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An Interview with Richard M. Felder

Entrevista con Richard M. Felder

Liberato Cardellini

Dipartimento di Scienze dei Materiali e della Terra, Facoltà di Ingegneria, Via Brecce Bianche, 60131 Ancona, Italy E-mail: libero@unian.it

Abstract

In this interview, Professor Richard Felder outlines several strategies for improving the learning process by addressing the full spectrum of student learning styles. The strategies including writing formal instructional objectives that span a wide range of thinking and problem-solving skills, involving the students in active learning experiences during lecture classes, and getting students to work in teams under conditions that assure individual accountability for all learning. He also discusses effective applications of technology-based education and distance learning.

Key words: instructional objectives, learning styles, active learning, cooperative learning, technology-based education.

Resumen

En su entrevista el Profesor Richard Felder, menciona varias estrategias para mejorar el proceso de aprendizaje con ayuda de diferentes estilos de estudios. Estas estrategias incluyen objetivos de educación formal los cuales abarcan una amplia gama de habilidades intelectuales y de solución de problemas. Dichas habilidades involucran a los estudiantes en las experiencias activas de las clases y del trabajo colectivo, a la vez estas condiciones aseguran las ventajas individuales de todo el proceso de aprendizaje. En el contexto también discuten los problemas de aplicación efectiva de métodos de tecnología educativa y de educación a distancia.

Palabras clave : Objetivos educativos, estilos de aprendizaje, aprendizaje activo, trabajo cooperativo, tecnología educativa.

Richard M. Felder is Hoechst Celanese Professor Emeritus of Chemical Engineering at North Carolina State University, Raleigh, North Carolina. He is a coauthor of the book *Elementary Principles of Chemical Processes*, which has been used as the introductory chemical engineering text by over 100 universities in the United States and abroad. He has authored or coauthored over 150 papers on chemical process engineering and engineering education and has presented seminars, workshops, and short courses in both categories to industrial and research institutions and universities in the United States, Europe, and South America. Since 1990 he has codirected the National Effective

Teaching Institute under the auspices of the American Society for Engineering Education.

Dr. Felder won the R.J. Reynolds Award for Excellence in Teaching, Research, and Extension in 1982, the AT&T Foundation Award for Excellence in Engineering Education in 1985, the Chemical Manufacturers Association National Catalyst Award in 1989, and the ASEE Chester Carlson Award for Innovation in Engineering Education in 1997. He was selected as one of five Outstanding Engineering Educators of the Century by the Southeastern Section of the American Society for Engineering Education in 1993.

INTRODUCTION

Why don't we begin with a brief biography?

Okay. I was born in New York City in 1939, spent seven years there and another six in Buffalo, New York, and went to high school in Florida. In those days, most high school students with any ability at all in science and mathematics chose to go into engineering, and that's what I did. So in 1957 I enrolled for a degree in chemical engineering at the City College of New York. Luckily, it was a perfect choice—what I didn't know then, but know now, is that a background in chemical engineering equips you to do almost anything.

I graduated from City College in 1962, enrolled in graduate school at Princeton University, and got my Ph.D. in chemical engineering in 1966, writing my dissertation on energy distributions of high-energy atoms slowing down in a gaseous medium. After that I spent a year on a NATO postdoctoral fellowship at the Atomic Energy Research Establishment in England and two years as a research engineer at Brookhaven National Laboratory, and finally took a faculty position at North Carolina State University. I've been there ever since, eventually being named Hoechst Celanese Professor of Chemical Engineering. I retired in 1999 and now plan to spend most of my time giving teaching workshops to faculty members and graduate students, occasionally teaching a course, and playing with my grandchildren.

Education is not something that most engineering professors emphasize in their careers. Has it always been your focus?

No. I was very conventional in the first half of my career at N.C. State. I devoted my time and energy primarily to research on a variety of topics, most of which involved mathematical modeling of chemical and environmental processes, and in whatever time was left I taught classes. I always liked teaching and got a lot of personal satisfaction from it, but it was definitely less important than my research in terms of my career advancement. I earned tenure and promotion to associate professor after four years and then to full professor after another five, strictly on the basis of my research performance—whether I taught well or poorly had nothing to do with it.

I had been teaching for about 15 years when I first became aware that something was wrong in my undergraduate classes and had been from the beginning. I would cover material thoroughly in my lectures, giving lots of examples and illustrations of the methods I was presenting, but when I asked questions about it the next day most of the students seemed not to have heard a word I said, and when I gave examinations many of them did terribly. I knew they were all intelligent—you have to be to get into chemical engineering at North Carolina State—and I started to wonder what the problem was. It dawned on me that no one had ever taught me anything about how to teach—the bizarre fact is that it's just not part of how faculty members are prepared for their jobs. I thought it might be a good idea to learn something about what I was supposed to be doing for a living. The change in my career focus really began then.

What did you do?

I started looking into the literature of cognitive and educational psychology to see if those folks could tell me anything about what I was supposed to be doing for a living, and I discovered that some of them could. The main point of what I discovered is that people acquire and retain knowledge and develop skills in only one way—by doing things and getting feedback on the outcomes, not by watching and listening to someone else telling them what they are supposed to know. When all I did was prepare and deliver lectures and respond to questions, *I* was learning the material at a far deeper level than I knew it before, but the students were not learning much of anything. Those who managed to learn it did so when they went home and worked through assignments by themselves, and most of them could have done the same thing if I had just given them my lecture notes and not even bothered delivering the lectures.

Once I recognized that, I started to change how I taught, involving students much more actively in the learning process in and out of class, and later I began trying to pass on what I discovered about teaching and learning to my colleagues in articles and workshops. I found this work both more satisfying and more enjoyable than research on mass transfer and batch process optimization, and over the next 15 years I gradually decreased my involvement in engineering research and made education my primary focus.

What are the main teaching strategies you recommend in your papers and workshops?

Before I answer that, let me point out that "teaching" can mean two completely different things. First, it can simply mean presenting information, so that if I lecture on something I can say that I taught it, whether or not anyone learned it. The second meaning of teaching is "helping someone to learn." According to this meaning—which I personally accept—if I lecture on something and the students don't learn it, I have not taught it.

The usual approach to teaching a course implicitly uses the first meaning. You write a syllabus, listing the topics you plan to cover, then present the topics in class, and collect your paycheck. It doesn't matter how much students learn—if you covered the syllabus, you did your job. The approach I try to follow is sometimes called *outcomes-based education*. Rather than defining a course by simply writing a syllabus, I try to define in as much detail as possible the knowledge, skills, and attitudes I want the students to acquire by the end of the course. Then when I teach the course, I try to present and explain the specified knowledge, provide practice and feedback in the specified skills, and offer guidance and models for the attitudes. Even if I cover the entire syllabus, if they don't learn what I said they should, I've failed.

The principal strategies I use in following this approach are first, writing clear instructional objectives and using them to structure the courses I teach; second, addressing the full spectrum of student learning styles when I teach; and third, using active and cooperative learning.

INSTRUCTIONAL OBJECTIVES

What are instructional objectives?

They are explicit statements of what students should be able to do if they have learned something. An instructional objective has two parts: a *stem*, which states when the students should be able to carry out a specified action, followed by the action. Typical stems are “When you (or “the students”) have finished Chapter 6 in the text, you (they) should be able to…” or “In order to do well on next week’s examination, you should be able to….” The phrase following the stem must begin with an observable action verb, such as *list, explain, calculate, prove, derive, design*, or *optimize,* and should be a clear statement of what the student is expected to do. Verbs like know, learn, understand, and appreciate should not be used—those actions cannot be directly observed. For example

- In order to do well on the next examination, you should be able to **list** the components of an environmental impact statement and **explain** each component in terms your grandparents could understand.

- By the end of this course, if given the flow chart of a chemical process production plant, you should be able to **identify** potentially hazardous pollutants, **design** a system for reducing an emission level of one of them, **calculate** the expected emission level if your system is implemented, and **identify** possible flaws in the system.

What’s wrong with stating the things you want students to know and understand? Aren’t those your real goals?

Of course they are, but they’re not directly observable—you can only determine what students know and understand by observing how they do something that demonstrates their knowledge or understanding. For example, you may tell me that your goal is for your student to understand the ideal gas equation of state. I would then ask, “*How will you know whether or not they do*?” You might answer, “*Well, I’ll give them several temperatures and pressures of an ideal gas and ask them to* ***calculate*** *the corresponding specific volumes*” or “*I’ll specify P and T and ask them to* ***estimate*** *the error that would result if they use the ideal gas equation of state to calculate V*” or “*I’ll ask them to* ***derive*** *the ideal gas equation of state from the kinetic theory of gases*.” I would then say “*Fine—<u>those</u> are your instructional objectives.*”

One reason for writing instructional objectives is to give students benchmarks against which they can check their understanding. If you tell them you want them to understand something, they cannot possibly know whether or not they do unless you tell them how you expect them to demonstrate their understanding. The more explicit you are in stating your objectives for the students—especially the ones that require high levels of critical or creative thinking—the more likely the students will be to achieve them.

Aren't students intimidated when you give them a long list of things they're expected to do?

Sure, and if you gave them a huge list of objectives for the entire course on the first day, most of them would just ignore it. I’ve had the greatest success when I give them my objectives in the form of study guides for tests. Most students want to do well on tests—in fact, that’s the only thing that motivates some of them to learn the material. When I tell them what I expect them to be able to do on a test, most will try to learn how to do everything on the list.

Aren't you making it too easy for the students when you tell them everything they will have to be able to do on the tests?

Not at all. Remember, I'm not giving them the exact questions, but rather a comprehensive list of the types of questions that *might* be included. If it's easy for them to master everything on the list, it just means that I'm not including enough high-level objectives. I always make sure that the list includes some things that normally only the top students in a class are able to do—explaining complex phenomena in jargon-free terms, for example, or identifying possible sources of discrepancies between predicted and observed system behavior, or choosing between alternative systems or experimental designs and justifying their choices. If I base my examinations on the instructional objectives and the students can do everything I've said they should be able to do, it means they've learned what I wanted them to learn and they deserve a high mark. If they lack the understanding or the basic ability to meet the objectives, they will not get a high mark, whether or not they have the list before the test.

How can I find out more about writing instructional objectives?

One place to start is a paper that Rebecca Brent and I wrote for the journal *College Teaching* (FELDER, *et al.*, 1999). There's also a good little book by Gronlund (GRONLUND, 1994) that's quick to read and very informative.

LEARNING STYLES

You said the second component of your teaching approach is to make sure you address the full spectrum of learning styles. What are learning styles?

They're the ways that students characteristically take in and process new information. Students function in a variety of different ways in learning situations. Some prefer to deal with concrete information—facts, observations, experimental data—and others are happier working with abstract concepts and mathematical models. Some take in and retain more from visual information (figures, diagrams, pictures, plots) than from verbal information (spoken and written words), and others get more from written and spoken explanations. If you teach students in a way that strongly conflicts with their learning style, they may not learn much. Unfortunately, mismatches are common between the way most engineering and science professors teach and the learning styles of most of their students.

For example?

A common mismatch is that most students are visual learners and the way we present information in most college courses is overwhelmingly verbal. We use only words when we lecture and mainly words and mathematical formulas on the board and on transparencies and in textbooks. Another problem is that many students are active learners, who gain the greatest understanding when they are doing something physical—solving problems, discussing ideas, even just moving around—and most college teaching involves primarily lecturing. (Laboratory courses are notable exceptions.) For active learners, sitting passively hour after hour watching professors lecturing is a great waste of time—they are not learning anything and would do just as well to skip the classes and copy a classmate's notes.

Perhaps the most serious mismatch in undergraduate science and engineering courses arises from the fact that most students are *sensing learners (sendors)* , who like working with facts and real objects and are uncomfortable if they cannot see connections between what they are being taught and the "real world," and who tend to work slowly and meticulously, paying attention to details and checking their work frequently. Unfortunately for them, most engineering and science professors teach in a way that works against these students and in favor of the *intuitive learners (intuivors)* , who are much more comfortable with abstract theoretical material and tend to work quickly (although not necessarily carefully). Starting in the first year of college, we plunge the students into the “fundamentals”—mathematical techniques, basic scientific principles, molecular theories, and so on—and make them wait for several years to get to the applications of these abstractions. We also tend to give long tests that only the fastest-working students can finish, so that the careful and methodical “sensors”, who may understand the material very well and would make excellent engineers and scientists, do poorly and may even fail the tests and the courses.

I imagine that students being taught in a way that conflicts almost completely with their learning style would find school unpleasant.

You’d be right. It feels to them like the instructor is teaching in a foreign language they don’t understand—they are likely to get bored quickly, stop paying attention in class or stop coming to class altogether, do poorly on tests, and get discouraged. Not surprisingly, the research shows that students taught almost entirely with mismatched teaching styles don’t learn as much as students taught in their preferred styles and they retain less of what they learn (FELDER, 1996 a).

Wouldn't it be difficult for instructors to find out the learning styles of each of their students and teach each student in the way that best fits his or her learning style?

The first part isn’t difficult but the second part is impossible. You can use a variety of instruments to assess learning style preferences (JOHNSON, *et al.*, 1998), including one I’m developing called the *Index of Learning Styles* that can be taken and scored on-line (FELDER). What you can’t do is implement simultaneously as many teaching approaches in a class as there are learning styles among the students, however. Fortunately, you don’t have to do that. In fact, even if you could somehow manage to teach students only in the way they prefer, it would be a bad idea.

Why?

Because to be successful, professionals have to function effectively in all learning style categories, not just the ones they prefer. Most obviously, engineers and scientists have to deal with both visual and verbal information. Also, they have to work well in the manner of both sensors—being observant, methodical, willing to repeat experiments and calculations enough to be confident in the results—and intuitors, interpreting the results and speculating on what they might imply. The same argument can be made for every dimension of every learning style model.

On the other hand, if you teach students only in their preferred style, they will develop their skills in their preferred ways of functioning but they won’t get practice in the other categories, which means they won’t graduate with all of the skills they will need to succeed as professionals. In short, when we teach in a way that heavily favors one type of learner or the other—which is what the traditional lecture-based teaching style does—we do a disservice to *all* learners.

So what do we do?

The key is *balance*—making sure that we address both sides of every learning style dimension rather than always favoring one side at the expense of the other. In most engineering and science classes, improving the balance means significantly increasing visual content, putting more emphasis on observable phenomena and experimental data and less on theories and mathematical models, and providing more opportunities in class for student activity rather than requiring the students to spend all of their classroom time watching and listening to us.

So I don't really need to know the learning style preferences of my students—I just need to make sure I teach to each type part of the time?

Exactly!

Wouldn't it be useful for the students to know their own learning styles?

Yes, but you have to be careful about this. Learning style preferences contain useful clues about how students function and things they might do to become more effective as learners, but they say nothing about what fields students should or should not pursue or even about what they are or are not good at. The fact that you prefer a learning style category says nothing about how good or bad you are in either that category or its opposite. For example, a student with a strong preference for visual presentation may be excellent, average, or poor at comprehending verbal information—or visual information, for that matter. A student who says "I'm a sensing learner so I can't be good at math and I'd better not major in physics" is missing the point of learning styles, and an instructor or advisor who tells students something like that could be making a serious and potentially harmful mistake.

ACTIVE LEARNING

Moving to another topic, what is active learning?

It's instruction that engages students in any course-related activity other than watching and listening to lecturing. The idea behind it is that people acquire skills through active practice and feedback, not by passive observation, so the more practice they get at doing something, the better they are likely to become at it.

Isn't that where homework comes in?

Yes, and assigning homework could technically be classified as using active learning, but the term usually refers to giving brief exercises in class for the students to do individually or in small groups and then providing immediate feedback on their efforts. The exercises might involve answering questions, solving short problems, brainstorming, or formulating questions. The idea is that as long as we have students with us for 30 to 40 hours of class in a semester, we may as well try to get some meaningful learning to happen during those hours instead of pushing it all to the homework.

Can you get students active in a large class in a fixed-seat auditorium? If so, how?

It's just as easy as doing it in a small class with movable chairs. Several times during a class period, you ask a question or pose a short problem, tell the students to turn to one or two neighbors, randomly designate group recorders if calculations are involved (the student on the right end of the group, the student with the closest birthday,...) and give them anywhere from 30 seconds to three minutes to come up with an answer or solution. Then call randomly on students to tell you some or all of what their groups came up with, continuing until you are satisfied with the responses, and proceed with your lecturing or whatever else you want to do at that point. I've used this technique with groups of up to 400 people and it works beautifully, although you have to do it several times with students who are new to it before you start getting the results you're looking for. The keys are to keep the activities short and to call on at least a few individuals initially rather than just asking for volunteers.

Why are those things so important?

Because if the activity takes more than about three minutes, some groups will finish early, get bored, and wander off task, and other groups will flounder for long non-productive periods. If you want the students to solve a longer problem, break it up into small chunks. If the students know you might call on anyone in the class, most of them will be motivated to do the work so they won't be embarrassed if they are selected. If you just ask for volunteers, many students won't bother to work on the exercise, knowing that someone else will eventually supply the answer. Incidentally, I tend to load heavily on the back of the classroom, where students usually go to hide. They quickly learn that they can run but they can't hide.

I've tried something like that, and I notice that whatever I do some students refuse to work in groups in class. What should I do about them.

How about nothing? I know instructors are really bothered when they see non-participating students and some of them conclude that the method is failing, but that's the wrong way to look at it. Let's suppose that you're doing an active learning exercise, and 10% of the students in the class are not participating. (It's never that high in my classes after the first week, but let's just say it is.) That means that while the exercise is going on, you've got 90% of your class actively engaged in thinking about what you want them to think about and doing what you want them to do. At any moment when you're lecturing, what percentage of your students would you guess are actively engaged in thinking about what you want them to think about, let alone doing anything with it? Ten percent, tops.

No instructional method is guaranteed to reach all students at all times; all we can do as instructors is try to maximize the percentage we're involving. I like 90% active involvement a lot better than 10%, and so I use some active learning in every class period, even if it's only five minutes in an hour-long period. Those five minutes are likely to be where most of the learning takes place during that period.

COOPERATIVE LEARNING

How about cooperative learning—what is that?

It's a subset of *collaborative learning*, instruction that involves students working in teams. In cooperative learning, the team activities are structured to meet five criteria: *positive interdependence* (if all team members fail to do their parts everyone is penalized), *individual accountability* (each team member is held accountable for all the learning that was supposed to take place in the assignment), *face-to-face interaction, appropriate use of interpersonal skills,* and *regular self-assessment of team functioning.*

How do you get individual accountability?

The obvious and most common way is to give individual tests covering everything the team members were supposed to have learned. When teams work on homework in a lecture course, this is usually done routinely. In a laboratory course, instead of basing the entire course grade on the lab reports you can give tests on the total content of the experiments, including the experimental design, equipment calibration and operation, statistical data analysis, and theoretical interpretation of the data. You can do the same thing in any project-based course, like the capstone design course in an engineering curriculum—test the students on the equipment design, instrumentation and control provisions, economic analysis, and all other components of the final report. Students who were not fully involved in the project probably won't do well on the tests, which will affect their course grades.

Are there other ways?

Lots of them. For example, when teams give oral presentations on a project, they normally just choose the best and brightest team member to do most of the talking, or the team members present the parts of the project that they mainly did, which may be the only parts they really understand. What you can do is complicate their lives a bit. When you assign the project, tell them that a short time before the presentation—a day, an hour, five minutes—you will randomly designate which team member will present which part of the report, and then when the time comes, do it. Doing this not only provides individual accountability but also positive interdependence. If I am on a team, my grade may depend on how well someone else on the team reports on my part of the project, so I end up teaching my teammates what I did and all of them do the same with their parts. Since we learn best what we teach others (as every teacher knows), the result is that everyone learns at a deeper level. Other ways of getting individual accountability are suggested in references on cooperative learning (JOHNSON, *et al.*, 1998; MILLIS,*et al.*, 1998; FELDER, *et al.*, 1994; FELDER, 1996 b).

How do you know cooperative learning works?

Research—hundreds of studies in both laboratory and natural classroom settings. Some investigators at the University of Wisconsin recently did a meta-analysis of cooperative learning research in science, mathematics, engineering, and technology (SPRINGER, *et al.*, 1997). They put the results of 39 rigorous studies on a common basis, and showed that on average cooperative learning significantly improved academic performance, lowered dropout rates, and increased student self-confidence. Many other studies point in the same direction (JOHNSON, *et al.*, 1998; MILLIS, *et al.*, 1998).

TEACHING WITH TECHNOLOGY

One final topic. What role do you think technology will play in the education of the future?

I can't predict exactly what role it will play, but I'm confident that it will change almost everything (FELDER, 2000). More and more textbooks now come with courseware that can do almost everything an instructor can do in a lecture—present information, ask questions or pose problems, and provide immediate positive or corrective feedback to student responses. The courseware also does things lecturers cannot do. With a simple mouse click, students can interrupt a lesson to get detailed explanations of terms and concepts, bring up illustrative diagrams, animations, and movies, look up physical properties, solve algebraic and differential equations, and then return to where they were in the lesson and proceed. They can go to the Web, activate a search engine, and find out almost anything about the subject at hand from encyclopedias, articles and research reports, and expert discussions on archived listservers. They can also bring up simulations of physical, chemical, or biological systems and actively explore the effects of parameter changes on system behavior, getting a concrete sense of how the systems work that cannot possibly be gained by watching and listening to a professor. They can even work in virtual cooperative learning groups using e-mail and chat facilities, and within a few years they'll have easy access to videoconferencing.

Most significantly, the students can have these experiences whenever and wherever they wish; they don't have to be on campus between 9 and 10 on Monday morning but may be anywhere in the world at any time of day or night. Some institutions that specialize in distance education recognize the potential of instructional technology and are starting to offer it in competition with traditional universities. Compare all that with someone writing words and formulas on a board and gue ss which form of instruction does a better job of promoting learning. Let students decide between having all those things in a distance environment and sitting through lectures on a campus for four years and guess which option they will eventually choose.

So does that mean that the traditional university will no longer have a function?

It could very well mean that—and I think it *will* mean that if universities don't change with the times. It doesn't have to be that way, though. There are some things that live instructors will always be able to do better than virtual ones, like motivate and inspire students to learn, promote a sense of community among them while maintaining individual accountability for learning, and help them develop desirable professional, social, and ethical values. Traditional universities will remain in business if they start supporting and rewarding faculty members who do those things with the kind of enthusiasm, responsiveness, and sense of caring that students still remember fondly years and decades later. For the sake of the next generation of students, I hope that most universities put themselves in the last category.

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