

Review of Educational Technology: Closing the Gap Between Modern Technology and the College Engineering Classroom

Abstract

This paper aggregates information from past and current studies regarding the implementation of technology in engineering classrooms and identifies the most promising ideas, technologies, and techniques. This paper provides insight into best practices for implementing technologies to improve the education of engineering students. This paper provides recommendations to adopt non-traditional teaching methods. Educational tools and techniques are evaluated on the basis of: Adoption and Assimilation, Access, Community, Intellectual Presence, Student Perception, and Development of Social and Professional Skills. Best practices are highlighted with descriptions of the technologies and techniques that were found most promising.

Introduction

The past 20 years were dominated by technological advances, but many modern classrooms are run the same as they were in the 1990s. An overarching goal of educational institutions is to maximize the quantity, quality, and accessibility of education for their students [1], [2]. There is currently a gap between the technologies available and the ways they are implemented to improve education accessibility [3]. This “tech-lag” is an opportunity and necessity for colleges everywhere to close the gap and create classrooms with diverse access points to learning, increasing each student’s chance for academic and professional success. From virtual reality classrooms to increased mobile accessibility to independent learning modules, there is a wealth of potential for educational breakthroughs.

The incoming college freshman demographic is much more diverse than it was just 25 years ago. Though the incoming freshman is still the statistical norm, more students have jobs outside of school, children or other dependents and/or are more life-experienced (often in their 30s or older). This resulted in a surge of first-generation college students up to 63% of the total US college population. The diverse group that comprises a college class requires varied access points to learning [4].

“For many universities, the Internet revolution arrived on campus faster than anticipated” [5]. The traditional classroom model has served academia to its full ability, but change has come. Some US universities have average college class sizes upwards of 50 students [6]. A standard lecture in a 40+ student class often falls short in answering individual student questions and struggles to foster a cohesive community where peer-to-peer interaction is so limited [7].

There is a consensus that both incoming freshman engineering students and recent engineering grads need different skills and support systems to succeed in college and career than they did before the internet revolution.

Methodology

The following methodology was used for identifying Factors of Success for Educational Technologies and Best Practices.

Keeping in mind the ever-changing technological landscape, information and statistics were solely gathered from publications less than 10 years old. Best practices were selected based on consistent evidential support across multiple studies. The following questions helped serve as a guide for identifying best practices:

What methods of educational technology implementation will be best for the future of...

1. The student?

What advantages will the student gain from this experience cognitively, socially, professionally, or otherwise? What difficulties could this impose on the student? Is the technology better than other similar technologies? Is it better than nothing?

2. The professor and college/university?

Does this further the mission of the school? Is this prohibitively expensive? Does it require more training/set-up than it is worth? Does it increase or decrease workloads of professors and staff?

3. The engineering workforce?

Will this student be a better worker and employee? Will they be responsible, safe, and communicative when called upon? Will the technologies used in the classroom carry over to industry?

4. General Society?

Will this help the student be an engineer with good ethics? Will this help students speak up when necessary? Will this uphold the professional engineering ethical responsibility of keeping the public safe?

Definitions

The following terms are either used in, or are important concepts to, this paper:

Access Point to Learning: A means by which students can obtain knowledge or skills. Examples would be: a tutoring session, a textbook, or an online video.

Clicker: A classroom response tool used to record individual student answers to questions during lectures. Each student has their own device to record their answer; it could be a phone application or a third-party device. Answers are displayed on the projector as aggregate data similar to Figure 1 below [8].

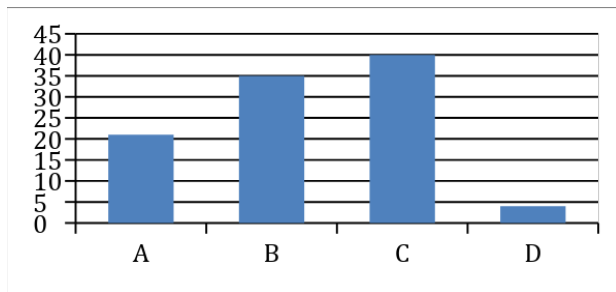


Figure 1. Example of Clicker Response Display. This graphic means that about 20% of students answered A, 34% answered B, etc.

Delphi Method: A standardized and commonly used method in flipped classrooms:

“The Delphi method works as follows: (1) the instructor creates a question; (2) students submit their answers; (3) the instructor displays the overall results to the entire class; (4) the instructor facilitates a brief discussion if necessary; (5) instructor asks students to modify and re-submit their answers as appropriate. The cycle ends when the instructor believes that most of the students have reached some agreement. Then the instructor moves on to another topic/question and repeats the steps” [9].

Flipped Classroom: “The flipped classroom is a pedagogical model whereby the typical lecture and homework components of a course are reversed. The content heavy lecture is usually replaced by direct computer-based individual instruction such as online videos, and the face to face classroom time is spent on interactive group learning activities, discussion of difficult concepts and problem solving” [10].

Makerspace: A physical space filled with tools and equipment for people to use, meet, and collaborate in. The core focus of the space is creating and making physical things [11].

Mobile Learning: Learning through remote, electronic access points [12].

Peer Learning: A pedagogical model in which student interaction and discussion, and teaching amongst students are encouraged [13].

Peer Created Content: Learning materials created and shared among students.

Traditional Classroom: A 2-3 meeting per week theoretical lecture with worked examples and assigned problem sets and reading.

Virtual Office Hours: Any one or a combination of online student-teacher interactions held in conjunction with, or replacing traditional office hours [14].

Factors of Success for Educational Technology

The following factors were deemed crucial to successful implementation of new pedagogies and techniques:

1. *Adoption and Assimilation*
2. *Access*
3. *Community*
4. *Intellectual Presence*
5. *Student Perception*
6. *Development of Social and Professional Skills*

Adoption and Assimilation

In order to be impactful, most technologies must be adopted by both students and professors. Therefore, it must be assessed whether participation will be sufficient or if it will be necessary to encourage use through class credit. Because technologies do not exist for their own sake, they should be implemented only if an improvement to the learning environment with adequate participation is expected [15].

If a technology is going to be integrated into an institution, it must also be supported by the administration. The overhead projector and handheld calculator are examples of well-integrated technologies. While institutions avoid requiring items that are an extra cost to students, calculators have become so integral to the education environment, that their benefits outweigh the costs [16].

New educational tools should feel like natural and obvious additions to the curricula. Technologies with seamless adoption phases generally are warmly welcomed by students, professors, administrators, and the public, receive political and financial backing and are regarded as a wholly positive influence on learning [17], [18].

Access

If the mastery of a technique, tool, design program, programming language, machine, etc. is projected to be necessary for the future career of a student, an ideal institution would provide as much access and training for that tool, etc. as possible. Students must be prepared for the workforce as it is today, not as it was 10 years ago.

Educators should seek to create useful access points to learning wherever possible. Many access points can be reused, and often the time input for the professor is mostly up front with long-term benefits. This is true for online content like videos and notes, hands-on project plans, group-work activities, interactive practice problem sets and exams (created through Typeform, Classmarker, the institution's own site, etc.), and other access points devised by educators.

Examples of Access Points to Learning (List not exhaustive):

- Class time
- Homework
- Textbooks
- Virtual and in-person office hours
- Online notes and related content
- Online lecture videos

- Online Q&A between students and instructor
- Peer-learning sessions
- Peer-created content
- E-Books
- Makerspaces
- Training sessions for equipment
- Peer tutors for programming, CAD, etc.
- e-Portfolios for record keeping/CV
- Collaborative online editing tools

Community

Creating a community within the college where students are comfortable asking questions and sharing opinions is crucial to innovation and peer learning. Students are more driven to succeed when they feel they are an integral part of the school [19], [20]. A collaborative community helps students develop team skills, social skills, and friendships during college [1].

Interactive and/or personally made online content is also crucial to a learning community. The online learning environment should remain human and be a place where personal connections can be developed or the students feel that it is merely an online program [2]. Regular interactive online activities like live Q&A sessions with video, or peer learning sessions with chat are encouraged.

Intellectual Presence

Professors should actively seek to maintain student involvement throughout class time and have homework and/or online activities that are fully engaging and require an active learner [2]. Unfortunately, it is physically and mentally difficult for most people to pay perfect attention for extended periods [21]. In summary, active learner presence is a pillar of education [1].

Use of technology that takes away from intellectual presence of the student and/or professor should be avoided. A simple example would be a difficult-to-read font on a lecture slide. A more complicated example would be requiring that students use their phones or laptops for the duration of class. While there is obvious educational potential, the distractions could outweigh the risks (especially in introductory classes where most students are younger and accustomed to public K-12 style classes) [2]. However, in an upper-division course, that kind of multitasking can be good practice for career.

Student Perception

The student's perception of a university and the perceived quality of their education will directly affect a school's reputation. An alumni is forever an ambassador of the college, and their opinion of the school shapes the surrounding narrative. Students invest their lives and money in their education and, just like any customer, appreciate the colleges and professors that show an interest in making it worth every penny.

Students expect a modern education in every sense of the word. They want to be prepared for the future [20]. New educational technologies that students perceive to be beneficial have higher usage/attendance rates and have a smoother adoption phase [18], [23].

Ideally, students will feel that class time is productive, planned, and entertaining, and that homework is relevant and academically challenging. The technologies and pedagogies are merely a means to help achieve that reality [2], [15], [20].

Development of Social and Professional Skills

The requirements of the engineering workforce have shifted. Proficient computer programming knowledge and CAD skills are absolute requirements for a modern mechanical engineering graduate. Twenty-five years ago, tools like these were essentially nonexistent; they either had not been invented or were only necessary in small niches [24].

Educational technology needs to be in sync with industry technology. Businesses, especially large, international ones, have to stay up to date on specific industry and communication technologies to interface amongst multiple locations. Some provide remote training and often rely on the employee to train themselves. Versatility is paramount [3]. Educational institutions are responsible for preparing students for the engineering workforce and should adopt some of the industry trends like interactive video conferencing, the prominent use of data-collection software like LabVIEW, FEA in CAD software [3], and soft trends like more communication between interdisciplinary teams on projects [24].

These factors (Adoption and Assimilation, Access, Community, Intellectual Presence, Student Perception, and Development of Social and Professional Skills) were used in combination with the questions in the Methodology section of this paper to serve as a guide for identifying best practices.

Best Practices

Professors should use technology to facilitate student collaboration and communication over attempting to enhance a solo lecture. Lectures that are mostly one-sided and don't include student interaction and involvement greatly reduce intellectual presence and student satisfaction [15]. Each student can contribute a unique perspective to material. In and outside of class, there are numerous access points to learning, including the students themselves.

Intellectual presence from students as both a learner and contributor can be achieved through creating a sense of community with the students and professor. This is not unlike the business goal of creating a healthy collaborative environment. It is important to create a community both within the classroom and within the engineering school itself, not just the university as a whole. Social research suggests that it is easier for humans to identify with groups of less than a few hundred people, such as the size of a department or large class. The larger groups usually develop core groups of about five or ten students [19]. All educational technologies should consider basic human social needs as they pertain to community and intellectual presence.

Virtual office hours have much higher student satisfaction than traditional office hours [14], [20], [21]. Virtual office hours require significantly less commitment from both parties (can be done from home/mobile), but must be easy to access and communicate through. Instructors should be comfortable enough with the technologies so that issues can be resolved as they arise. Students tend to use virtual office hours more in upper division classes [20].

An engineering school with an average budget cannot afford to implement all best practices, but it can specialize its instruction, equipment, and space for one or two specific disciplines instead of attempting to cover every discipline and falling short [25]. This hypothetical low-budget college could have a Makerspace dedicated to, for example, electronics and coding. Free peripheral material could be borrowed from an online resource but professors could take the time to create personal content for their core subjects.

High-quality, organized, online content that can be accessed by students 24/7 greatly increases overall student satisfaction and provides extra access for non-traditional students who can't stay on campus as often. Online tools have nearly no drawbacks unless they are off-topic, misleading, or too disorganized to navigate. They can be as intertwined with a curriculum as the professor sees fit. Benefit can be found in something simple like handwritten notes, or from fully interactive video/reading lectures with activities and quizzes. It is up to the professor/administration to decide what is best for the individual courses. However, at least a small amount of targeted, posted content is strongly suggested and can keep students and professors more focused on relevant subjects [13]. Online material doesn't need to be exhaustive, it needs to capture the essence of the current material so students know what to study to succeed.

Outside-of-class activities that involve online communication tools already familiar to students like social media, blogging, and video sharing platforms, are extra useful for breaking the ice and getting students to know each other. Peer-created content is also useful for fostering community [2]; students can write a blog or post an instructional or response video on a shared drive that the whole class has access to.

Materials made by the professor, such as videos or notes, are more personal than third-party materials like textbooks or YouTube videos. Posting original content demonstrates a commitment on the part of the instructor and makes the class unique and memorable. Surveys have shown that students use virtual office hours not just for content but also as a means of familiarizing themselves with the instructor and other students [20], [26].

Requiring students to purchase tools or materials with personal funds should be avoided if possible. Studies have repeatedly shown that "students who complain about little else will complain about the cost of a clicker" [16]. Any unnecessary charge negatively affects student perception, leading to compromised presence. When student's personal lives and financial security aren't taken seriously by the university, the student will struggle to take the university seriously [5], [16].

In larger classrooms, professors can use digital-response software to encourage collective agreement and problem solving through Delphi-style discussion and iteration to create a sense of

community within the classroom [9]. This is commonly done using clickers (which requires additional student money). There are some alternatives:

1. Digital-response software using free cell phone applications: Phone apps don't force students to buy clickers, but do require all students to have phones and use them during class, opening up a potential distraction.
2. Plickers: Each student has a unique QR-code printed on a small sheet of paper. The professor asks a question, the students hold up the QR code in one of four orientations, signaling one of the multiple choice answers, the professor then scans the class with a free phone app, recording all answers (and taking attendance) simultaneously.

Conclusion

Educators that are considering a technological addition to a course could benefit from carefully considering whether the technology and the implementation plan will follow the Six Factors of Success: Adoption and Assimilation, Access, Community, Intellectual Presence, Student Perception, and Development of Social and Professional Skills. Honest, personal performance reviews of classroom/mobile educational technologies coupled with regular, concerted changes to techniques are necessary to ensure successful integration. If a pedagogy is not achieving a noticeable, positive effect or feedback, one should consider eliminating the practice.

Technologies that are prone to malfunction and cause troubleshooting delays during class or that students or professors have consistent technical issues with should be abandoned or postponed unless they are useful engineering tools. Live testing of new educational technology/technique is necessary for progress but shouldn't be done without careful planning, solid supporting evidence, a fully committed staff, and an informed and willing student body.

Examples of practical technologies/tools that require extensive adoption/assimilation planning are machining equipment (lathes, mills, bandsaws, etc.), programming languages, common CAD programs, and data collection and mapping softwares. These examples have been successfully implemented into many engineering schools even though they require more effort and infrastructure to include [25]. Inherent learning curves, use of class time for training/troubleshooting, and student participation requirements should be weighed before inclusion in curricula.

The modern engineering lesson plan and classroom should adapt constantly to match the improving communication technologies and make regular attempts to blend the most useful technological advances with up-to-date, relevant curricula. Keeping educational technology up to date should be thought of as an integral part of an engineering curriculum and in-step with the cutting edge of innovation.

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