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Engaging Engineering Students with Mobile Learning Technologies

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Abstract

New theories of education matched with new technologies have been rapidly transforming the way instructors teach and students learn. This paper documents one model an engineering librarian has created to incorporate the ideas expressed in "connected learning pedagogy" and the theory of constructivism (active, collaborative learning with the instructor as a guide and facilitator) into instructional "one-shot" sessions designed to teach information literacy skills to college students at various stages of their careers. The sessions utilize electronic devices students already bring to class (laptops, tablets, smartphones, etc.) and the Nearpod or Top Hat learning applications to provide instruction that can be delivered in-person or online, both synchronously and asynchronously. Examples include multiple different activities that encourage active learning and student engagement. The sessions are scaffolded so that students learn more advanced concepts as they go from First-Year Seminars to Capstone Design Projects, all while maintaining the learning outcomes set forth by the Association for College and Research Libraries (ACRL) Framework for Information Literacy in Higher Education and the Accreditation Board for Engineering and Technology (ABET). Successes, failures, and modifications to the model are discussed.

Introduction

Instruction is a primary role for engineering librarians. Information literacy is considered such an important part of the discipline itself that that the Accreditation Board for Engineering and Technology (ABET), the official U.S. accreditor for post-secondary engineering and computer science programs, has made it a part of their standards that all American engineering programs must follow if they are to obtain and maintain their credentials:

> Criterion 3.7: [Students must have] an ability to acquire and apply new knowledge as needed, using appropriate learning strategies. [1]

The most common way for engineers to acquire new knowledge is by conducting research. Although considered "soft skills", the ability to formulate a research question, effectively search through literature found in different resources, and evaluate the information found to help solve problems are skills that are highly valued by engineering firms. Therefore, knowing how to find, understand, and utilize university library resources early in their college careers, whether those resources are in analog or digital form, can help students to develop these skills to succeed as engineers after graduation. [2]

The Association for College and Research Libraries (ACRL) has created a "Framework for Information Literacy in Higher Education" which contains six core concepts that library instruction should include to ensure that college students graduate with the research skills they need to be successful, not only in their careers but with any life-learning task. Concept 6, "Searching as Strategic Exploration", is most relevant to the task of database use. The following outcome goals can be found under "Knowledge Practices" with the Framework:

> Learners who are developing their information literate abilities
> • match information needs and search strategies to appropriate search tools
> • design and refine needs and search strategies as necessary, based on search results
> • understand how information systems (i.e., collections of recorded information) are organized in order to access relevant information [3]

Teaching engineering students how to find, access, and utilize engineering literature increases their ability to understand and use search strategies for finding any kind of information they may require to answer their questions.

Literature Review

Constructivism and Connected Learning Pedagogy

Constructivism is a learning theory where students use prior knowledge to create or "construct" new understandings about a topic or idea. It has been found that students often know far more than they originally understand about subjects that they have previously studied. By using constructed ideas based on their previous studies (which can occur even before the beginning of formal education), learning with understanding can yield higher student engagement, more active learning opportunities, and better retention ("transfer") of knowledge than the more common rote/memorization learning. "Understanding" in this case means more than just having knowledge about a subject, but also being able to use that knowledge to solve problems, make decisions, and adapt older ideas to new situations. [4]

Research shows that centering learning environments around the student rather than the instructor provides a better overall understanding of concepts and even improved transfer of knowledge. Most student-centered environments are grounded in constructivist theory. By using "grounded design", which is the systematic implementation of processes and procedures that are rooted in established theory and research in human learning, student-centered learning can support multiple, diverse points of view and conflicting beliefs without overwhelming the class. The purpose is to support the learner in their quest to construct meaning out of the knowledge they discover; however, to fully participate in this environment, the student must be able to take on greater responsibility for their own learning. [5]

A commonly used student-centered constructivist learning environments is known as "problem-based learning". This type of learning environment is where students collaborate to understand and solve complex, vaguely designed real world problems. Much of the learning is self-directed, with the focus on student activity through learning tasks and the provision of educational tools for individual and collaborative work. [6] Educational experiences that are anchored in problem-based learning can form the backbone for a connected learning pedagogy, also known as "connectivism".

According to Siemens, connectivism is a learning theory that places the social and networked interactions between people at the forefront of learning. Like other learning theories, there are some major principles involved that make a learning environment a connected one:

- Learning occurs through a process of connections between different knowledge sources.
    - Knowledge sources can be other people, books, social media, etc.
- There must be a diversity of opinions.
- New information is constantly being acquired, which changes the foundations that decisions are based on.
- The ability to evaluate information is of paramount importance
- Knowing how to find information is better than amount of knowledge (or facts) currently known.
- Learners must be able to determine patterns and connections between different ideas and disciplines.
- Decision-making is a learning process.

Based on the above principles, connectivism fits well within information literacy, especially in the areas of finding and evaluating new information. [7]

Connected learning allows for learning to take place outside the classroom as well as within it [8]. It allows students to become more than test scores, which gives them the freedom to learn without fear. [9] This means that the role of the instructor must also change when using a connected learning model. Teachers now facilitate the experience rather than lead it, ensuring that the connections are made and maintained by the students. They act as guides and mentors, alongside other adults in the student's life. [8] Similar to much of 21st century learning, instructors can prepare students for jobs that don't yet exist [9], however, they are now also able to prepare students for a world and society that they can have an active role in changing.

This new learning environment also presents challenges for teachers, of course. They must be able to update their own knowledge and technical skills to keep up. They must ensure that the context of the learning goals can be understood by the students. They must be willing to take risks, keeping in mind that the rewards can make them worthwhile. There are great opportunities as well; for instance, teachers can use connected learning to obtain professional support for themselves, creating larger connections of both instructors and students. Their classrooms can be connected digitally to provide additional support to students. Connected learning encourages more student participation in the learning process, with students' extracurricular activities brought into the classroom, while classroom learning can be extended to those activities. One of the most important opportunities is that this allows students to be assessed in ways beyond standardized tests. [9]

There are challenges to implementing a connected learning environment as well. Most notably, there is a growing gap between schools that can afford the connected infrastructure and those that cannot. In addition, teachers need to begin viewing digital devices as assisting education rather than distracting from it. [8] Both Ito, et.al. and Garcia, et.al. highlight the difficulty of changing peoples' attitudes about what can and cannot be accomplished in a classroom. There is a need for buy-in from both school administration and parents, both of whom have probably been educated in the traditional older styles. And on a more practical level, it takes a lot of work to set up a connected classroom. [9]

The basis for much of modern connected learning is mobile technology. With wide-spread student ownership of smartphones, tablets, etc., they now can learn at any time, inside the classroom and out, using their own personal devices. They can also easily connect with other students in their class and work on collaborative projects outside of regular school hours. [10] Problem-based learning using existing mobile technology and connected learning is completely changing the educational experiences of students.

One final area of connected learning deals with the use of Web 2.0 technologies in the classroom. By creating a "knowledge community", instructors can utilize social media and other self-expressive applications to ensure their students are able to work together to produce a knowledge base and use that base as a resource in accomplishing a sequence of collaborative inquiry activities that address the basic themes that emerge within the community. As with the other pedagogies mentioned above, the instructor is only facilitating the activities; the students are playing the active role. [11]

Nearpod and Top Hat in Instruction

Classroom Response Systems (CRS) such as Nearpod and Top Hat can be utilized to enhance the mobile connected learning experience. They can be used in "flipped learning" environments -- where students complete most of their learning outside of class and use the class time to discuss what they learned -- for larger university class sizes. Nearpod is a software product that includes media, assessment, and engagement tools for instructors who teach from preschool to graduate school and beyond. It allows for engagement of the entire class at the same time (all students can answer in-class questions at once, for example) and can create interactive presentations out of pre-existing slideshows. [12] Top Hat is a competing product created by the Tophatmonocle Corporation[1] which includes similar tools, but also can incorporate interactive textbooks and online STEM labs. [13]

There have been several recent examples of how Nearpod and Top Hat have been used successfully by instructors. Mattei and Ennis (2014) used Nearpod to create a flipped learning experience for an undergraduate course on using physical therapy with pediatric patients. They found that

> [Nearpod] provides a means to continuously monitor student performance in real-time instead of the customary test or class participation approach. Real-time feedback is a key element in successfully deploying this model for larger class sizes. Second, it provides “interactive features” on the iPad that facilitate active learning in the classroom. Third, it motivates students to complete the pre-class work since students are assessed on comprehension of the material in every class. As a result, about 80% of the students came to class prepared versus the approximately 20% using the traditional passive learning approach.

[1] That is the actual company's name.

They also discovered that students' results on the final exam were greatly improved compared to the traditional way they had taught the course in the past. Overall, the use of Nearpod not only enhanced the learning experience of their students, it also helped them to better retain the knowledge they learned. [14]

Top Hat was recently used in an undergraduate food science course entitled "Wines and Vines" taught at Virginia Tech. A student survey was used to determine attitudes towards the use of the CRS. They also compared student academic performance with previous classes that did not use Top Hat. For each question, the student average response fell into either the "agree" (5) or very high "somewhat agree" (4) range. It was also found that student performance on tests and other assessments improved with the use of Top Hat over how the course had been presented in the past. They concluded that "[w]ith the prevalence of smartphones among students, [CRS] such as Top Hat offer a strategy for turning ubiquitous phones into useful tools that can facilitate a collaborative teaching and learning environment through engagement." [15]

Top Hat has also been used in an undergraduate nursing course. Like Virginia Tech's experience, a survey was created to capture students' thoughts on the app's usability, its level of engagement, and whether it enhanced their overall learning experience. It was found that Top Hat's perceived benefits include overall improved learning, formative assessment, and increased participation. However, some of the limitations discovered included practical drawbacks such as like accessibility issues, while several students even wondered why the instructor was even needed, since they could learn everything required through the app. The researchers' own conclusion was "Instructors should consider a series of factors when deciding whether to adopt a CRS technology in their classroom. These include the intended audience, the learning content, and technological competence of the instructor." [16]

A more unique experience with Nearpod has been its use in Saudi Arabia to allow male instructors to teach female university students remotely. Students used their smartphones to access Nearpod and interact with the instructional modules, while a video-conferencing system was running simultaneously to help the instructor speak directly to the students. As in the previous studies, students were surveyed afterwards to obtain their opinions on the learning experience. What they found is that students overwhelmingly enjoyed the collaborative opportunities and interactive lessons Nearpod provides. However, they did not like the clumsy integration with the video-conferencing system. The study concludes with the comment that for CRS to be successful, instructors must transition from "knowledge provider" to "learning facilitator" and allow students to have more autonomy in the process. [17]

Narrative

Previous Instructional Method

The Pennsylvania State University (Penn State) is a Carnegie Level-1 research university located in University Park, PA. The College of Engineering, officially founded in 1894, offers bachelors', masters', and doctoral degrees in ten departments. The college's average annual enrollment includes approximately 10,700 undergraduates and 2000 graduate students. [18]

The Library system at Penn State is one of the largest in North America, with several million volumes of books and materials along with several thousand journal subscriptions. The Engineering Library works as a partner with the College to provide learning services and support to students, faculty, and researchers. These services consist of information literacy instruction, research guidance, access to the Libraries' collections, student and faculty engagement, and library outreach.

The previous instructional model for teaching information literacy to the students at the College was primarily via a 50-minute "one shot" class embedded in an engineering course. It immediately became apparent that the engineering librarian needs to make use of every available tool to maximize the amount of time they have available to help their students acquire research learning skills. It was determined that using mobile technology could be an excellent option, mostly because students were already bringing their smartphones and laptops to class anyway – might as well create instruction that makes use of the devices they already own.

To encourage active learning and allow students to have equal opportunity to participate in the class, it was decided to use a CRS that can deliver instruction both in-person and online, as well as synchronously and asynchronously. Both Nearpod and Top Hat contain multiple activities that encourage active learning and student engagement, including polls, videos, quizzes and open-ended questions, direct links to websites, and embedded collaboration boards. They also fit in very well with the RASE mobile learning design framework:

- Resources: Student-owned devices, the CRS app, strong Internet connection (provided by the university)
- Activities: Student-centered with collaborative elements that are very close to the same activities that they will encounter outside of the training session, like running their own catalog and database searches using keywords that are relevant to their real-life research interests.
- Support: The library has created subject guides that cover every discipline to assist in both reference (aiding students with questions) and instruction. Both the engineering subject guides and the citation guides are used to enhance the teaching material. There are also many websites embedded into the slides that students can use to gain more information on how to write reports and avoid plagiarism.
- Evaluation: Several "check on learning" quizzes at the end of the short modules where students can prove that they understand the main ideas taught in those modules, as well as a Google Form embedded into the CRS app at the end of the session that allows students to provide feedback on what went right, what went wrong, and how to improve. [19]

A CRS can be a very powerful tool when used with an existing learning design framework. The Nearpod application was originally chosen for its ease of use and ability to embed slideshows, websites, and videos seamlessly.

A Three-Tiered Model for Engineering Information Literacy

As for ensuring that students were able to learn how to utilize the vast corpus of engineering literature to assist them with their projects, it was determined that instead of continuing to overload as much information as possible into one session, it would be best to break the topics up into multiple sessions taught at strategic points throughout a student's undergraduate career. This would allow for full coverage of the literature as well as multiple opportunities to review what had been learned in previous sessions with time built-in for in-class exercises. The topics are geared towards what would work best in each individual course, with introductory information in first-year seminars while more advanced topics are covered in capstone courses.

Figure 1 shows a basic overview of the different sessions, also known as "tiers".

The Three-Tiered Model of Engineering Literacy Instruction		
Tier One – First-Year Seminar	Tier Two – Cornerstone Engineering Design	Tier Three – Upper-level Capstone Course
The Engineering Library – Physical and Virtual	Why Do Engineers Need Research Skills?	Review of Previous Tiers
Finding Books and Placing Holds	The Engineering Literature	Subject-Specific Databases
Subject Guides and Databases	Using the Library's Resources to Find the Information You Need	Standards
Citation Guides	Evaluating Information	Government Reports
Course Reserves and Interlibrary Loan	Communicating Your Findings	The National Technical Report Library
Help When You Need It		Patent Searching

Figure 1: The Three-Tiered Model of Engineering Literacy Instruction

The three-tier concept was only introduced during the Fall 2021 semester and will take several years to fully implement. Students currently in their first year will not get to their capstone course for at least two more years.

Interactive In-Person Instruction

The setting for this learning is the regular classroom where the class usually meets. Classrooms at Penn State include computers with Internet access for instructor use connected to projectors that can display the instructor's screen to monitors and large screens easily visible to the entire class. The technology, students are already bringing what they need into class already. Their willingness to use their mobile tech in class can be seen as a strength rather than a weakness; this makes it easier to integrate a CRS like Nearpod or Top Hat into course instruction. Allowing students to use their own devices while linked on the University's excellent Wi-Fi network allows the instructor to follow mobile learning best practices. [20]

The lesson plan used for the sessions is based off the design principles brought forth in *Understanding by Design*. [21] The instructor begins with a couple of "enduring understandings" that they wish for their students to master, then creates a plan around "essential questions" and "transferable learning" that supports those "understandings". The lesson plan allows for an in-depth "follow the steps" instructional experience and is meant to also help any substitute teacher who may have to quickly step in to teach the class.

The learning goals of the instruction are to give students an overview of the library's services and location, understand how various online resources work – including the catalog and engineering-specific databases, where to find how to cite the sources they use, teach them how to access course reserves and inter-library loan materials, and most importantly, who to talk to when they need help. Students will use their own personal devices to access course materials via the Nearpod app, which will contain Microsoft PowerPoint slides, direct links to library websites and databases for demonstrations, an internal collaboration board, a Google Form for their post-session feedback, and activities designed to actively engage them and keep them motivated during the 50-minute session.

The activities that break up the monotony of the presentation and allow for student engagement are based on real-world activities. [19] [22] The topics chosen for the example and activity searches are those that engineering students will have to search for, not only while in school, but after graduation. The databases and websites used for those searches are the same that are used by professional engineers and are considered some of the best in the world. The training they receive in class is meant to teach them skills that they will find useful long after the semester is over.

Interactive Online Synchronous Instruction

Because of Nearpod's adaptability and that it can be used with students' own electronic devices, there is no loss of interactivity or collaboration when using the in-person instructional module online synchronously. A class can be taught using the same lesson plan, with the same activities and materials. This gives the instructor the ability to provide meaningful instruction remotely, which is especially important given the impact of events in recent years.

Interactive Online Asynchronous Instruction

Nearpod can also be used to create modules that students can access on their own asynchronously outside of class time. In addition to the materials mentioned above, instructor-created videos can also be placed into the module to replace in-person demonstrations and lectures. With asynchronous learning, modules can be extended into longer lessons, with more opportunities for hands-on learning. They can also be broken down into smaller sections based on a general topic, giving the student flexibility on when they complete each task. One drawback to using a CRS asynchronously is that collaboration does not happen in real time; however, the collaboration boards can still be used if students and the instructor are able to regularly monitor them.

Limitations

A major issue arose when it was discovered that Penn State does not have the institutional license for Nearpod. This did not affect engineering literacy sessions held in person or synchronously online, but without the license, it was impossible to embed the application into Canvas, the software used by the University as a Learning Management System (LMS). However, the University does have a license to Top Hat, a competing product to Nearpod, and this application will be used in the future for creating asynchronous information literacy modules.

Results

The change in teaching methods showed immediate results. The engineering library instructor noticed that students had begun to pay more attention throughout the entire class time and engaged with the activities without complaint or hesitation. They are also speaking up more often when the instructor asks for responses to his questions and have even begun to ask questions of their own. Although the Fall 2021 semester was the first time in over a year that the Engineering Library was physically open, the number of patrons per week had gone up compared to statistics gathered two years previously, though how much of that is due to general reopening rather than the new instructional method is unknown. The fact that the number of online reference questions dealing with engineering topics has gone up may be a better indicator of success.

Engineering Faculty Feedback

Although it is too soon to know how much the interactive, connected learning environment is helping students with class projects and research, engineering faculty members have reacted positively to the Nearpod presentations. The library instructor has had several faculty members mention after class that they learned new things about the library and our resources that they hadn't known before (and some have been here for decades!). Some faculty members who have been reluctant to bring in outside engineering literacy instruction are now sending in requests for sessions and the librarian has even been invited to departmental faculty meetings to present on how engineering literacy instruction can help students in their courses.

Several faculty anecdotes include:

- "I've been doing this long enough to know when the students are paying attention in class and when they are distracted by other things. Your session was the first time I've seen them actively paying attention to a library skills class." – Lecturer, School of Engineering Design, Technology and Professional Programs

- "I think the Nearpod worked pretty well. Thanks again for coming up with a customized presentation for us." – Assistant Professor, Civil and Environmental Engineering
- "I loved the format with the quizzes etc. Keeps the students more engaged and attentive." – Assistant Research Professor, Aerospace Engineering
- "Your talk was solid, and I liked the style. I may try adopting the tech for smaller groups." – Associate Teaching Professor, Engineering Science and Mechanics
- "The instruction session was scaffolded to allow for discipline-specific resources and services to be demonstrated early in the session followed by live activities to allow students to immediately implement what they had been shown. The actives used during the session were timed well and permitted students to respond and ask questions without feeling rushed." – Peer Review by Associate Librarian, STEM Department

Student Feedback

Feedback acquired from student surveys also support these findings. Before the switch to the interactive applications, students had been requesting more opportunities for classroom engagement and hands-on activities. After the switch, student responses have been overwhelmingly positive, with comments stating that the interactive quizzes and hands-on searching activities were the best part of the class. In fact, the biggest complaint now is that students want more time to go over the material.

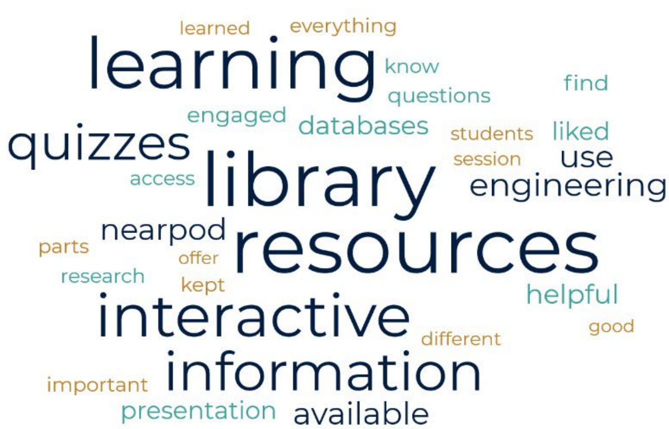

Figure 2: Word Cloud created from student feedback

The above is a word cloud that was created using student responses to the question "What have been the best aspects of this lesson?" As can be seen, the words "interactive", "quizzes", and "Nearpod" were often used in their answers.

Future Plans

The biggest update planned for the immediate future is the transfer of the Nearpod slides for the cornerstone engineering design course to Top Hat, so that they can be used by course instructors beginning in the Fall 2022 semester. Instead of one module to cover all engineering literacy topics in the course, as is currently done with in-person sessions, separate modules will be created to go further in depth on each following area:

- Why do engineers need research skills?
- The engineering literature
- Using the library's resources to find what you need
  - (May be broken down into smaller modules)
- Evaluating what you find
- Writing your report and citing your sources
- Presenting your findings

Over the next few years, all engineering literacy modules will be transferred over to Top Hat to ensure compatibility with the University's LMS, in case any collaborating engineering faculty member wishes to use asynchronous instruction for library support.

Conclusion

Creating a collaborative, connected learning environment using mobile technology and applications such as Nearpod has resulted in an improved learning experience for engineering students in information literacy sessions. By grounding the teaching in instructional theory while using the Framework and ABET standards, librarians can ensure that the information taught is in line with the overall goals of the course. Students who are engaged in learning research skills may be more likely to remember them in future courses (and their future career) and find more success with their projects.

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