

# Teaching Methods – What Engineers Can Learn From Liberal Arts

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**Abstract** – The purpose of this project is to identify a few active learning techniques that are effective for students in liberal arts and analyze whether they have the same effectiveness when used in undergraduate engineering classes. The focus of this study is on active student-centered teaching and learning strategies. The active learning techniques are inspired from a variety of disciplines including mathematics, language, arts, music and law.

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## THE POLYTECHNIC STUDENT

All generalizations are just that—the overview of the issue with little regard to specifics. When applied to a large pool, generalizations will often offer exceptions, but for the most part, they also offer the big picture. In this introduction, we are attempting a definition of the engineering/polytechnic student in general in order to develop interactive teaching strategies and tactics that are appropriate for the majority of our students in our classes in all disciplines.

We used the Myers-Briggs Type Indicator [1] to establish the personality type of typical engineering/polytechnic students. They are generally more introverted than extroverted. In getting information, they exhibit for the most part little intuition, and prefer sensing. Rather than feeling, they tend to take decisions not through emotions but by means of rational thought, and so their position vis-à-vis the world is the result of judgment, not perception. In the end, their general profile is ISTJ, Introversion, Sensing, Thinking, and Judgment.

Active learning is synonymous with the concept of student centered learning. For the purpose of this paper we will define active learning as whenever students in a classroom situation are doing something besides just listening to a lecture. Students are reacting to the lecture material and they are engaged. Cooperative learning takes the engagement beyond the individual student to an interaction with others in the classroom.

Following is the list of techniques that we believe are most effective for active learning in the various disciplines of a polytechnic institution.

## ENGINEERING

In our experience, the following list of techniques work well for freshmen engineering students [2, 6].

1. The muddiest point - Ask students about the concept they did not understand in a class and then go over it again at the end of the class.

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2. True False questions - Students are asked to answer T/F questions during class. This serves better than quizzes because they learn while being assessed. They can be given participation points.
3. Use of props - Students get engaged when they can see or touch an object or a model.
4. Candy questions - Students get a reward for actively participating in the class. Every once in a while, a hard question is asked. The first person to answer the question gets a candy. This motivates students and encourages active classroom participation.
5. Mind break - The instructor talks about something completely off-topic for a few moments e.g. in a thermodynamics class, the instructor will ask about the capitol city of Canada.
6. News Share - Students are asked to share the latest news about certain technology. Students are eager to speak and tell everyone what they saw. Sometimes they pull up the news on their hand held devices so they can discuss it in class.
7. Hand Raise - Students are asked to raise their hands after about 20-30 minutes of lecturing. This helps them focus again on the topic of discussion in class.

Cooperative learning techniques have also been utilized in engineering classroom environments with some success [2, 3]. Cooperative learning is an instructional approach in which students work in groups on a learning task. The 5 essential elements required for implementing a cooperative learning technique in an engineering classroom are: positive independence, individual accountability, face-to-face interaction, appropriate use of interpersonal and teamwork skills and regular self-assessment of team functioning [4, 9].

By using the above techniques, we have discovered that students remain engaged, are motivated to learn, and actively participate in class. The following examples illustrate these concepts.

**Engineering class example: Mechanical/Machine Design Class:**

Example problems are key to assimilation of the topic, the conditions, parameters, failure modes, equations, data etc. However a large percentage of students tend not to actively participate in the class practice problems counting on others to complete and respond to the instructor. Each of these students are in a design team, thus know their team mates better than other classmates. When asked to do the practice problem as a team, they take care of each other in answering question, clarifying any question and finally solving the problem. Action comes from the ownership of the situation, in this case the team problem. This takes a little longer class time, but most of the time does not require additional clarification and the students develop confidence in solving this type of problem.

**Engineering Technology class example: Circuit Analysis Class:**

During the semester, the review of content taught in each chapter is performed by means of a group assignment. The duration of each assignment is 15 – 20 minutes and is typically given at the end of a class period. Each group is expected to submit a single report, and the answers for the assignment will be presented by the professor. For each group, there will be 3 – 4 group members. Each member will work in one of 4 defined roles. The roles are: solver, recorder, checker, and manager. The role of each group member will be rotated with each successive assignment. The format of these group assignments was specifically chosen to encourage the use of the five essential elements of cooperative learning mentioned above.

In one semester, students were allowed to give feedback on the group assignments by completing a questionnaire. Their response to questions related to the effectiveness of the assignments in promoting learning was mostly favorable. Five out of six respondents agreed or strongly agreed with the statement, ‘The group chapter review assignments have increased my understanding of the learning objectives assigned for each chapter.’ Also, five out of six respondents agreed or strongly agreed with the statement, ‘The group chapter review assignments have been more effective than the instructor-led chapter reviews in helping me understand the learning objectives of each chapter.’

## MATHEMATICS

Active learning in the mathematics classroom can be helpful to move students from passively following along as the instructor solves a problem to getting the students ready to tackle problems on their own from homework assignments. These active learning pauses can be illuminating for students who are sure they are understanding what is happening in class - until they try to actually solve the problems on their own. Active learning techniques which encourage them to work with others can lead students to form study groups outside of class. The following active learning techniques are effective in mathematics classes:

1. Clarification pauses - Many instructors delay response to problems for a few minutes. Many students don't think of their questions until 2-3 minutes after an example problem has been completed
2. Wait time - Giving all of the students time to work a sample problem before allowing other students to provide the solution steps
3. Evaluation of another student's work, students put solutions on the board and then the class critiques the solution. This technique is most effective ideally after they've had a chance to compare their answers with someone else, since they're more willing to show their work
4. Cooperative groups in class
5. Work at the blackboard - If the class is small enough for everyone to have board space, not allowing them to use pencil and paper can help to push them to the board
6. Jigsaw group projects - Each group is given a different problem, they complete one step, and hand it on to the next group, who checks the work of the first group and completes the next step before handing the problem on to the next until the problem is completed
7. Group quizzes
8. Soliciting test hints from students. Students write down three hints for their classmates to think about as they take their exam next week. It shows the instructor what the students are thinking about as they work problems, and then the instructor can compile a list to hand out to the class to help them study.

## LANGUAGES

There are numerous active learning techniques that may be employed in foreign or world language classes. In order to implement these techniques educators must be aware of 6 areas of skills acquisition in their students—especially in the introductory and intermediate levels of study. These areas are listening comprehension, speaking, reading, writing, culture, and grammar. In order to learn or acquire a second language (L2), a student MUST be active [8]. However in the case of the Introvert, whom we find frequently in the Polytechnic University, that activity is not intuitive. The instructor must create situations by which the student will respond as comfortably as possible, with as little fear of making a mistake in public. The instructor must move that student from the mechanical, to the meaningful, and finally to the communicative level of activity, wherein s/he is completely free of the instructor, and truly independent. This happens repeatedly through each structure introduced to the student.

The following are some techniques to help the student arrive at this point of ownership of the material [5, 6]:

- Classroom management
- Repetition of material
- Active participation regarding listening and speaking (without seeing the written words)
- Writing independently with student ownership rather than teacher dependence
- Practicing and rehearsing cultural norms

- Deductive approach, use the rule in class situations rather than memorize use alone

Specific strategies and explanations for use of the techniques listed above include:

1. The class seating arrangement is circular, so students are encouraged to talk to one another. The teacher is not the focal point of the class. The class arrangement will change within the class period and between one class period and the following one. The teacher's role is now that of the class facilitator.
2. The instructor moves from repetition of a new concept, to directed dialogue, and finally to free use of the new concept, withdrawing from the role of animateur. The teacher can have choral work, small group work, and finally individual work in order to reduce anxiety levels.
3. The above involves listening and speaking. After the student has acquired that material, it is then that the student is permitted to see the written word. Adult learners are graphically bound. That is, they hunger for the concept in its written form. The Polytechnic student is particularly bound in this manner. However, seeing the written word prematurely can create speech that is so heavily accented that it impedes communication. Furthermore, it can create a dependence on English in order to understand the target language. So in fact, instead of taking into account the Polytechnic Student's penchant for deductive learning, and using that very technique, L2 instructors MUST do the exact opposite. This is not to frustrate the student, but rather to encourage growth in his/her other learning strategies.
4. Just as listening comprehension and reading are, on the surface at least, passive skills, speaking and writing are active. How many times do L2 faculty hear "I took 2 years of Spanish in high school, but I cannot speak a word." How many heritage speakers of the target language who use that language orally in the home cannot write correctly! The technique we use for listening comprehension moves, as we saw above, from mechanical, to meaningful to communicative, i.e., independent comprehension. This is ongoing so long as the student studies and speaks the target language. With respect to writing, current pedagogical trends take the emphasis off the final product, seen only by the instructor (a dependency), and places it on the student and his/her peers (independence). The new emphasis in writing is on the process or development of the piece, whereby the student controls the various versions, not the instructor.
5. The acquisition of cultural skills in the target language must deal with the so-called BIG C—civilization, literature, art, film, music, etc. BUT it also MUST include little c—"bread loaf" culture, i.e., practices of daily life, birth, death, courtship and marriage, meals, attitudes toward work and time, etc. There are several vehicles that can be employed to convey cultural products and to assist the student's acquisition of the skill in dealing with those cultures. Since the Polytechnic student tends to rationalize rather than intuit cultural differences, using simulations such as proxemics, the distances considered comfortable among the speakers of the target language, helps these students have the experience in a safe classroom environment so that s/he can "rehearse" it before having an authentic cultural experience.
6. The issue of grammar with Polytechnic students divides itself into what they prefer: a deductive approach rather than an inductive one. Give him/her the rule, and then practice it. BUT to challenge their skills of observation, an inductive approach can and should be used at times. That is, have students use a structure, perhaps in different formats, and then ELICIT THE RULE. Again, the instructor is there pointing the way, and the student has to gather up the courage to go places theretofore unknown. They learn how to think about the language not from memorized rules, but through the target language itself.

## ARTS

There are many activities that may be used with art appreciation/visual art classes to engage students in active and cooperative learning. These approaches go beyond traditional lecture typical of Art History classes. Students in art appreciation classes consider the visual arts from multiple perspectives including concepts, interrelationships and relevance to different disciplines and with everyday life. Many strategies support and reinforce critical thinking that is essential to all disciplines at a polytechnic institution.

The activities included are just a sampling of techniques [10]. The following examples illustrate the active and cooperative learning techniques.

1. Affective Response-provide an emotional or evaluative response to material:

Students look at works of art and note the reaction/response they have to the image/artwork. They reflect on what they see and what has been discussed regarding the components of a work of art the Elements of Art and the Principles of Design. They consider other information such as how colors have symbolic meaning as well as have psychological effects on individuals.

Students consider the work of art in the context of the time it was made vs. how it may be perceived today. Discussions in class consider what we know, and how we learned or acquired the information. Students evaluate how connections, associations, or summations are made and how that may be reflected in the way we view art. The student may work alone (active learning) and/or in small groups (cooperative learning).

2. Puzzles & Paradoxes:

Students become familiar with a topic, concept, etc. through activities in and outside class. These include research, videos and reading (articles, newspapers, online). Students discuss issues and defend their opinion(s). (Examples: A. The topic of Blockbuster Art Exhibitions, pro's, con's and student's opinion. B. Reparation of artworks to country/culture of origin or owner. The topic includes artworks such as The Elgin Marbles. Factors for students to consider include current events such as a country's economic stability. In 2011 this was the debt crisis in Greece.

Evaluation of another students work:

Students create a variation on a Coat of Arms or Blazon in a visual design that represents them, using symbols and images. In class students in pairs or small groups review the original sketches of the other student(s). Positive feedback on the symbols and composition is given and then considered when the final version is made. The final version is also reviewed in class and pairs of students write out their comments on the finished work regarding "readability", referencing such aspects as symbolism and composition. The instructor considers the comments in grading.

3. Visual Lists:

Variation is with the literal looking at art images and comparing them for various aspects. One example is comparing ancient Egyptian and Greek sculptures.

4. Games:

Modifying games such as Jeopardy and Bingo are ways to engage teams or the entire class in reviewing lessons/lecture/ readings for class. Students respond to the aspect of competition and can become very engaged [7].

## MUSIC

Polytechnic Students are not music majors and do not equate the arts valuable to their college studies. Arts teachers continually reiterate the importance and value of the arts in the lives of polytechnic students. Learning objectives for non-arts majors include becoming consumers of "good art." This is contingent upon students having broader listening skills and an extended music vocabulary to express what is heard within the music; and the ability to express individual preferences for music. These skills aid polytechnic students with the ability to make educated judgments about music with the expectation that they continually seek the aesthetic experience that music provides.

Effective techniques for active learning in music courses within a polytechnic institution are:

1. Music Presentations: Each class begins with an assigned student presenting a personally- chosen musical selection of any genre. As the class listens to this selection, they must list ten "things" heard within the

piece which increases the polytechnic students' aural skills and musical vocabulary. At the conclusion of the piece, the assigned student reads the ten reasons why it was selected for presentation. This exercise has polytechnic students introduced and listening to other genres of music, including music from other cultures.

2. **Building Blocks:** Polytechnic students are introduced to the two "systems" of music (pitch and rhythm) and the basic language of music. Students are taught how individual pitches are able to create triads and how triads relate to a "whole" [piece of music] through the study of Roman Numeral Analysis (I, IV, V7). Students are asked to associate this concept of an individual pitch; chord; whole relationship; to a concept within their own major and submit their written answers and drawings.
3. **Concert Attendance:** Students are required to attend two symphonic or band concerts and write a report on each concert detailing all musical selections and aesthetic experiences. These reports incorporate music vocabulary; the recounting of what was heard in each piece; and explanations to support why selections of music were or were not preferred. Written reports have polytechnic students consciously thinking about the music (melody, harmony, rhythm, patterns, instrumentation, orchestration, dynamics, etc.) and how these individual concepts combine together to create a larger essence. The concert attendance requirement has polytechnic students attending an event outside a comfort zone and provides the 'stepping-stones' for future attendance.
4. **Transformative Assessment:** Each student is given three different colored folders or cups (red: not understanding; yellow: slight understanding; and green: full understanding.) While instructing, the teacher is able to view each of the students and the colored folder they have placed in front of them. Without causing embarrassment or disrupting the class, it is known which student understands in the moment. Students may also change their folder colors anytime during the lecture. An educator is able to assess one's own teaching in the moment and change it to accommodate the student or class. This assessment technique relaxes the classroom climate and works especially well during music theory instruction. Another teaching technique employed is the use of colored chalk during lectures which assists students in correlating the information written on the board.

Through the study of music, polytechnic students' aural skill awareness is heightened; music vocabulary and the basic language of music understanding are increased. Confidence in attending arts events is gained. The ability to make informed and educated decisions about music is acquired.

## LAW

Active and Cooperative Learning techniques have proven to be advantageous for the law classes on a polytechnic campus. However teaching law in an undergraduate institution to polytechnic students presents a number of challenges. First, many students are not interested in the content as they feel that it is irrelevant to their discipline (i.e. I'm studying to be an engineer...why do I have to learn law?)

Second, polytechnic students often have trouble "thinking like a lawyer" as opposed to thinking like an engineer (although the thought processes are not so different, both being logical and analytical in nature.)

Third, there is often a lack of material suitable for undergraduate level law courses, especially once you go beyond the basic business law courses. This leaves only law school materials to choose from. Using these materials however only magnifies the issues mentioned above. Due to the complexity of these materials, the content is even more uninteresting and difficult for undergraduate students to grasp.

As such, it is necessary to think outside of the traditional legal education "box" and use some active learning techniques to keep undergraduate law students engaged.

The following are active learning techniques that have been used in undergraduate law courses across disciplines:

1. **Mock Trials** – Students are assigned various roles (attorneys, witnesses, jurors, etc.) and act out in a complete trial starting with jury selection and proceeding all the way to a verdict.

2. Mini-Case Studies – In this method, the instructor spends a minimum amount of time lecturing in class and most of the class period actively engaging students in case studies. The instructor breaks the class into groups and presents a fictional legal scenario demonstrating a legal problem. The groups discuss and then present 1) the facts of the fictional case, 2) the applicable law, 3) an analysis of the problem and finally, 4) a conclusion.
3. The Socratic Method – Often used in law school, this method forces students to be engaged and “on their toes.” In this method, the instructor calls on students at random and asks them questions about the material (regardless of whether he/she has lectured on that material yet). Should that particular student not know the answer (or sometimes even if they do), the instructor calls on another student to verify or challenge the first student’s answer. At the risk of being embarrassed or proven wrong, students are forced to be prepared for class. Students are given points for correct answers preparedness.
4. Student polling (Use of “Clicker Systems”) – Throughout the lecture, the instructor asks survey-style questions and students answer the questions using hand held clickers. Results display on the screen anonymously. This gives the classroom more of a game-feel and keeps students engaged. Typical clicker technology interfaces with Microsoft PowerPoint, so instructors are generally able to use their existing lecture content.
5. Student-Generated Content – Making students responsible for the content to be learned is a frequently used technique. This can take many forms including:
  - Exam questions (Have students generate 5 exam questions based on the material for that day/week)
  - Student-led discussions (Have 1-2 students each class come prepared with 2-3 discussion questions and lead the class in a discussion based on the material for that day/week)
  - Student-led classroom activities (Have 1-2 students come to class prepared to lead their classmates in a 30-minute activity that demonstrates the material covered that day/week).
6. Debates – Students divided into groups and are given two opposite sides of an issue and allowed to make an argument for their position. The opposing side is given a chance to respond to arguments made and a lively discussion ensues. This obviously lends itself to a law class.
7. Game-based learning – In this technique games are used to demonstrate concepts to students. The games can be as simple as Jeopardy or as complex as video/computer games.

The techniques and methodologies listed above are summarized and compared across disciplines in table 1.

**Table 1:** Comparison of active learning techniques across disciplines

	Engineering	Mathematics	Languages	Arts	Law	Music
Muddiest Point / Clarification Pause	X	X	X			X
Group Quizzes	X	X	X			
Use of Props	X		X			
Incentives (Candy Questions)	X		X			

Mind Breaks	X		X	X		X
Ownership of Class	X		X			
Wait Time	X	X				X
Evaluate Each Other's Work		X	X	X		X
Cooperative Groups	X	X	X	X		
Games		X	X	X	X	
Student Generated Content		X	X		X	X
Changing Seating Arrangement			X			
Problem Solving / Writing		X	X	X		X
Puzzles / Paradoxes				X	X	
Student Polling			X	X	X	
Debates			X	X	X	

There are several techniques and methods, as can be seen in Table 1 that are effectively used in various disciplines. There are other techniques that certain disciplines use more effectively than others.

### CONCLUSION AND FUTURE WORK

In this study, we have identified polytechnic students as having ISTJ type personality. The research instructors in this study come from a variety of backgrounds ranging from engineering, to law, arts, languages and mathematics. We have identified a few active learning techniques that, in our experience, work effectively for polytechnic students. These are a subset of techniques and methodologies that faculty members use in various polytechnic areas. Our goal is to map these across disciplines to qualitatively and quantitatively explore and identify which techniques work best in general for engineering students. Although the list of student centered active learning techniques is long, we have identified the top few techniques applicable across disciplines.

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