

Learning-Through-Teaching, a Collaborative Learning Strategy

Chiang Shih, Namas Chandra, Patrick Hollis

Department of Mechanical Engineering
FAMU-FSU College of Engineering

Abstract

We have proposed the promotion of collaborative learning by systematically engaging all students in an innovative “Learning-Through-Teaching” (LTT) pedagogical practice in the core Mechanical Engineering curriculum. The LTT program empowers students with self-learning capability by involving them in the actual classroom/laboratory teaching. Through LTT, students learn from and teach to their own peers, thus developing a horizontal bonding among students that helps create a communal desire for mastery of the material. This practice not only enhances their study skills but also changes their attitude toward the overall educational experience.

We have practiced the LTT concept in our department recently by implementing the program from the sophomore-level “Introduction to ME” class, to the junior-level “Thermal and Fluids Laboratory” class, and to the senior-level technical electives; all with different degrees of success. Based on our preliminary assessment, most students who have participated in the LTT practice indicate that the program had a positive impact on their overall learning experience. We believe that the systematic involvement of students in the LTT experience can transform them from being passive recipients into active learners thus preparing them for a life-long self-learning experience.

Introduction

Traditional engineering education relies heavily on a passive classroom lecture approach. Studies^{1,2} have shown that students learn much better when active learning strategies are used. In the conventional learning setting many students, especially incoming freshmen, feel left out of the process and are not able to reach their true potential. In light of this, we believe that a major shift in the current educational mode is essential, whether it is mandated from outside or emerges from inside. Though the overall philosophy of fostering an active learning environment is clear, what is not obvious is the optimal way of creating the right setting. Further, faculty members, already facing an increasing workload to satisfy teaching, research and service requirements, do

not have sufficient time or resources to investigate different alternatives even if they are convinced of the paradigm shift. The authors clearly recognize this need and have found a reasonable method to implement the idea. The problem still remains of how to convince enough faculty to move away from their practically ineffective yet more comfortable lecture teaching mode to the uncharted territory of collaborative learning. With limited resources and many other competing priorities, the goal is to design a collaborative learning environment for the entire program that is both initially cost effective and ultimately sustainable. The only way to achieve this is to involve the other stakeholders - the students - into the practice as active partners. As educators have known for a long time, given the opportunity and proper guidance, students can always rise to the challenge.

In light of these observations, we propose an implementation of the innovative “Learning Through Teaching” (LTT) pedagogical practice by making students responsible partners in their own educational process. Educators from the University of Pittsburgh³ adopted a similar concept by using students to develop engineering laboratories. However, their scope of implementation is limited to laboratory development. The LTT concept has also been adopted with success by educators from North Carolina A&T State University⁴. They designed a vertically integrated learning experience, where experienced (upper-level class) students assist less-experienced (lower-level class) students to use progressively more sophisticated software packages throughout the curriculum. We have combined their experience to include the LTT component in the mechanical engineering (ME) core curriculum⁵. Students were asked to be involved in not only laboratory preparation but also in the actual traditional teaching of new materials to their fellow classmates. The LTT program empowers students with self-learning capability by involving them in the actual classroom/laboratory teaching by tentatively designating them as surrogate professors. Through LTT, students learn from and teach to their own peers, thus developing a horizontal bonding among students. This practice not only enhances their study skills but also changes their attitude toward the overall educational experience. Currently, the LTT concept is still in the developing stage and has been applied by three faculty in selected classes. Noticeable success has already been achieved⁵. It is believed that a more coherent implementation, both vertically throughout the curriculum and horizontally across all disciplines, can greatly improve the educational experience of engineering students. In this paper, we will discuss in detail our experience, self-evaluation, and recommendation concerning the potential implementation of this innovative educational approach to the entire engineering curriculum.

The Integrated FAMU-FSU ME Curriculum:

In 1997, ME introduced an “integrated curriculum” by restructuring the traditional curriculum to place more emphasis on the inherent connectivity between disciplines in engineering practice^{6,7,8}. The curriculum is vertically integrated throughout the entire program to provide a more holistic approach as compared to the traditional ME -curriculum and has been quite successful⁸. In addition, we have added a three-hour weekly workshop to every ME core course to provide an environment for collaborative learning through group work. Here the term workshop is used in a broader sense in that it not only represents a place, where students create products or conduct specific experiments, but also a large modernized computer room that allows students to freely interact and work together. The workshop is designed to provide an environment for the implementation of collaborative learning by assigning students to groups working together on in-

class assignments or projects for an extended period of time with the assistance of an instructor and teaching assistants. Consequently, “just-in-time” assignments on key and/or complicated concepts are given in the workshop period to reinforce these areas. Based on our experience to date, extended discussion on these difficult-to-comprehend concepts in a cooperative setting is an effective tool for students to acquire a better understanding of the subject material. Through this new format, we have noticed an improvement of interpersonal interaction among our students. All these activities have paved the way for our program to move toward the adoption of the LTT program.

Learning-Through-Teaching (LTT) Practice

“Tell me and I may forget, show me and I may remember, involve me and I will understand.” Regardless of whether the quote is from the old Chinese Proverb or Benjamin Franklin, it clearly illustrates the importance of actively involving students in learning. We would like to add one additional statement in summarizing the significance of implementing the LTT concept: “*Ask me to teach and I learn.*” Teaching is the ultimate learning activity since it requires the utilization of higher order learning skills such as analysis, synthesis, self-evaluation as well as effective communication. Empowering students to teach can stimulate the practice of these skills in teaching projects and beyond. Through this interactive exercise, students who teach will likely develop a better understanding of the art of teaching, thus establishing appreciation of the teacher’s perspective. Students who were taught by their fellow students can also learn from this experience through a process of observation, self-reflection and peer judgment.

Our Prior LTT Experience

The LTT concept was first adopted by Shih and Hollis in an NSF-sponsored project for the creation of a dynamics system laboratory. It was used as a cost-effective way to train students to provide assistance to their fellow students in the laboratory. Students working in a group were asked to be responsible for the complete set up and operation of only one out of a set of experiments so that they could gain valuable experience by fully mastering one experiment. The responsible students were then asked to serve as teaching assistants to assist other students during the actual implementation of the laboratory. This practice was successful, but was limited in scope⁵. We recognized quickly that this process could encourage interaction among students and bring together a true collaborative learning community and therefore should be expanded for far greater influence on students’ overall education process. Consequently, this concept has been introduced to and adopted by several other faculty in other classes. A LTT web site was developed in the College at www.eng.fsu.edu/LTT for the internal promotion of this pedagogical practice.

Based on our preliminary assessment, most students who have participated in the LTT practice indicate that the program had a positive impact on their overall learning experience. In these classes, students were asked to rate two questions that address the effectiveness of the LTT program from 1 (excellent or strongly agree), to 5 (poor or strongly disagree). The first question asked students’ opinion on whether it would be a good idea to implement LTT throughout the curriculum. The second asked whether they thought LTT was useful to their overall educational experience.

The average response can be interpreted as a quantitative measure of the students' collective perception on the LTT program and a value less than 3.0 is considered positive. The average responses of a sequence of five courses are presented in Table 1 as a reference. It is clear that the overall perception toward the LTT practice is positive for both questions. From statistical data, more than 80% of students either strongly agree or agree that the LTT is a positive experience and should be implemented throughout the curriculum. Closer examination of the data reveals that 100% of students surveyed feel their teaching experience is positive but some have reservations about receiving critical material from their peers instead of the instructor. This is consistent with one of the major concerns raised by faculty - that critical information may be left out or wrong information be given by student-teachers. This issue will be addressed later in our LTT implementation plan.

Table 1. Surveyed response of students' perception on LTT program

Course Title, Semester	Response scale on Question 1	Response scale on Question 2
Dynamic Systems I, Summer 2001	2.0	2.1
Thermal/Fluids Lab, Fall 2001	2.4	1.8
Intro to Propulsion Systems, Spring 2002	1.7	1.6
Analytical Tools in ME, Fall 2002	1.8	1.4
Analytical Tools in ME, Spring 2003	1.2	1.3
Analytical Tools in ME, Fall 2003	1.4	1.6

Scale: 1 (strongly agree), 2 (agree), 3 (neutral), 4 (disagree) , to 5 (strongly disagree)

Qualitative responses and reflective comments were also solicited from students to discuss their experience in the LTT program. A few selected quotes:

- “If students could experience this earlier in their curriculum it might provide more benefits. It will provide the students with the teacher’s perspective and in some cases provide more tolerance and understanding on the students’ part.”
- “The whole process of gathering information, deciding how to present it and giving a presentation made us to learn far more than we would have if we were just being taught and tested on the material.”
- “We have acquired more confidence that we can teach ourselves a subject. We understand that engineers must continue to learn in order to keep up.”
- “We learn how to do time management and realize the importance of self-learning.”

It is encouraging to receive this kind of feedback from students as it suggests that they seem to be practicing higher-level learning skills when they talk about time management, understanding teacher’s perspective, self-learning, etc.

Based on our experience and the documented positive impacts of active learning, we propose the full integration of the LTT program into the ME core curriculum. This complements our outreach program by systematically stimulating our students with higher-level learning skills to not only prepare them for their future careers but to also prepare them to be competent mentors/tutors/TAs in our learning community.

Current Implementation Plan

Based on our previous experience, all interested parties, including program administrators, faculty, and students, need to buy-in to the LTT practice before it can be successful. In addition to clearly emphasizing the importance of active learning in achieving program objectives, administrators have to support the program by scheduling an LTT-friendly curriculum, providing logistical and academic support, and recognizing and rewarding faculty efforts and students' achievements. Faculty need to optimize the teaching schedule by prioritizing critical subjects and making room for LTT activities. They also need to be passionate advocates by continuously communicating to and receiving feedback from students about the program. Students have to be convinced that the practice is not an additional assignment but an opportunity to expand their learning potential. Although it may seem like it will require more effort at the outset, students need to see that developing a more thorough understanding through LTT will ultimately make the learning process easier. The success of the program relies on both faculty and students being truly committed. To facilitate this, we have proposed to implement the program by steadily building up their awareness and competency in LTT practice through different learning activities presented in stages.

The first step is exposing students to the concept of collaborative learning early by engaging all incoming freshman in tutoring and mentoring activities as described in a later section. Although only recipients in the learning/teaching partnership at this stage, incoming students will be well informed about the LTT practice and will be prepared for their future participation. Further, the freshmen will be exposed to the tutoring methods adopted by professors, graduate teaching assistants, and finally their seniors.

The first real LTT practice will begin during the sophomore year in the "Introduction to Mechanical Engineering" class. One of the objectives of this course is to present ME as a profession by including topics such as professionalism, career choice, ethics, and life-long learning, among other issues. These topics introduce a wide range of important subjects of general interest to students and are very amenable for learning in group environments. Students in small groups will be required to select one topic from an approved list (see Table 2 for a partial list) to prepare and present to their fellow classmates in a weekly workshop. The presentation is in an electronic PowerPoint format with additional write-up material prepared by the group. All the material, presentation, and the write-up are made available to the students on the course web site.

Table 2. LTT topics in Introduction to ME Class

Main Theme	Topics	Examples
ME as a Profession	Historical Facts about Engineering or ME	History of Technology Development
	Case Studies of Engineering or ME	Greatest Engineering Achievements in 20 th Century
Professionalism	Professional Societies and You	What is ASME and how Does it Affect Your Daily Life?
	Ethics	Engineering Failure Analysis

	Professional Responsibility	Engineering and Public Policy Making
Career Choices	Industry/Research lab/Graduate School	Pros and Cons
	Other options	Business, Law, Medicine, etc..
Life-long Learning	Professional Engineer	PE/FE Exams
	Continuing Education and Self-Development	Technological and Professional Advancements

Students are required to prepare a 15-minute presentation followed by a 5-minute Q/A and discussion session in the weekly workshop. We believe that it is more interesting to have several student groups present these diverse topics in a mini-symposium format than by one faculty lecture in the traditional sage on stage mode. The follow-up discussions for every topic were made very lively by letting students take adversarial roles for promoting in-depth discussions. For example, some students supported that engineers should be licensed similar to physicians while others claimed that license to practice is unnecessary. Such an open discussion mode not only promoted a healthy discussion but also highlighted the basic concepts of the problem very clearly. The role of the faculty member is to serve as a facilitator to promote questions and discussion.

While teaching is the best form of learning, formulating the right questions to test knowledge assures that the learning is achieved at a much deeper level. Each group was required to formulate a set of questions that were then selectively used in a class test. Informal feedback from the students indicates that they have a positive feeling about their experience, although a quantitative analysis has not been made at this point.

Finally, students are required to be fully involved in the LTT program in a sequence of ME core courses engaging in activities such as delivering lectures in the classroom, proctoring experiments in laboratory, and serving as TAs in various classes. See Table 3 for a list of these proposed activities.

Table 3. LTT Activities in ME Core Curriculum

Timeline	Course, Faculty	LTT Activities
Freshman	1 st year Engineering Class	Mentored/Tutored by upper class students
Sophomore (1 st Semester)	Intro. to ME *	Mini-Symposium with multiple presentations plus Q/A sessions
Junior (1 st Semester)	Thermal-Fluids I	Workshop Assignment Presentation and TA
Junior (1st Semester)	Thermal-Fluids Lab *	Laboratory Set-up, data analysis, report preparation, Lab TA
Junior (2 nd Semester)	Mechanical Systems II *	Lectures on supplementary topics, group assigned lab or homework problem, lab TA assistance, and problem grading
Senior	Technical Electives	Lectures on Supplementary Topics (Fuel Cells, Alternative Energy, Rocket Technology, etc.)

* Class is currently implementing some aspects of LTT concepts

It is clear that students going through this program will perform a variety of different learning-through-teaching responsibilities such as being tutors/mentors, classroom teachers, and teaching and laboratory assistants. They will collaborate with their lower, current, and upper classmates in roles as both providers and recipients of the knowledge exchange. They will also interact with faculty and graduate assistants from a different perspective as true partners in being a teaching practitioner. At the end of semester, all students will be asked to prepare a LTT assessment report to evaluate their overall experience. We believe that the systematic involvement of students in the LTT experience can transform them from being passive recipients into active learners and partners engaged in the establishment of the mechanical engineering department as a genuine learning community.

As discussed earlier, one of the concerns about the LTT strategy is that misinformation or poor presentation of critical information is more likely to occur in student-directed lectures. To prevent this from happening one has to approach the problem from two directions: (1) faculty should ensure that critical and difficult-to-comprehend subject matter will be covered in the regular lecture schedule, with LTT being reserved mostly for supplementary teaching and (2) all presentation materials should be proofread and approved by teaching assistants and/or instructors before being presented to the class. According to our prior experience, some overlooked or misguided information could actually serve a good entry point for discussion and debate and thus encourage greater interaction. Therefore, as long as the instructor is always at hand to interject and make necessary revisions, we believe that the concern about misinformation is generally avoided.

Lecture/Workshop

Some LTT activities are carried out in traditional lecture style classes. In the following we will use the Thermal-Fluids I class to demonstrate how we implement the LTT program.

In Thermal-Fluids I, the proposed LTT activities will be integrated into the three-hour workshop period. In fact, one of the original objectives of the workshop was for all students to collaborate on team assignments synchronized with the recently taught topics. The execution of the LTT program in conjunction with the workshop assignments can further enhance the level of collaboration. Based on the central theme presented during the week, student-teaching groups will review the recently covered material for their fellow classmates by using a combination of presentation and group activities such as in-class demonstrations or group discussion. Considering the just-in-time nature of the workshop relative to the lectures, the responsible group will have to learn these subjects on their own, emphasizing the notion of self-learning, before the subjects are actually taught in the classroom. A complete list of teaching groups and their assigned projects will be made available at the beginning of the semester. This will provide students with sufficient time to organize and prepare their presentations for the compulsory rehearsal with the teaching assistant and faculty at least one week before the actual classroom performance. After their presentation, LTT students will be responsible for interacting with their fellow classmates as teaching assistants in the workshop.

The following procedure is given as a guideline to complete the LTT project in a lecture:

- (1) Working with instructor and TA, the students prepare the teaching materials and present the assigned subject to all students in a formal classroom setting.
- (2) Working with instructor and TA, the students prepare an assignment for the workshop session and serve as teaching assistants for the assignment.
- (3) The students turn in a self-evaluation report concerning the teaching project by emphasizing their self-learning experience and how this affects their educational perspective.

Hands-on Laboratory

The LTT program was also applied to hands-on laboratory courses. Each experiment in a class was assigned to two student groups at the beginning of the semester. The assigned groups have to learn the designated experiments on their own from scratch, with limited assistance provided by the instructor, the TA, and the laboratory manual. The group is then responsible for the following activities:

- (1) Arrange with TAs to conduct the specific experiment from scratch two weeks before the actual laboratory to learn everything about the experiment.
- (2) Prepare the teaching material and present the experiment to all students in a formal classroom setting. Rehearsal with the TAs and instructor is required before the actual presentation.
- (3) Present the experiment, including setup, data analysis, and other relevant information to their fellow students.
- (4) Assist fellow students during their assigned laboratory sessions as TAs.
- (5) Prepare self-evaluation reports concerning the LTT experience and develop a web page based on the experiment presented.

Potential Impact

We believe that the successful implementation of LTT has reformed not only our department but will also impact engineering education in many ways, including (1) enhancing self-learning capabilities to improve students' overall confidence and professional competence; (2) introducing a new perspective on learning to improve students' overall attitude toward education; (3) encouraging more students to pursue advanced degrees by improving their educational experience and increasing their desire to share their knowledge. We believe that by treating our students as equal partners in their learning process, we can empower them to establish confidence in learning and to become first-rate professionals.

The pedagogical strategies are universally applicable to all programs beyond engineering. It is possible that we can transfer our success to educators in other programs and cultivate similar programs within the college and other universities. We believe that our efforts will lay the foundations upon which exemplary accomplishments and far-reaching recognition can be built to produce a *broader impact* on engineering education at the national level.

Summary

We have successfully implemented the LTT concept to encourage the active participation of all students in the ME curriculum. The adoption of the LTT practice assists students in achieving a

deeper understanding of the subject by requiring them to participate in the teaching process. The implementation of this LTT concept can enhance full collaboration between faculty and students and among students themselves to make the classroom a truly cooperative learning community. Although this concept is still in the developing stage, its success in several classes has convinced us that the concept can be applied to a series of classes at different levels. Based on preliminary assessments, it is believed that a more coherent implementation, both vertically throughout the curriculum and horizontally across all disciplines, can greatly improve the educational experience of engineering students. A systematic effort to integrate this pedagogical practice may have a more far-reaching impact on engineering education at the national level. A more careful program assessment and dissemination process is needed to showcase the practice to a wider audience.

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CHIANG SHIH is a Professor of the Department of Mechanical Engineering at the FAMU-FSU College of Engineering. He has received a teaching award for his efforts in the development of the Mechanical Engineering Integrated curriculum. Dr. Shih received his Ph.D. from the Aerospace Engineering Department, University of Southern California in 1988. He is a member of the American Society of Engineering Education.

PATRICK HOLLIS is an Associate Professor of the Department of Mechanical Engineering at the FAMU-FSU College of Engineering. Dr. Hollis received a Ph.D. Degree from the Mechanical Engineering Department, Cornell University in 1986. Dr. Hollis has been the recipient of two teaching awards from FSU.

NAMAS CHANDRA is the Karamcheti Professor of the Department of Mechanical Engineering at the FAMU-FSU College of Engineering. Dr. Chandra received his Ph.D. from the Mechanical Engineering Department, Texas A&M University in 1986. He is a Fellow of American Society of Mechanical Engineering.