ASEE Prism, 6(4), 18-23 (December 1996).

MATTERS OF STYLE

Richard M. Felder
Department of Chemical Engineering
North Carolina State University
Raleigh, NC 27695--7905

Students have different *learning styles*--characteristic strengths and preferences in the ways they take in and process information. Some students tend to focus on facts, data, and algorithms; others are more comfortable with theories and mathematical models. Some respond strongly to visual forms of information, like pictures, diagrams, and schematics; others get more from verbal forms--written and spoken explanations. Some prefer to learn actively and interactively; others function more introspectively and individually.

Functioning effectively in any professional capacity, however, requires working well in all learning style modes. For example, competent engineers and scientists must be observant, methodical, and careful (characteristics of the *sensing* style in one of the learning style models to be described) as well as innovative, curious, and inclined to go beyond facts to interpretation and theory (characteristics of the *intuitive* style in that model). Similarly, they must develop both *visual* and *verbal* skills. Information routinely comes in both forms, and much of it will be lost to someone who cannot function well in both of these modes.

If professors teach exclusively in a manner that favors their students' less preferred learning style modes, the students' discomfort level may be great enough to interfere with their learning. On the other hand, if professors teach exclusively in their students' preferred modes, the students may not develop the mental dexterity they need to reach their potential for achievement in school and as professionals.

An objective of education should thus be to help students build their skills in both their preferred and less preferred modes of learning. *Learning style models* that categorize these modes provide good frameworks for designing instruction with the desired breadth. The goal is to make sure that the learning needs of students in each model category are met at least part of the time. This is referred to as "teaching around the cycle."

FOUR LEARNING STYLE MODELS

Before looking at some examples of teaching around the cycle, let's examine four learning style models that have been used effectively in engineering education.

The Myers-Briggs Type Indicator (MBTI)

This model classifies students according to their preferences on scales derived from psychologist Carl Jung's theory of psychological types. Students may be:

- *extraverts* (try things out, focus on the outer world of people) or *introverts* (think things through, focus on the inner world of ideas);
- *sensors* (practical, detail-oriented, focus on facts and procedures) or *intuitors* (imaginative, concept-oriented, focus on meanings and possibilities);
- *thinkers* (skeptical, tend to make decisions based on logic and rules) or *feelers* (appreciative, tend to make decisions based on personal and humanistic considerations);
- *judgers* (set and follow agendas, seek closure even with incomplete data) or *perceivers* (adapt to changing circumstances, resist closure to obtain more data).

The MBTI type preferences can be combined to form 16 different learning style types. For example, one student may be an ESTJ (extravert, sensor, thinker, perceiver) and another may be an INFJ (introvert, intuitor, feeler, judger). Engineering professors usually orient their courses toward introverts (by presenting lectures and requiring individual assignments rather than emphasizing active class involvement and cooperative learning), intuitors (by focusing on engineering science rather than design and operations), thinkers (by stressing abstract analysis and neglecting interpersonal considerations), and judgers (by concentrating on following the syllabus and meeting assignment deadlines rather than on exploring ideas and solving problems creatively).

Kolb's Learning Style Model

This model classifies students as having a preference for 1) *concrete experience* or *abstract conceptualization* (how they take information in), and 2) *active experimentation* or *reflective observation* (how they internalize information). The four types of learners in this classification scheme are

- *Type 1* (concrete, reflective). A characteristic question of this learning type is *"Why?"* Type 1 learners respond well to explanations of how course material relates to their experience, their interests, and their future careers. To be effective with Type 1 students, the instructor should function as a *motivator*.
- *Type 2* (abstract, reflective). A characteristic question of this learning type is *"What?"* Type 2 learners respond to information presented in an organized, logical fashion and benefit if they have time for reflection. To be effective, the instructor should function as an *expert*.
- *Type 3* (abstract, active). A characteristic question of this learning type is *"How?"* Type 3 learners respond to having opportunities to work actively on well-defined tasks and to learn by trial-and-error in an environment that allows them to fail safely. To be effective, the instructor should function as a *coach*, providing guided practice and feedback.
- *Type 4* (concrete, active). A characteristic question of this learning type is *"What if?"* Type 4 learners like applying course material in new situations to solve real problems. To be effective, the instructor should stay out of the way, maximizing opportunities for the students to discover things for themselves.

Traditional engineering instruction focuses almost exclusively on formal presentation of material (lecturing), a style comfortable for only Type 2 learners. To reach all types of learners, a professor should explain the relevance of each new topic (Type 1), present the basic information and methods associated with the topic (Type 2), provide opportunities for practice in the methods (Type 3), and encourage exploration of applications (Type 4). The term "teaching around the cycle" was originally coined to describe this instructional approach.

Herrmann Brain Dominance Instrument (HBDI)

This method classifies students in terms of their relative preferences for thinking in four different modes based on the task-specialized functioning of the physical brain. The four modes or quadrants in this classification scheme are

- *Quadrant A* (left brain, cerebral). Logical, analytical, quantitative, factual, critical;
- *Quadrant B* (left brain, limbic). Sequential, organized, planned, detailed, structured;
- *Quadrant C* (right brain, limbic). Emotional, interpersonal, sensory, kinesthetic, symbolic;
- *Quadrant D* (right brain, cerebral). Visual, holistic, innovative.

Engineering professors on the average are strongly Quadrant A dominant and would like their students to be that way as well, according to Edward and Monika Lumsdaine (see references). Most engineering instruction consequently focuses on left-brain Quadrant A analysis and Quadrant B methods and procedures associated with that analysis, neglecting important skills associated with quadrant C (teamwork, communications) and quadrant D (creative problem solving, systems thinking, synthesis, and design). This imbalance is a disservice to all students, but particularly to the 20-40% of entering engineering students with strong preferences for C and D quadrant thinking.

Felder-Silverman Learning Style Model

This model classifies students as:

- *sensing learners* (concrete, practical, oriented toward facts and procedures) or *intuitive learners* (conceptual, innovative, oriented toward theories and meanings);
- *visual learners* (prefer visual representations of presented material--pictures, diagrams, flow charts) *or verbal learners* (prefer written and spoken explanations);
- *inductive learners* (prefer presentations that proceed from the specific to the general) or *deductive learners* (prefer presentations that go from the general to the specific);
- *active learners* (learn by trying things out, working with others) or *reflective learners* (learn by thinking things through, working alone);
- *sequential learners* (linear, orderly, learn in small incremental steps) or *global learners* (holistic, systems thinkers, learn in large leaps).

For the past few decades, most engineering instruction has been heavily biased toward intuitive, verbal, deductive, reflective, and sequential learners. However, relatively few engineering students fall into all five of these categories. Thus most engineering students receive an education that is mismatched to their learning styles. This could hurt their performance and their attitudes toward their courses and toward engineering as a curriculum and career. In the section "Teaching to All

Types" I suggest some instructional methods for addressing the learning needs of the full spectrum of learning styles.

LEARNING STYLES IN ACTION

Here are some ways that engineering educators have applied learning style models to provide students with an education that addresses both their learning strengths and weaknesses.

Applications of the Myers-Briggs Type Indicator

During the 1980s, thousands of engineering students and hundreds of engineering professors took the MBTI as part of a research study conducted by a consortium of eight engineering schools and the Center for Applications of Pyschological Type. The study examined the effects of psychological type differences on the education and career development of engineering students. Educators have used the results to design methods for improved teaching and advising.

For example, Charles Yokomoto, an electrical engineering professor at Indiana University-Purdue University at Indianapolis, uses the MBTI as a diagnostic tool for students having academic difficulties. He administers the instrument to them, gives them the results, and describes the characteristics of their type. If the descriptions seem accurate to the students Yokomoto helps them devise remedial approaches that not only capitalize on their strengths but also use their weaker modes when doing so is the more appropriate learning approach. Letting the students assess the accuracy of the descriptions is essential. Like all other assessment instruments, the MBTI provides clues, not infallible labels. The student is the ultimate judge of his or her behavior patterns.

Working with an ISTJ (introvert, sensor, thinker, judger) student who was failing the introductory course in electrical circuits, Yokomoto speculated and confirmed that the student relied too heavily on memorization and drill (traits of ISTJs) as approaches to problem solving. The professor persuaded his student to add strategies based more on a fundamental understanding of the concepts. The student's performance began to improve: by his senior year he was earning A's, and he subsequently received a master's degree in electrical engineering.

In another case, Yokomoto found that an ENTJ (extrovert, intuitor, thinker, judger) student jumped directly into mathematical derivation on every homework and test problem (behavior consistent with extroverted intuition) rather than using routine procedures for routine problems. The resulting demands on the student's time caused problems with assignment completion and test performance. Once the student realized what he was doing, he began to apply his analytical talents when needed rather than using them indiscriminately and inefficiently. As a result, his performance improved.

(*For more information about this work, contact Charles Yokomoto, yokomoto@tech.iupui.edu*.)

Applications of the Kolb Model

Julie Sharp, an associate professor of technical communications in the chemical engineering department at Vanderbilt University, has administered the Kolb Learning Style Inventory to her technical communication classes and senior chemical engineering laboratory course for the past six years. In the communication class, she gives the students a handout describing ways to communicate effectively to the four different learning types. The students then prepare and give 10-minute presentations designed to appeal to all types. In the laboratory course, the students keep journals in which they describe conflicts and accomplishments within their lab groups, relating them to the group members' learning styles. Sharp has found that teaching students about learning styles helps them learn the course material because they become aware of their thinking processes. More importantly, she says, it helps them develop interpersonal skills that are critical to success in any professional career.

(*For more information, contact Julie Sharp, sharpje@vuse.vanderbilt.edu*.)

In 1989 the College of Engineering and Technology at Brigham Young University initiated a faculty training program based on Kolb learning styles. About one-third of the engineering faculty members, all volunteers, were trained in the concepts of the Kolb model and methods of teaching to each Kolb type. The volunteers implemented the approach in their courses, reviewed videotapes of their teaching, and discussed their successes and problems in focus groups. The benefits of the program have been significant. Many faculty members--including some who did not participate in the original training --have redesigned their courses in an attempt to reach the full spectrum of learning styles. They do so by using a variety of teaching methods such as group problem solving, brainstorming activities, design projects, and writing exercises in addition to formal lecturing. Additionally, discussions about teaching have become a regular part of department faculty meetings; the general level of interest and concern about teaching has increased throughout the engineering college; and several faculty members have become involved in the "scholarship of teaching," presenting and publishing peer-reviewed papers related to engineering education.

(*For more information, contact John Harb, jharb@caedm.byu.edu,* or *Ronald Terry, ron_terry@byu.edu*.)

Applications of the Herrmann Brain Dominance Instrument

In the early 1990s, Edward Lumsdaine and Jennifer Voitle, then of the University of Toledo's engineering college, studied the HBDI types of the college's students and faculty members. They found that many engineering students and professors were left-brain thinkers--logical, analytical, verbal, and sequential. Their data also indicated a strong attrition rate among right-brain thinkers, with many of them dropping out despite earning top grades in analytical courses. "A dominant reason for their choosing other majors is the inhospitable learning climate in engineering, which does not accommodate their thinking preferences, even though voices in industry are increasingly demanding engineers with precisely those thinking skills," Lumsdaine and Voitle claimed in a 1993 paper on their research.

The authors reviewed the existing mechanical engineering curriculum, found it skewed toward left-brained thinking skills, and set out to provide a better balance by introducing more creativity, design, innovation, and teamwork into selected courses. One course, "Introduction to Computing," originally consisted of 20 percent quadrant A activities (structured programming) and 80 percent quadrant B activities ("following the rules" in canned, routine programs). The redesigned version involved approximately 20 percent each for quadrants A and B and 30 percent each for quadrants C and D (student experiments, question formulation, design, modeling, and optimization). Students worked in teams formed by the professors to provide balance in HBDI types. Student performance levels and attitudes to the course improved considerably because of these changes.

These results and results of similar studies led Edward and Monika Lumsdaine to conclude in a 1995 Journal of Engineering Education article that the HBDI can serve several important functions. These include helping students gain insight into their learning styles and formulate successful learning strategies; helping instructors understand students' questions, comments, and answers in the context of their thinking preferences; helping instructors and students form whole-brain teams for optimum problem solving; and assessing the influence of curriculum changes on individual and collective student thinking skills.

(*For more information, contact Edward Lumsdaine, usfmdnan@ibmmail.com*)

Applications of the Felder-Silverman Model

Along with Barbara Soloman, the coordinator for advising in the First-Year College at North Carolina State University, I am developing an *Index of Learning Styles* (ILS) that classifies students on four of the five Felder-Silverman dimensions (all but inductive/deductive). The ILS is in a beta version, and some professors are already testing it with their students.

For example, Peter Rosati, a civil engineering professor at the University of Western Ontario, has used the ILS to assess the learning styles of engineering faculty members and first-year and fourth-year engineering students at his university. Rosati found that faculty members were significantly more reflective, intuitive, and sequential than the students. The results suggest that professors could improve engineering instruction by increasing the use of methods oriented toward active learners (participatory activities, team projects), sensing learners (guided practice, real-world applications of fundamental material), and global learners (providing the big picture, showing connections to related material in other

courses and to the students' experience).
(*For more information, contact Peter Rosati, prosati@charon.engga.uwo.ca*.)
At the University of Michigan, Susan Montgomery, an assistant professor of chemical engineering, is developing multimedia instructional modules that address the spectrum of Felder-Silverman preferences. To do this, she assessed her students' learning styles with the ILS and surveyed them to determine the attitudes of the different types toward different features of instructional modules. She reports that sensing and visual learners rated demonstrations highly; sensing learners liked having access to derivations of equations (which they may not have grasped as fully as the intuitors when the instructor first presented the equations in class); and active, sensing, and visual learners preferred movies more than their reflective, intuitive, and verbal counterparts did.
(*For more information, contact Susan Montgomery, smontgom@engin.umich.edu*.)
In another style-based approach to software instruction, Curtis Carver and Richard Howard, assistant professors at the U.S. Military Academy, have developed a hypermedia package for a computer science course on information systems. The package, which is distributed on the World Wide Web, is based on the Felder-Silverman model. Every lesson starts with a list of objectives and is followed by several different presentations of the lesson material, each geared toward a different learning style. For example, students can learn how to install a hard drive by going through a Harvard Graphics slide show, which is mostly text and appeals to verbal and sequential learners. Alternatively, they can learn the same thing by viewing embedded pictures, animations, and movies, which would appeal to visual and global learners.
The hypermedia package allows students to assess their learning styles using an online version of the ILS. The Web interface then provides them the option of having the material presented in a manner compatible with their style preferences, structuring the lesson so that the preferred media elements come first. Students who prefer to organize the presentations themselves without following a particular sequence may do so also.
(*The hypermedia package can be accessed at*

http://www.eecs.usma.edu/cs383/tools.htm. For more information, contact Curtis Carver, carver@eecs1.eecs.usma.edu, or Richard Howard, howard@eecs1.eecs.usma.edu.)

At North Carolina State University, I've used the Felder-Silverman model to design the instruction in a longitudinal study of engineering education. I taught five sequential chemical engineering courses in a way that would appeal to a range of learning styles. I presented course material inductively, moving from facts and familiar phenomena to theories and mathematical models rather than always using the "fundamentals, then applications" approach. I used realistic examples of engineering processes to illustrate basic principles and occasionally provided opportunities for laboratory and plant visits. I stressed active learning experiences in class, reducing the time I spent lecturing. In homework assignments I routinely augmented traditional formula substitution problems with open-ended questions and problem formulation exercises. I used extensive cooperative learning, and tried to get the students to teach one another rather than rely on me exclusively. So far, the results of my study suggest that teaching to the full spectrum of learning styles improves students' learning, satisfaction with their instruction, and self-confidence. (*For more information and references to papers on the longitudinal study, contact Richard Felder, felder@eos.ncsu.edu.*)

TEACHING TO ALL TYPES

Here are some strategies to ensure that your courses present information that appeals to a range of learning styles. These suggestions are based on the Felder-Silverman model.

- *Teach theoretical material by first presenting phenomena and problems that relate to the theory* (sensing, inductive, global). For example, don't jump directly into free-body diagrams and force balances on the first day of a statics course. First describe problems associated with the design of buildings and bridges and artificial limbs, and perhaps give the students some of those problems and see how far they can go before they get all the tools for solving them.

- *Balance conceptual information* (intuitive) *with concrete information* (sensing). Intuitors favor conceptual information--theories, mathematical models, and material that emphasizes fundamental understanding. Sensors prefer concrete information such as descriptions of physical phenomena, results from real and simulated experiments, demonstrations, and problem-solving algorithms. For example, when covering concepts of vapor-liquid equilibria, explain Raoult's and Henry's Law calculations and nonideal solution behavior, but also explain how these concepts relate to barometric pressure and the manufacture of carbonated beverages.

- *Make extensive use of sketches, plots, schematics, vector diagrams, computer graphics, and physical demonstrations* (visual) *in addition to oral and written explanations and derivations* (verbal) *in lectures and readings*. For example, show flow charts of the reaction and transport processes that occur in particle accelerators, test tubes, and biological cells before presenting the relevant theories, and sketch or demonstrate the experiments used to validate the theories.

- *To illustrate an abstract concept or problem-solving algorithm, use at least one numerical example* (sensing) *to supplement the usual algebraic example* (intuitive). For example, when presenting Euler's method for numerical integration, instead of simply giving the formulas for successive steps, use the algorithm to integrate a simple function like $y = x^2$ and work out the first few steps on the chalkboard with a hand calculator.

- *Use physical analogies and demonstrations to illustrate the magnitudes of calculated quantities* (sensing, global). For example, tell your students to think of 100 microns is about the thickness of a sheet of paper and to think of a mole as a very large dozen molecules. Have them pick up a 100 ml. bottle of water and a 100 ml. bottle of mercury before talking about density.

- *Occasionally give some experimental observations before presenting the general principle, and have the students (preferably working in groups) see how far they can get toward inferring the latter* (inductive). For example, rather than giving the students Ohm's or Kirchoff's Law up front and asking them to solve for an unknown, give them experimental voltage/current/resistance data for several circuits and let them try to figure out the laws for themselves.

- *Provide class time for students to think about the material being presented* (reflective) *and for active student participation* (active). Occasionally pause during a lecture to allow time for thinking and formulating questions. Assign "one-minute papers" near the end of a lecture period, having students write on index cards the lecture's most important point and the single most pressing unanswered question. Assign brief group problem-solving exercises in class that require students to work in groups of three or four.

- *Encourage or mandate cooperation on homework* (every style category). Hundreds of research studies show that students who participate in cooperative learning experiences tend to earn better grades, display more enthusiasm for their chosen field, and improve their chances for graduation in that field relative to their counterparts in more traditional competitive class settings.

- *Demonstrate the logical flow of individual course topics* (sequential), *but also point out connections between the current material and other relevant material in the* *same course, in other courses in the same discipline, in other disciplines, and in everyday experience* (global). For example, before discussing cell metabolism chemistry in detail, describe energy release by glucose oxidation and relate it to energy release by nuclear fission, electron orbit decay, waterfalls, and combustion in fireplaces, power plant boilers, and automobiles. Discuss where the energy comes from and where it goes in each of these processes and how cell metabolism differs. Then consider the photosynthetic origins of the energy stored in C-H bonds and the conditions under which the earth's supply of usable energy might run out.

CONCLUSION

A learning style model is useful if balancing instruction on each of the model dimensions meets the learning needs of essentially all students in a class. The four models I've discussed in this article satisfy this criterion. Which model educators choose is almost immaterial, since the instructional approaches that teach around the cycle for each of the models are essentially identical. Whether educators are designing a course or curriculum, writing a textbook, developing instructional software, forming cooperative learning teams, or helping students develop interpersonal, leadership, and communication skills, they will benefit from using any of these models as the basis of their efforts.

ADDITIONAL READING

For more information on each of the learning style models discussed in this article, check the following sources.

<u>Myers-Briggs Type Indicator</u>

G. Lawrence, *People Types and Tiger Stripes*, 3rd Edition. Gainesville, FL, Center for Applications of Psychological Type, 1994.

M.H. McCaulley, "The MBTI and Individual Pathways in Engineering Design." *Engr. Education*, *80*, 537-542 (1990).

M.H. McCaulley, G.P. Macdaid, and J.G. Granade. "ASEE-MBTI Engineering Consortium: Report of the First Five Years." Presented at the 1985 ASEE Annual Conference, June 1985.

<u>Kolb Learning Style Model</u>

D.A. Kolb, *Experiential Learning: Experience as the Source of Learning and Development*. Englewood Cliffs, NJ, Prentice-Hall, 1984.

B. McCarthy, *The 4MAT System: Teaching to Learning Styles with Right/Left Mode Techniques*. Barrington, IL, EXCEL, Inc., 1987.

J.E. Stice, "Using Kolb's Learning Cycle to Improve Student Learning." *Engr. Education, 77*, 291-296 (1987).

J.N. Harb, S.O. Durrant, and R.E. Terry. "Use of the Kolb Learning Cycle and the 4MAT System in Engineering Education." *J. Engr. Education, 82*(2), 70-77 (1993).

Herrmann Brain Dominance Model

N. Herrmann, *The Creative Brain.* Lake Lure, NC, Brain Books, 1990.

M. Lumsdaine and E. Lumsdaine. "Thinking Preferences of Engineering Students: Implications for Curriculum Restructuring." *J. Engr. Education, 84*(2), 193-204 (1995).

Felder-Silverman Learning Style Model

R.M. Felder and L.K. Silverman. "Learning Styles and Teaching Styles in Engineering Education." *Engr. Education, 78* (7), 674-681 (1988).

R.M. Felder, "Reaching the Second Tier: Learning and Teaching Styles in College Science Education," *J. Coll. Sci. Teaching, 23*(5), 286--290 (1993).