Experimenting with Learning and Teaching Methods

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Abstract

This paper describes my current involvement in an ongoing experiment with learning and teaching methods in engineering/ technology courses. In particular, it contrasts student-motivated with teacher-motivated methods of learning. In the latter approach, the instructor determines his students' program of learning. All topics of study are prescribed by the teacher and explained in his or her classroom. Specific tasks to be performed as homework assignments and/or laboratory experiments are outlined for the students, and tests are scheduled to verify that each topic has been learned as prescribed. All students are required to learn the same topics, at the same rate, and in the same way, under the false assumption that all students will share the teacher's orientation, pace, and learning style. In a student-motivated approach, on the other hand, students take primary responsibility for their own learning. They decide, within the constraints allowed, what they will learn, in what order and manner. In the classroom sessions, the instructor outlines and contextualizes a body of knowledge; flags ideas, theories, and problems for students to consider; suggests activities and experiments to aid learning; and identifies available resources, including a bibliography. Using this information, students set their own objectives, outline the necessary procedures to accomplish their objectives, and learn the standard topics of their discipline in the manner that best fits their individual learning style. In order to meet grading requirements, this program must also conclude with an effective evaluation of each student's performance. This paper will describe my experimental use of a student-oriented approach, acknowledging its advantages and disadvantages. I will describe a course in the EET program at BYU to demonstrate specifically how this approach can function in engineering courses.

1. Teaching and Learning Examined

I have been teaching in the American university system for almost twenty years. During this time I have attended closely to the teaching and learning processes, studying learning styles and experimenting with various teaching approaches, trying to understand what motivates students to learn and how to best assist them. This paper describes my recent efforts and conclusions. To illustrate my arguments, I have several stories to tell. These stories relate to my experience with the standard teaching and evaluation methods currently practiced in our educational system and will, I hope, influence the reader to contemplate suggested alternatives.

The first story recounts a family adventure with student-initiated learning. When my daughter Jenny was four years old, she decided on her own that she wanted to know how to read. Our home was a lively "print culture," so Jenny was surrounded by books to choose from--books her big sister was reading, books her mother had read to her since she was old enough to sit up and listen, books out of reach on shelves near the ceiling. So she picked up a Little Golden Book from her sister's stockpile, followed her mother around, and at each new word encountered asked "What's this word, Mommy?" Driving the car to the market, her mother would suddenly find a book thrust in her face and hear "What's this word Mommy?" A favorite television program gave her the theory she needed: "Who can turn tap into tape? Silent E! Silent E!" The result was that at four Jenny was reading well. By Christmas she was reading about the Grinch. It seemed a natural and easy process, though one that required initiative and persistence.

I want to suggest that a wholly different outcome was possible for Jenny. Suppose that her mother responds like this: "So you want to read, Jenny? That's good. I can teach you, but learning to read is not easy and requires structure. Here is my outline of what you must do, and here is my reading list. We'll read *this* book, not that one. We'll read thirty pages a day." So Jenny and her mother sit down and make up lists of vocabulary. "I will teach you each word,"says Mom. "You must study until you memorize them all, and then I will give you a quiz." Jenny soon finds that the words on the lists are not the same as the words in the book that interests her, so she slides the book under the bed and concentrates on the lists her mother has made. At the end of each day, Jenny is tested. At first Jenny knows only a few of the words, so she gets a "C" for the day. "You are not doing well, Jenny. You must study harder," says Mom. "When you learn all the words on the list, you will earn an "A." Jenny works harder at her mother's program, and soon she is earning an A every day. To show how proud her mother is, all the A's are posted on the refrigerator. Jenny is praised for her A's, and her mother chooses a new book for her. As Jenny works on each new list, she forgets most of the words on the previous list. But no one seems to notice this. Her A's are the celebrated outcome of her learning. Jenny finds that her mother is right, learning to read was hard. At six, when she is ready to start school, her book is still under the bed and her interest in reading is low. (Other scenarios are also possible; e.g., Jenny slides the vocabulary lists under the bed and takes her book outside and climbs a tree.)

These two versions of the story illustrate two theories of learning and teaching. One is learner-motivated and designed; the other is planned and motivated by an instructor. I will focus on one basic question raised and answered differently by these two theories: Who takes responsibility for learning? In a learner-motivated style the learner takes responsibility for what is learned, when and how learning takes place, and at what pace. In a teacher-motivated style, all of these parameters are governed by the instructor.

I suggest that when responsibility for learning is intercepted, a student may lose interest in pursuing education. Such a scheme dislocates not only initiative and motivation but also accountability. When a teacher assumes responsibility for the learning process, it then becomes the fault of the teacher, not the student, if learning does not occur. Shifting responsibility back to students encourages--in fact, obliges--them to comprehend the scope of their field and discipline their efforts to achieve competence in it.

My experience as a student and teacher in engineering fields suggests that the teacher-oriented approach is dominant in current practice. This is not only true in our colleges, but in the entire public educational system. When my daughter Jenny was enrolled in the public school we asked her new 1st grade teacher what Jenny would do, since she was already reading at a third grade level. Her response was, "We will teach her to read!" Moreover, the current educational system, with its grading system and accreditation requirements, virtually sponsors this "official theory" of learning.[1] Nevertheless, within these constraints classes can be modified to a greater or lesser degree to better motivate the students to take responsibility for their own learning. Examples are given in the following sections.

2. Teaching and Learning Experienced

When I first began teaching at the university, my new-faculty orientation seemed to support a teacher-motivated learning method. I was already very familiar with this mode as I had experienced it in my own college training: students sat in a classroom where the professor lectured on the required curriculum topics, deriving equations on the chalkboard as he spoke. Typically the material generated on the board was also available in the text for the course. In particular, I remember one course in electromagnetic theory. Most class sessions for this course consisted of watching the professor derive Maxwell's equations for various mediums. If I had sufficiently studied the text before class, I understood his presentation--but then I didn't need it, since it only reproduced what I had already learned from the text. On the other hand, if I had not studied the text before class I could not follow his derivations; again, attending the class seemed a misuse of time. Study rendered most lectures superfluous; non-study rendered them incomprehensible. I wondered at the time if there was not a better way to teach and learn engineering concepts than lecturing to a class. I still do.

There is a place for lecture in the educational system. For example, it is helpful to reinforce difficult concepts that have not been well understood, that is, to respond to specific student questions. But the primary function of lectures in many classes has been to provide students with their list of required study topics. What students really learn from watching their teacher derive equations is that their teacher can derive equations.

My experience with lecture in the engineering technology program at my university confirms that it is not the most effective way to help students learn. Repeatedly, I have had the experience of covering thoroughly a selected topic in class, demonstrating in detail the principles students are required to understand; but later, when the students need to use this information in the laboratory or on tests, they appear to have little understanding of what presented. Over time, I have concluded that wholly teacher-directed lecture fails to create long-term learning, either conceptual or procedural--except perhaps in the teacher who has generated the work. And though a teacher may enjoy the clarification that occurs in his own mind while he actively toils at the board he cannot suppose that this is duplicated in the minds of the students passively listening to his performance. I will show how the student-motivated style of learning can improve this situation, but first I will briefly review other complications of teacher-motivated learning.

A primary problem with teacher-motivated methods of teaching/learning is its confident reliance on formal exams to measure learning. In this mode, the teacher completes a series of lectures, after which he or she examines the students to see whether and what they have learned. Presumably, a high exam score indicates competence in the curricular material, while a low score indicates inattention and a lack of rigorous learning. In my classes, however, I have never been able to establish such a direct correlation between test results and learning. Instead, I find that students who do poorly on exams do not necessarily do poorly when applying the principles in practice; or, put the other way, students who successfully demonstrate principles in the lab may still perform poorly on exams. While short quizzes and periodic reviews may be useful as a means of indicating strengths and weaknesses--of directing and motivating a student's focus--on the whole test results seem to simply measure how well a student has adapted to taking tests. I believe that learner-motivated teaching/learning offers better means of evaluation than formal examination.

A second problem is the rigid predetermination of laboratory work in a teacher-determined course. In this mode, the teacher writes the laboratory procedure, usually a list of experiments with their expected outcomes--current engineering technology textbooks are full of such examples. When I began teach, I was expected to produce these laboratory procedures but found it frustrating. To begin with, if every student must follow the same procedure, a dampening of experimental creativity may occur. In many cases it was the prospect of this creative tinkering that drew the students (and their teachers) to the profession in the first place. Moreover, if all students are expected to perform at the same level and reach the same outcome, many organize to "share" results rather than make the individual effort at something that does not particularly interest them. Quickly, they move on unofficially to something that does. When one student reaches the desired outcome, word gets around quickly. I realized I had to make changes one day when I received a log book in which the student had carefully cut out each procedure from my prefabricated lab sheet, pasted it into his log book, and written "done" beneath each step.

Lectures, predetermined assignments and lab procedures, and exams are the tools of the teacher-motivated method of teaching/learning. They leave the responsibility for learning with the teacher, who lays out the course meticulously according to his own perspective as if still earning his or her own credential. It is the lecturer's responsibility to cover all course topics in the class sessions, faithfully reproducing textual materials. In addition, in exclusive control of the content and direction of his course, the teacher must prepare a full set of workable laboratory experiments that demonstrate the topics covered in the class. Finally, he must construct an exam that meticulously measures what was covered in the classroom lectures, a difficult task And since these mapping and ordering activities are all centered on the teacher, learning is also centered on the teacher rather than on the student. Each students must adapt to this method, which usually means finding some way to cram short-term memory with facts that may seem arbitrary, disconnected, or irrelevant. As will be shown below, the responsibility for learning must be shifted from teacher to student for long-term learning to occur.

In the teacher motivated-learning style each of the teaching/learning tools is applied to all students in the same way. This assumes that all students learn in the same way, while the best current research on learning refutes this theory:

> students possess different kinds of minds and therefore learn, remember, perform, and understand in different ways. . . . [T]hese differences challenge an educational system that assumes that everyone can learn the same materials in the same way and that a uniform, universal measure suffices to test student learning. . . . The broad spectrum of students--and perhaps the society as a whole--would be better served if disciplines could be presented in a number of ways and learning could be assessed through a variety of means."[2]

According to this viewpoint, lectures and lab sessions need to be individualized for efficient learning. Students need to help determine what is learned and how and set their own objectives. Assignments may usefully accompany lectures, but these need to be adapted to a student's individual learning style rather than being distributed as a blanket instrument focused on the same problems and requiring the same solutions. Evaluation must measure what the student has actually accomplished, meaning that it, too, must be individualized rather than indiscriminate, asking all students to work the same set of problems in the same time. Finally, lab procedures should be initialized by the student, with the guidance of the instructor. When students develop their own objectives, outlining the procedures they are most interested in, creativity is encouraged rather than suppressed.

3. Teaching and Learning Experiments

My final story details my experience teaching linear integrated circuits to undergraduates, a course that is well-adapted to student-motivated learning. The objective of the course is to study the operation of a number of IC's, then use each in some form of experiment in the laboratory. There are few planned lectures, no formal assignments, and no exams. I distribute no prepared lab procedures. Rather, the scope of the class is flexible enough to accommodate the particular interests and learning style of each student.

At the beginning of the course I outline for the class a number of possible circuits for study during the semester, circuits that demonstrate most of the common linear integrated circuit chips currently used in the industry. Through student input, we select the circuits we wish to study. Then the semester's work consists of studying as many of these selections as time permits. The course is very informal, with essentially no set schedule. During the classroom sessions we consider each circuit and discuss its function and some of its applications. Students participate in all discussions, as we work out together an understanding of the circuit's operation.

Sometimes I bring a working circuit to class and show how it operates. Sometimes the students themselves put together a working circuit in class and demonstrate its operation. One of the functions of each class session is to ensure that each student has outlined his or her own objectives for testing these chips in the laboratory. Students bring their log books to class, and I encourage them to record their ideas and objectives as we study, noting the things they want to investigate further in the lab. When I a topic that I believe will make a good learning experiment is covered, I suggest, “Here is something you may want to check out in the lab.” By lab time each student has a set of objectives that he or she has personally constructed, a self-tailored list of ideas to experiment with. I review the students’ objectives prior to the lab session to monitor any unreasonable expectations--there are usually a few; then we adjourn to the lab for hands-on exploration of whatever ideas have attracted them.

Each lab will typically have a final specified outcome, a circuit that must perform to certain specifications. Students usually spend one or two lab sessions preparing for the final lab, where they try the various ideas they have outlined. Since there are no prepared lab procedures, they must have their own objectives for each session. Some students require more help preparing good objectives, others quickly come up with their own. The important thing is that each student works at their own pace on their own ideas. When they are comfortable with their knowledge of the particular experiment being studied they construct and test the final circuit. Then they present their results for examination, either by the instructor, or before the entire class.

Some topics require more theory that others, hence more class lecture time. For example, the phase-locked loop requires considerable understanding of principles such as feedback and stability. In this case, I simply warn the students that these topics will likely require intensive work. Then in the lab I plan extra time to help students apply the ideas. Commonly, the problems encountered in getting the phase-locked loop to operate are loop stability and double frequency filtering. If the students have not factored these principles into their design, their circuit probably will not work. They get an excellent review as we work together, making the necessary adjustments to bring the circuit into the desired operation.

Shifting the responsibility for learning to the student, in this way, usually has the desired result of compounding the student’s interest and involvement in the topics under study. Formal assignments are not needed, since the students have already assigned themselves to work with the precise ideas they need to understand. Additional assignments are, in fact, only a distraction. Occasionally, with complex topics such as the phase-locked loop, we work out examples together as a class. Or I may present a problem and ask the students to work on it and bring a solution to discuss at the next class session.

There are no formal exams or tests conducted in this class. I evaluate the students by asking them to explain the operation of their completed lab experiments--their design as well as their test results. They must also be able to competently answer questions about their design and circuit operation. If they don’t understand the theory or cannot explain their design, they are required to continue work on the circuit until they do, or to take a lowered score on the assignment. Each student keeps a portfolio of all work completed during the semester, including lab preparation and log book registering of all completed lab work. At the conclusion of the course, grades are easily determined according to the content of this portfolio, taking into account regular participation in class discussions and performances in the lab. No final exam is required. Throughout the term, I work closely enough with each student in the lab to be familiar with his or her accomplishment; an exam would only add unnecessary work and stress on both teacher and student--again, an insupportable diversion from the real work at hand.

4. Conclusions

I will conclude with a discussion of some of the problems that arise from encouraging a student-motivated learning style. The first problem is getting students to relax into a learning mode that, even if liberating, is unfamiliar. Students are accustomed to the teacher assuming all responsibility for their learning and determining its parameters; for most, this has been their only experience. It is hard for many to understand what taking responsibility means. Some will show up in lab waiting to receive instructions, with no plan for using the time, even though many suggestions were made during classroom sessions.

A second problem is procrastination. Students are typically overloaded, and it is easy to put off preparing objectives for their lab assignment. Some means of motivation is required to keep the majority of the class on schedule, such as short quizzes, pre-lab checks, and deadlines that may result in lower grades if missed. Students are required to write reports at the completion of each project; during extended projects of more than a week they write progress reports. But the best solution to these and other problems is simply to keep the student personally involved and excited about his or her learning. When interest is high, timely preparation and learning generally follow.

A third problem is the occasional student who abuses the unaccustomed freedom of this approach to learning. Some students feel that taking responsibility for their own learning licenses them to learn less, if they so choose. That is, since it is their responsibility to determine what they will accomplish, they decide to accomplish a minimum. In a purely student-motivated educational system this may be satisfactory, but the constraints of a degree within an accredited university curriculum require otherwise. Motivation often increases, however, when students compare themselves to one another. Having students report their work periodically to the entire class motivates them to keep up with the class norm.

Another difficulty with student-motivated learning is that it is time- and labor-intensive for the teacher. The teacher needs to be very involved in each students work in order to identify proposed lab experiments that are likely to become disasters, as well as to help insure the success of valid lab objectives. It is easy for a student to fall behind and become discouraged when he or she is not making progress. In some cases, lab experiments will be quite similar for all students; in others, there may be a variety of options for individualized experiments. To keep the students motivated, most lab experiments need to be successful most of the time for most of the students, and with significant outcomes. For many teachers, this requires a different kind of class preparation than the customary composition of an all-purpose lecture.

5. Student Response

To date, I have not used any method, subjective or objective, to measure or track any increase or decrease in learning as a result of student-motivated methodology. However, improvement in two significant areas has been readily noticeable. Students become visibly more excited and involved when the class-time is centered on their learning rather than their instructor's lecture. They participate more often and more enthusiastically and voluntarily. As it was with my daughter Jenny in learning to read, student motivated learning seems to be a natural and easy process.
And second, since I work closely with the students in the lab, the success rate is higher. With few exceptions, all the student lab experiments work.

Following are some of the comments taken from the student course evaluations giving their impressions:

> "I like the way the class is structured."
> "I like [the instructor's] outlook on learning and school."
> "I like how emphasis is put on labs and accomplishing something rather than doing homework problems after homework problems. I think the students appreciate the trust given to us."
> "I like [the instructor's] method of teaching."
> "I love the subject. [The instructor's] teaching methods are different from anything I am used to but I learned a lot."
> "I liked the course flexibility. I wish the class was more structured on the work. I liked being able to learn about what we wanted, I felt like what we studied was very pertinent."

Bibliography

1. For an in-depth discussion of learning and teaching methods see Smith, Frank, *The Book of Learning and Forgetting,* Teachers College Press, 1998.

2. Gardner, Howard, *The Unschooled Mind, How Children Think and How Schools Should Teach*, Basic Books, 1991, pp. 11-12.

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