees could live anywhere (adjusting salaries to local norms). [8] Google announced they are testing a hybrid work model that would allow some employees to work from home at least part of the week. [9] For some employees, such as those who need access to specialized equipment, either lower cost alternative equipment is used remotely (similar to hands on USB instrumentation), or they must travel to the office (similar to hybrid labs). Nearly all future engineers will work as part of a remote or hybrid team.

To help address the disruptions caused by COVID, ECEDHA and IEC began an initially unfunded pilot called Project RECET (Remote ECE Teaching) to demonstrate that it is possible to *collect and disseminate ECE learning materials* that can have an impact on remote or blended delivery at multiple universities. This effort went public the week of 17 August 2020. This pilot is based on the Minimum Viable Product (MVP) concept from Lean Startup that is part of the NSF I-Corps Curriculum. We started with the simplest possible approach, with an initial focus on establishing that there are course materials relevant for remote delivery that our colleagues across the US will share, and that faculty from Organizaion2 are anxious to download and use. This turned out to be the easiest goal to achieve. We quickly received content to be shared from a variety of academic and industrial sources that more than adequately covered the critical ECE topics of circuits and electronics. Labs for these topics were among the largest challenges for remote delivery. The project began with a high level of confidence that such sharing would be achievable because faculty from nearly all IEC ECE departments have a solid track record of doing so. [10] At that point, there were contributions of content covering all aspects of Circuits, plus other ECE topics, from four companies and six additional universities. Funding was obtained to complete the pilot project in the summer of 2021.

When the collected content was first presented in a simple format to the ECEDHA community during online meetings, the clearest message received was that the content needed to be well organized and easily searchable. We also decided that we needed a platform that was of high quality and sustainable, two characteristics that are rarely realized when supported solely by academics. The software firm that was developing online educational infrastructure for ECEDHA seemed like the ideal choice for creating and supporting the platform we required.

In the following section, we present the repository status, which is now the final form of the Minimum Viable Product (MVP) as presented to the ECE leadership community for feedback. It looks good, works well, and provides multiple opportunities for visitors to provide feedback on their experiences with Project RECET. In the next section, we list the barriers we have identified and the hypotheses and tasks we have developed to address them. Most of these barriers were observed during previous IEC large-scale projects that involved content sharing between institutions. Unfortunately, the key pain point driving the development of the MVP – the pandemic – has turned out to also be one of the biggest barriers. When everyone returned to campus, there were too many other problems to address, which left little or no bandwidth to build on lessons learned during COVID-19. Finally, we present our conclusions based on received feedback. Lessons were learned during the pandemic but apparently not any that have encouraged much of the ECE community to more fully embrace the kind of remote hands-on learning activities facilitated by RECET. There is, however, some anecdotal evidence to apply the RECET approach to expanding educational opportunities for smaller programs.

## Project Status

The overall vision of Project RECET is a searchable, curated, ECE content repository, with a focus on hands-on learning. If successful, it should facilitate communication across all of the ECE community. Figure 1 shows a simple visualization of RECET. Content is submitted by the Content Provider, approved for use by Editorial and made use of by the Content User. Editorial is presently an informal process provided by the academic/industrial project team. As requested by early visitors to the RECET site, content is tagged by topic, course level and hardware and/or software platform for search identification and mechanisms are in place for Content Users to provide feedback. Screen captures of the main RECET content page follow in Figures 2 and 3.

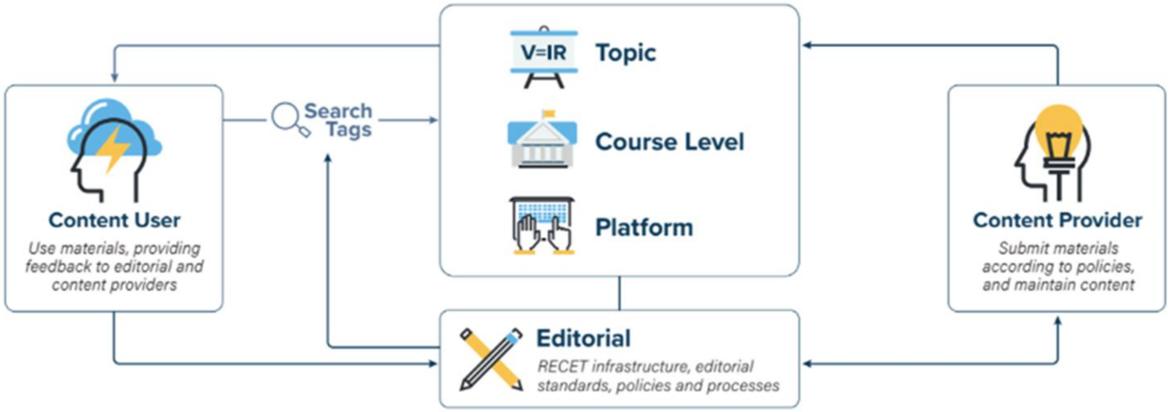


Figure 1: Project RECET

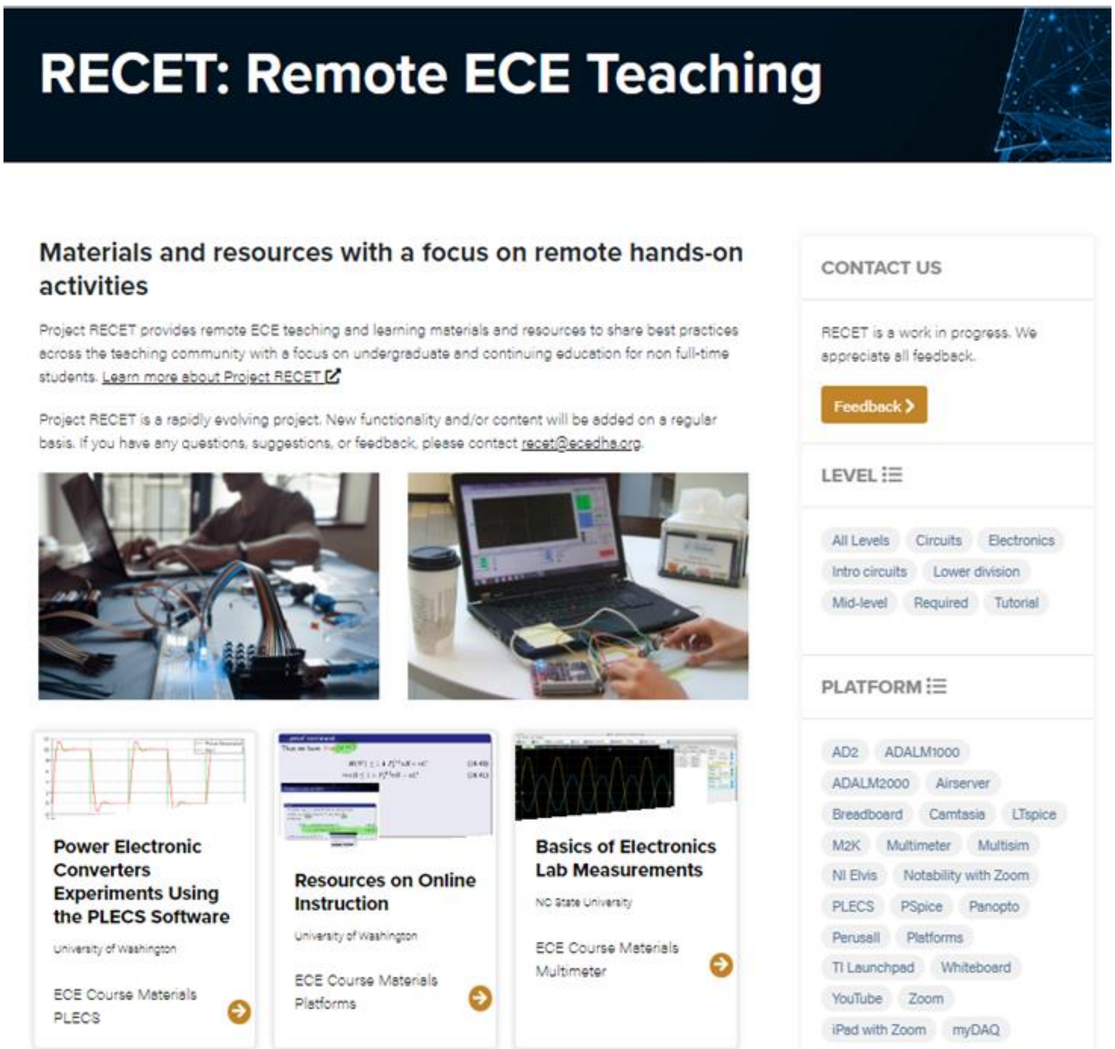


Figure 2: RECET Screen Capture

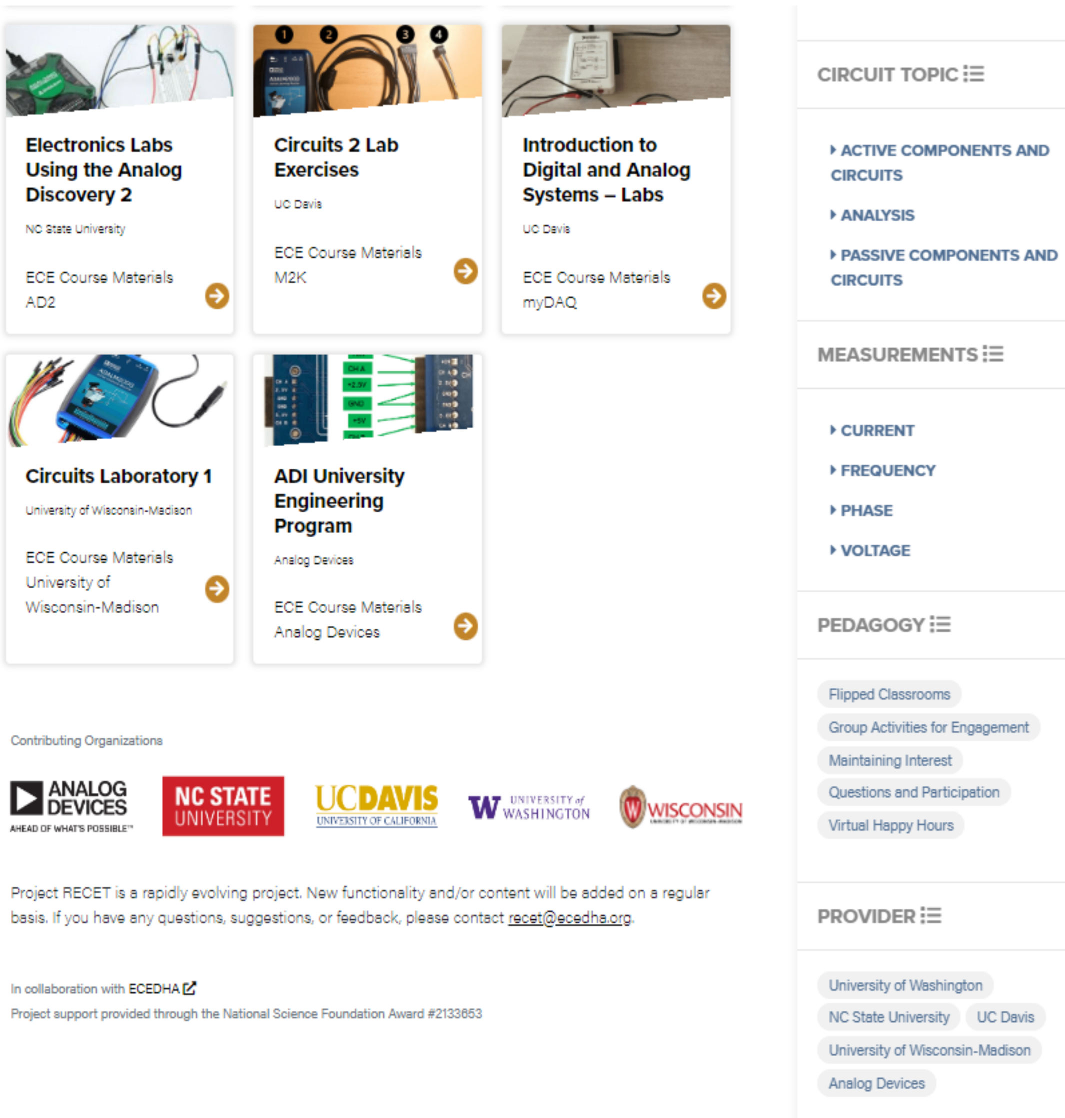


Figure 3: RECET Screen Capture

A key component of the project is to create educational experiences that better prepare students for success in industry and to help industry better understand how their products are used in the classroom. Consequently, participation by industry in the creation of the proposed online materials is essential. To date, Analog Devices, Inc., is an active participant in the pilot project and other companies have contributed content. When the project is scaled up, we will add participants through our collaboration with ECEDHA and their corporate members.

### Barriers, Hypotheses and Tasks

There are several barriers to creating, supporting, sustaining and using an ECE content repository like RECET. During the pilot phase we developed a series of hypotheses that address these barriers which we were able to partially test. We have been updating the list of barriers as the project has progressed. Some we have been able to address and some not. Barriers are summarized in Table I, along with some status information that will be discussed in the following section on Project Feedback and Conclusions.

| **Barriers** | **Hypotheses** | **Tasks** | **Status** |
|---|---|---|---|
| There is little or no tradition of content sharing outside departments. | There is a large cohort of ECE instructors that appreciates the value of freely sharing content. | Collect a reasonably complete set of Circuit course materials. | Completed |
| Courses are developed locally by individuals or members of the same department. | Minimal branding and hardware agnostic approaches will encourage adoption of RECET content. | Collect feedback from Org1 leaders and look for examples from Org1 and Org2. | Branding and hardware agnostic approaches were not mentioned in feedback. |
| There is little or no reward for instructors to work directly with peers from other schools. | A collective academia-industry approach can produce a cultural shift. | Collect feedback from Org1 leaders. | No evidence yet of such a cultural shift. |
| COVID-19 impact on student learning and departmental resources. | Instructors and departmental leadership will work to identify productive lessons learned during COVID-19 and will build to a new normal. | Survey department leadership. | Most department leaders have moved on from COVID-19 and are not promoting a new normal. |
| A functional business model enabling the use of personal instrumentation by all students eludes departments. | Functional business models can be developed. | Collect feedback and survey department leadership. | This remains a major issue, especially for smaller programs. |

Table I: Project Barriers

In initial meetings with members of ECEDHA and IEC, one of the most common issues was that the original, very simple version of the RECET website was not easily searchable because content was not tagged. The website was produced in a manner that made the content available, but without much structure. A plan was developed to collect a set of tags for RECET content. The initial set was much too large to be convenient, so it was reduced to the present set that can be seen on the website. We did not rely on our own skills for website development, but engaged the firm building the ECEDHA site that provides easy access to the latest tech news and ideas. (The firm specializes in marketing and business development communications.) This decision kept the costs down for the first serious public version of the RECET site and resulted in a consistent look and feel with the rest of the organizational website. We also focused on a subset of submitted content, selecting the materials that were most immediately useful and that addressed most of the content tags identified.

Barrier: There is little or no tradition of sharing content outside the department in ECE and other engineering disciplines. The development of instructional materials is focused almost completely on each instructor's local program. There are some notable exceptions that suggest this does not have to be the case. Some faculty clearly believe in an open-source approach to education and publicly post most of the materials they use in their courses. For example, most IEC members participated in a project which was built on such sharing. [10] In almost all cases, however, there are learning materials and activities located behind LMS walls which limit access to local faculty and students. We hypothesize that there is a large cohort of instructors that sees the value of freely sharing content, even without NSF support. We tested this hypothesis in the RECET pilot phase by demonstrating that a reasonably complete set of Circuits course materials could be collected in a form that is useful for others. As noted above, faculty from six universities invested the time necessary to modify their materials so they can be useful to others.

Barrier: Instructors nearly always see the need to create their own course content individually or by collaborating with colleagues in their department. Course materials they find elsewhere (i.e., through web searches) are modified so that the only branding seen by students is associated with the school they are attending. There are even many cases where faculty and programs change the names of pedagogies developed elsewhere to something only used locally. We hypothesize that minimal branding and hardware/software agnostic approaches will encourage the adoption of content from RECET. In discussions with ECEDHA members, this barrier was rarely mentioned so, at present, it does not seem to be a significant issue.

Barrier: Faculty have almost always developed and delivered courses locally and are rewarded for doing so locally. They also do not generally make use of the strong, evidence-based research being done in engineering education. There is little or no direct reward to faculty to work together with colleagues from other schools so there is no tradition of jointly developing/delivering courses. A notable exception is found at NSF Engineering Research Centers, which are encouraged to offer courses to students at all partner institutions. The ERC program is encouraging a convergent approach to large-scale societal challenges, which is described in a report from the National Academies. [13] Meanwhile, industry and practicing engineers have little direct impact on engineering education. [2] We hypothesize that a collective, academia-with-industry, approach to developing and delivering courses can bring a fundamental cultural shift that encourages a greater use of evidence-based research from engineering education and a larger role for industry. RECET has already increased industry participation and plans to expand these activities further in the future. A variety of communication modalities including email updates, newsletters, in-person and online meetings have engaged faculty from ECEDHA and IEC member institutions in vigorous collective discussions of topics like the sharing of content and new pedagogies.

Barrier: The COVID-19 pandemic provided the ultimate motivation for delivering their educational programs remotely. Since few departments had much relevant experience, there was a lot of sharing information with colleagues from other institutions. At least during the early stages of COVID-19 there was a clear sense that at least some of what everyone had learned to do would translate into a new normal when everyone was able to return to campus. [3] However, people burned out on change and saw too much that had not worked well. When students were again attending in person, it became all too obvious that there was a significant deficit in learning when done only remotely. Discussions at recent meetings of IEC, faculty have been discussing ways to add additional tutorial sessions to their classes to build student understanding of fundamental concepts. This has the potential to produce a new normal but, for now, is focused primarily on addressing student learning that has not been occurring in recent years. We hypothesized that instructors and department leadership would identify lessons learned to be used to improve student learning, but that has not happened, at least not yet.

Barrier: During COVID-19, most programs were given additional resources to enable remote hands-on learning. However, a combination of very large price increases, technical difficulties with some products and the need to invest in other aspects of student learning infrastructure have put most departments back in the status they had pre-COVID-19: no sustainable business model that enables the use of personal instrumentation by all students. Schools with more resources are generally fine, as are schools with generous donors. Some schools are able to provide hands-on learning kits for all of their students from such donations. There are clearly business models that work, but, at present, most are not options for smaller, under-resourced programs. It is very likely that some kind of paradigm shift is necessary in how hands-on learning in ECE is paid for and maintained.

Additional details on project tasks can be found in Appendix I.

**Project Feedback and Conclusions**

The RECET webpage includes three opportunities for users to share their feedback with the design team. There is a 'Feedback' button near the top of the page and there is an email address provided at the top and the bottom of the page with the following request: 'Project RECET is a rapidly evolving project. New functionality and/or content will be added on a regular basis. If you have any questions, suggestions, or feedback, please contact recet@xxxx.org.'

Once some key milestones were met in this project (see below for a list), we made multiple attempts to connect with ECEDHA members to request that they explore the RECET page and provide their feedback and encourage the faculty in their department who teach Circuits and Electronics to do likewise. We also asked them to engage with RECET by providing materials from their organization, become involved in editorial/communications activities, help to create and organize tutorials, workshops, etc., join teams working to obtain additional resources, provide feedback to other content providers, and, most critically, recommend some next steps for RECET if we find the resources to scale it up. We then also had a Q&A period. We presented to an ECEDHA Online Summit in late fall 2021, addressed the ECEDHA annual meeting in three separate sessions in March 2022, and addressed each of the regional ECEDHA meetings in the summer and fall of 2022. The attendees for each of these venues tend to be a bit different. For example, smaller schools can be reached online and at regional meetings because annual meeting attendance is expensive.

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Initial set of milestones:

- A representative set of content with a focus on Circuits and Electronics was collected from both universities and corporations.
- A set of tags enabling easy search of content was developed and socialized with colleagues
- A simple landing page for corporate content made available by equipment vendors on their websites was developed and implemented for one company.
- A diagram showing the overall vision of Project RECET was developed.
- A professional website design was developed and implemented by a commercial firm specializing in marketing and business development communications.

These milestones were not met simultaneously, and each had their own challenges. Two of the milestone challenges resulted from the cultural mismatch between the academy and the commercial world. Developing a system that works for education and industry (here: equipment vendors) is always difficult, but the larger mismatch has been between academics and professionals who work in public relations, marketing and advertising. Mismatches result in a lot of poor communication. In the end, the experience is good, but development times are long.

RECET traffic increased during and immediately after our presentations. However, there was little long-term effect and essentially no feedback was received through the channel we built into the web site. We did receive some useful feedback/comments/suggestions at the meetings, mostly during the Q&A session. We also communicated with other ECE colleagues whenever the opportunity presented itself. There were three distinctly different responses we heard multiple times.

- Leaders from larger ECE departments told us that they had figured out how to deliver their lab courses online during the pandemic and considered the problem solved. They had moved onto other issues.
- Leaders from small departments have had difficulties sustaining the kind of hands-on learning opportunities they temporarily implemented during COVID because they did not know how to pay or have students pay for the personal instrumentation and other hardware they used. They basically did not have a working business model that enabled their students to have access to personal instrumentation. This is partly due to the significant increase in price for these devices. They also find that identifying the best devices from the many that are now available is a daunting task.
- Leaders from small departments were the most enthusiastic about a relatively popular way to expand RECET's coverage of ECE. Small departments are generally unable to offer new elective courses addressing hot technological topics like AI/ML. They would be open to using courses developed at large universities with robust research enterprises. This idea comes up over and over in meetings of ECEDHA and, especially, IEC because the latter is made up mostly of small departments. Small programs typically have very large teaching and advising responsibilities (often 4 courses per term), which means they rarely have the resources to keep their students abreast of the latest in ECE technology.

Based on these responses, we created a very simple, one-question survey to better understand why we were getting so little feedback through the RECET website. We briefly reviewed the many meetings we had to stimulate feedback. Then we asked department leaders to select the option that best describes their situation.

- I did not attend any of the meetings listed or receive any of the electronic communications that discussed RECET.
- During COVID-19, we replaced our hands-on labs with simulations and returned to in-person labs using conventional benchtop instruments as soon as we could.
- During COVID-19, we developed a stopgap approach to delivering our lab courses using personal instruments (e.g. Digilent Analog Discovery, Analog Devices ADALM2000) that we feel does not work as well as our traditional in-person labs or costs too much to continue, so we do not plan to utilize remote delivery in any of our courses.
- During COVID-19, we developed an effective approach for delivering our lab courses remotely so, for us, this is a solved problem. We now use a mixture of personal instruments (e.g., Digilent Analog Discovery, Analog Devices ADALM2000) and conventional labs with benchtop instruments and are investing our departmental resources on other issues.
- I had other reasons for not responding. They are: (please fill in the blank)

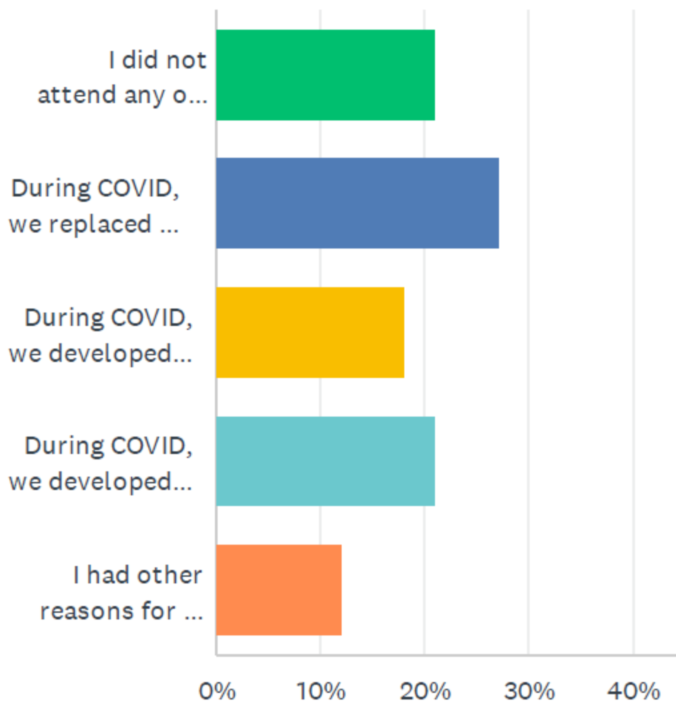


Figure 4: One-Question Survey Responses (See text for options)

The ‘other’ reasons largely boil down to ‘too busy.’:

- Looked at it. Looked interesting and helpful. But busy and it didn’t solve an immediate problem for us. Just didn’t get back to it.

- We did try to correspond with RECET but were never acknowledged / never received any reply. In the end, we just gave up. (This is on us. Not sure why we missed this.)
- I have been swamped, but plan to do it after the end of the Spring semester.
- Sorry, Department Chairs are just very busy people. Can't respond to everything coming my way.

From this survey, we see that only about 20% of respondents agreed that personal instrumentation enabled their educational offerings to move toward a new normal and they felt they were already there. The 'other' responses show that essentially all the department leaders we contacted were too busy. They had other problems to address that were more important. Other anecdotal information from colleagues at the more creative departments indicate that they are indeed implementing exciting new ideas in course delivery, with some arguing for HyFlex, even though it has been getting a great deal of pushback across the board in higher ed. [24] All departments responding are addressing their educational delivery by focusing inward rather than looking to collaborate with faculty elsewhere. The one constituency that shows support for collaborative solution to common problems is smaller departments. They see the potential to address issues they are unable to consider alone. The next stage for RECET must focus more on their needs and get more small school faculty involved.

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17. https://www.redpitaya.com/
18. https://www.picotech.com/oscilloscope/2000/picoscope-2000-overview
19. https://www.rigolna.com/products/digital-oscilloscopes/1000z/
20. https://www.seeedstudio.com/DSO-Nano-v3.html
21. https://www.liquidinstruments.com/product/mokugo/
22. http://www.analog.com/adalp2000
23. https://www.ti.com/lit/ml/ssqt010/ssqt010.pdf
24. https://www.insidehighered.com/advice/2022/01/19/hyflex-teaching-black-mirror-higher-ed-opinion

## Appendix I – Additional Information on Project Tasks

Presently, Project RECET is organized to address the general barriers described above by focusing on the following tasks. The task list is evolving as RECET matures.

<u>Collecting Content for Circuits and Electronics</u>: Demonstrating that ECE colleagues from both the academy and industry would enthusiastically contribute content on Circuits and Electronics was the key task of the pilot phase. With the help of ECEDHA and IEC, a few emails and phone calls produced the excellent results seen on the project website. The only significant barriers identified by potential contributors were that some materials existed behind their local LMS wall and some materials needed some polishing before they were happy to have others try to use them. Neither barrier delayed the contributions more than a few weeks, which speaks to the level of commitment shown by the contributors. Some of the contributors had already posted their materials in a publicly available location, so their materials required only a few days to prepare. Significantly expanding the collection of contributed content is expected to require the completion of some or all the following tasks.

<u>Developing a Topics List for Circuits and Electronics</u>: As mentioned above, we have constructed a list of core topics pertaining to introductory Analog and Digital Circuits that are widely considered to be essential. There is a significant consensus on what the key core topics should be in such introductory courses. This list guides and prioritizes our collection and development of materials covering these topics that can be adapted and personalized by instructors. The list of topics also serves as tags for the shared materials. In addition to topic tags, the content tag list also includes the level of the course content, whether or not it is a required course, the specific commercial hardware or software, measurements, pedagogy, and content provider.

<u>Tasks Considered, but Not Selected, for the Pilot Stage</u>

- <u>Collecting and Reviewing Existing Pedagogical Materials and Applying Best Practices</u>
- <u>Incentivizing Academic and Industrial Participation</u>
- <u>Establishing a RECET Governance Structure</u>
- <u>Supporting Instruction and Training</u>

<u>Addressing the incentives/challenges:</u> There are tensions between well-meant self-interest and the branding and ownership of materials as historically perceived by individuals and (even more so) their organizations. The tension here is not so much the *contributing* but the *using* of such shared resources by others, whose organizations could see this as diminishing their visibility or competitive market share. Branding is an issue because everyone would like credit for their work, but others do not wish to use content with a competitor's branding. This is true whether the contributor is academic or corporate. However, it is particularly an issue for the latter. Broadly workable branding guidelines will be the subject of a future expanded version of RECET, but some progress has been made, as can be seen in the next two issues.

- Educational use of commercial products requires well-developed and easy-to-use documentation. The users - students - of any technology will have little or no experience with any device used in their classes. Vendors who wish to sell their products to academics must make such materials available, which can be a challenge for companies that are new to the market, especially if they are small. By bringing together information on similar devices to one central location, it became clear that there had been some 'borrowing' of content by one vendor from another. This was easily addressed, with new content developed. This was a positive outcome for the project and helped reassure corporate contributors that their intellectual products will be respected.

- The present model developed for sharing corporate content is to have the materials created and maintained at a corporate site with RECET providing the appropriate links to the materials. Each vendor designs a landing page for their products and supporting information. This landing page is reached from a generic content page. It is only after the user leaves the RECET pages and moves to the vendor site that they will find extensive branding. This greatly minimizes the effort needed to enable RECET users to access the latest information and interfaces with all vendors equally.

A scaled-up version of RECET must incorporate processes that directly address participant incentives and local barriers to participation. Academics who have created original, innovative new courses need a place to rapidly share their work with colleagues and other schools and find collaborators they can team up with to build on their initial concepts. The need for a place to publish and share courses has been reflected by repository projects that have tried to respond. Most have been around for a few years and then disappear. Others, like TRYEngineering.org and NanoHUB.org have been quite successful, but they have their limitations by design. How we in the academy think of publishing must be expanded to incorporate contributions to such collections. Some changes to the promotion and tenure and annual evaluation processes also are needed so that educational professionals are not faced with disincentives for helping other schools directly improve the instructional experiences of their students.

<u>Reviewing Student-Managed Measurement Platforms</u>: An additional branding issue is addressed by requiring that academic materials developed should be as hardware agnostic as possible, to maximize their accessibility and to accommodate new or improved products more easily. Presently, we request that assignments can be completed on multiple (at least two) hardware platforms, from the following list (which can grow at any time):

- Digilent/National Instrument's Analog Discovery 2 [14]
- Analog Devices' ADALM1000 (M1K) [15]
- Analog Devices' ADALM2000 (M2K) [16]
- Red Pitaya's Red Pitaya [17]
- PIco's PIcoScope 2000 [18]
- Rigol's 1000Z [19]
- Seeed Studio's Nano v3 [20]
- Liquid Instruments' Moku Go [21]

Parts kits should be similar to:

- Analog Device's ADALP2000 [22]
- Texas Instruments myParts Kit [23]

Project RECET - **R**emote **ECE T**eaching

The recent proliferation of student affordable and accessible hardware (options above range from about $70 to $1500 with some prices doubling or more in the last two years), has made the transition to labs executed with equipment that is owned or managed by the student practical, however it still requires the correct approach to learning and teaching. Each choice of hardware/software has its own strengths and weaknesses required to create successful, enjoyable self-led hands-on labs, and preferences by both faculty and students require a hardware agnostic approach to be successful.