An Approach to Teaching Lifelong Learning

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Introduction

All of us continue to learn for all of our lives. The assumption that ABET2000 makes is that we can help our students to become more effective lifelong learners. This paper presents an approach to lifelong learning that has three components.

- Improving student motivation
- Understanding the dimensions of learning
- Understanding the styles of learning

Improving student motivation

Students are motivated to learn for a number of reasons, which can be divided into two classes, extrinsic motivators and intrinsic motivators. Here are examples of each.

Extrinsic motivators

- Grades
- Certificate of completion
- Good-paying job

Intrinsic motivators

- Love of learning
- Satisfying curiosity

There is general agreement that intrinsic motivators are inherently superior to extrinsic motivators in producing learning results, particularly in the long run. There is considerable controversy about whether extrinsic motivators are negative in the sense that students may not respond to intrinsic drives once they have been rewarded for learning. Educational research suggests that this is sometimes the case, but not always. Nonetheless we have assumed that it is desirable to increase intrinsic motivation in our students, and hence we have sought ways to accomplish this. This effort begins with the concept of a paradigm as developed by Thomas Kuhn in The Structure of Scientific Revolutions[1].

Kuhn argued that at any historical moment there exists a paradigm that describes the world in the eyes of science. This includes all of the laws, theories, practices, assumptions, beliefs that science holds collectively. Kuhn defines "normal science" as science that proceeds in small steps essentially within the accepted paradigm. Most all science is normal science. But when the scientific paradigm is found to be unable to explain newly observed phenomena, a breakthrough is required, a "paradigm shift" in Kuhn's words. Someone, who we will end up calling a scientific genius, will, in the vernacular of the day, "think outside the box." Once the paradigm shift is accepted by the scientific community (which, typically, takes about one generation) then we proceed with this new paradigm. Just as science has its paradigm or world view, so do each of our students, and each of us for that matter. Each of us has a view of how the world works, how things are. This includes our view of science, but also our view of every aspect of life. The view or paradigm that our students hold will necessarily be less developed than the scientific paradigm that Kuhn describes. It will be more naïve, less mature, less sophisticated. Our job as educators is two-fold. First, we are trying to align our students' paradigm as closely as possible with the accepted paradigm of the day. We are trying to teach them what the world is all about, or at least what we say it is all about. But we are also trying to teach them to break away from the paradigm, to create something new when the time comes to do so.

If they are to grow in their knowledge of the world, and provide leadership and creativity to move in new directions, they almost certainly will need to be motivated from inside. And if they are to do that they almost certainly will need curiosity. They need to wonder about how the world is, and about how it might be. In our teaching it is critically important that we nurture curiosity, to give our students opportunity to wonder. There are a number of ways to do that. We can come into class with an object that has some meaning for the lecture, put it in a prominent place, let it sit there, and hope that our students wonder about its significance, which we can explain at the end if some curious student has not already figured it out. We can raise questions and not give answers. When a student asks a question we can say, "that's a great question, what do you think the answer is?" But perhaps of greatest importance we can provide new information that is carefully chosen to increase our students' knowledge. Information that is too simple, too naïve, provides no incentive to work, has little impact on one's paradigm. Information that is too complex overwhelms. Information must be of just the right nature. But that will only happen if we understand what our students know. In the highly acclaimed study How People Learn: Brain, Mind, Experience and School[2] the authors give three "key findings" that they found central to the nature of learning. We raise the first one in this section, and the other two are brought up in the two sections to follow.

Key Finding 1: Students come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught, or they may learn them for purposes of a test but revert to their preconceptions outside the classroom.

If new information fits well into existing student paradigms, helps those paradigms grow, and is interesting because students see its relevance to what they are trying to learn, we can be optimistic that students will be excited about learning and curious about the next steps in the development.

The next two parts of the paper argue that students have better learning experiences if they understand something about the process of learning, something of the metacognition of thinking about what they are thinking about.

Understanding the Dimensions of Learning

Here is the second key finding from How People Learn.

Key Finding 2: To develop competence in an area of inquiry, students must: (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework, and (c) organize knowledge in ways that facilitate retrieval and application.

To address these points and help students understand the dimensions of learning we have adapted Benjamin Bloom's Taxonomy[3] to apply to engineering education, as shown in Figure 1. Knowledge and comprehension correspond exactly to Items (a) and (b) in Key Finding 2. We stress to students the difference between knowing something and understanding it. To further stress the difference and to assess for understanding we use concept inventories[4] that have been developed in recent years. We then show students how the other four competences fit into the education and practice of the engineer.

One way to see the role of this taxonomy in engineering is to use it to ask ourselves and our students the questions that ABET might ask, for each competence.

Knowledge: Do your students know the basic fundamentals upon which engineering is based?

Comprehension: Do they understand what they know? Are concepts clear?

Application: Can they apply what they know to the solution of relatively simple problems?

Analysis: Can your students understand a complex device or system, how its parts are interrelated, how each plays a role in the overall function of the object? And, do they understand the same thing about what they know? Can they analyze their education.

Competence	Skills and Key Words
Knowledge	Observation and recall of data, concepts, equations, laws of physics. Knowledge of engineering practice, degrees of accuracy, standards. Knowledge of test procedures and statistical data analysis. Knowledge of computer analysis techniques. Key Words: define, describe, label, name, recall, reproduce, tabulate, select, identify, recognize.
Comprehension	Understand the meaning of data, information, laws, theories, concepts. Work with data: interpret, order, classify, compare, contrast. Explain a procedure or theory in one's own words. Anticipate or predict the outcomes or consequences of one's work. Key Words: explain, classify, interpret, generalize, give examples, summarize, paraphrase, interpret
Application	Use information and concepts to solve simple engineering problems. Analyze experimental data statistically. Apply abstract ideas to particular concrete situations. Present engineering data or information in an effective way. Key Words: apply, solve, compute, manipulate, use, extend, organize, model, chart, illustrate
Analysis	Break a complex problem down into a set of simple problems. Determine how parts of a problem or a device are interrelated. Troubleshoot a piece of equipment through logical deduction. Analyze an engineering system to see how it works. Key Words: analyze, separate, subdivide, interconnect, distinguish, examine, inspect, question, contrast
Synthesis	Combine elements in a new way to create a new product. Combine ideas to create a new idea or concept. Devise a new experiment to obtain information. Relate knowledge from different areas. Key Words: synthesize, create, build, design, invent, devise, plan, organize, revise, manage, compose, formulate
Evaluation	Select the best design solution. Critique evidence or data obtained in experiments or other sources. Make decisions based on reasoned arguments. Assess importance of various ideas in preparing for a test or for a profession. Key Words: evaluate, judge, contrast, compare, justify,

Figure 1. Bloom's Taxonomy for Engineers

Do they know what are its parts, how they are related to each other, how they work together?

Synthesis: Can your students design new systems or devices to accomplish specified tasks?

Evaluation: Once your students have designed a system can they evaluate it, determine whether it does what it is designed to do, whether there are other solutions that would be more desirable, more economical, safer, more sustainable? Can they assess the value of what they learn, what they do not yet know, and might devote time to learning?

Understand the Styles of Learning

Key Finding 3: A "metacognitive" approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them.

To help students think about how they learn we introduced them to Gardner's[3] nine styles of learning: mathematical-logical, verbal-linguistic, visual-spatial, bodily-kinesthetic, interpersonal, intrapersonal, naturalist, musical, and existential. We had them do an exercise in which they used each of the nine styles to learn something during the day. We also had them take an internet-based inventory, that covers eight of the nine competences, at

http://www.ldrc.ca/projects/tscale/?PHPSESSID=5411287433414017d900a24e8c73b66d

to get an idea of where they scored high and low. Forty junior-level electrical engineering students took the inventory. With 50 as a maximum they scored the following averages:

Mathematics	38.5
Music	34.7
Naturalistic	34.6
Visual Spatial	33.4
Interpersonal	33.0
Body/Kinesthetic	32.3
Intrapersonal	30.7
Linguistic	26.6

These results are not very surprising. Our students scored highest in mathematics. They also are high in music, again not surprising since many engineers have a great interest in music. On the lower end they are not particularly introspective, nor do they read as much as we might like. It is important, however, to note that there is not a great difference among these scores. We all learn to some extent in all of these ways.

Later we asked these students anonymously what they thought of the exercise. These are the results, with some students making more than one comment.

Interesting	24
Useful	10
Waste of Time	9

Conclusion

We have reported on an approach to teaching for lifelong learning. It involves an attempt to increase motivation, and two approaches to metacognitive thinking about how learning happens. It is our experience to date that students are reluctant to give up their dependence on extrinsic rewards. We have some additional projects in progress that may affect this. One project directed at measuring and increasing student curiosity is reported on elsewhere.[4] We have found that the majority of students are receptive to the exercises in metacognitive thinking. Some resist. The hope here is that they will find the work they did in this area to be of use later in their lives.

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Biography

TIM HEALY received his BSEE from Seattle University in 1958, MSEE from Stanford University in 1959, and PhDEE from the university of Colorado at Boulder in 1966. He has taught electrical engineering at Santa Clara University since 1966, primarily in communications, and electromagnetics. He has also taught engineering ethics and has written a number of papers on ethics and other social issues.