HOW STUDENTS LEARN, HOW TEACHERS TEACH, AND WHAT USUALLY GOES WRONG

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Dr. Felder joined the NC State University faculty in 1969. He is a co-author 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, and he has authored or co-authored over 200 papers on chemical process engineering and engineering education. He won the 1982 R.J. Reynolds Award for Excellence in Teaching, Research, and Extension, the 1989 Chemical Manufacturers Association National Catalyst Award, the 1997 University of North Carolina Board of Governors Award for Excellence in Teaching, the 1997 American Society for Engineering Education Chester F. Carlson Award for Innovation in Engineering Education, the American Institute of Chemical Engineers 2002 Warren K. Lewis Award for Contributions to Chemical Engineering Education, the 2003 ASEE Chemical Engineering Division Lifetime Achievement Award for Pedagogical Scholarship, and a number of national and regional awards for his publications on engineering education. In 1993 he was designated one of five Outstanding Engineering Educators of the Century by the Southeastern Section of the ASEE. At North Carolina State he has won the Sigma Xi faculty research award and has been designated a University Outstanding Teacher and Alumni Distinguished Professor.

For a bibliography of Professor Felder's papers and reprints of his columns and some articles, access his World Wide Web page at ***http://www.ncsu.edu/felder-public.***

Workshop Faculty Biographies

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Dr. Brent is an education consultant specializing in faculty development for effective university teaching, classroom and computer-based simulations in teacher education, K-12 staff development in language arts and classroom management, and evaluation of the use of technology in K-12 classrooms. She coordinates faculty development activities for the College of Engineering at North Carolina State University. From 1997-2003, she co-directed the SUCCEED Coalition faculty development program. Dr. Brent has published more than 75 articles on a variety of topics including uses of writing in undergraduate courses, collaborative learning, public school reform, technology in K-12 classrooms, and effective university teaching. She was an Assistant (1989-95) and Associate Professor (1995-96) in the School of Education at East Carolina University in Greenville, North Carolina. While at NCSU, she led COE-Teach, a learning community of engineering faculty, and at ECU she organized and directed *Teachers Learning Collaboratively*, a faculty group that studied effective teaching practices and promoted change and growth in university teaching. She received the 1994 East Carolina University Outstanding Teacher Award.

Drs. Felder and Brent have presented over 200 workshops on effective teaching, course design, mentoring and supporting new faculty members, and faculty development on campuses throughout the United States and abroad.

How Students Learn, How Teachers Teach, and What Usually Goes Wrong

Instruction begins when you, the teacher, learn from the learner. Put yourself in his place so that you may understand what he learns and the way he understands it. (Kierkegaard)

Fact of Life 1: What students learn is always less than what we teach.

Fact of Life 2: How much they learn is determined by their

1. Native ability
2. Background in the course topic
3. Match between their learning style and our teaching style.

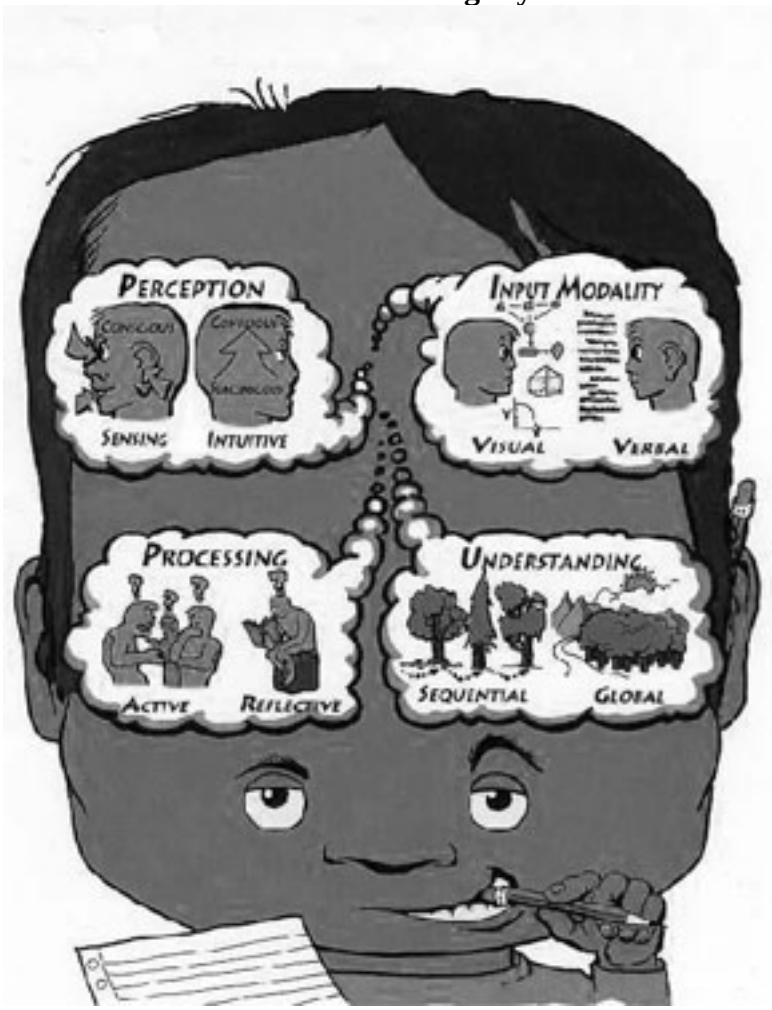
Fact of Life 3: We can't do much about their ability, background, or learning style.

Conclusion: *To maximize student learning, all we have to work with is our teaching style.*

Questions to be explored:

1. What are the different ways students take in information and process it? (*Learning styles*)
2. Which learning styles are favored by (i) most students, (ii) the teaching styles of most professors?
3. What are the consequences of mismatches between teaching and learning styles?
4. What can we do to reach students with the full spectrum of learning styles?

A Model of Learning Styles*



Sensing (S) Learners	Intuitive (N) Learners
• Focus on external input (see, hear, taste, touch, smell)	• Focus on internal input (thoughts, memories, images)
• Practical	• Imaginative
• Observant (notice details of environment)	• Look for meanings (miss details)
• Concrete thinking (facts, data, hands-on work)	• Abstract thinking (theories, math models)
• Learn through repetition (drills, numerous examples, replication of experiments)	• Like variety in learning experiences (bored with repetition)
• Methodical	• Quick
• Like working with details	• Like working with concepts
• Complaint about courses: No apparent connection to real world	• Complaint about courses: "Plug & Chug" (Lots of memorization, repetitive formula substitution)
• Problem with exams: Run out of time	• Problem with exams: Careless mistakes

* See papers accessible at R.M. Felder, "Learning Styles," <*www.ncsu.edu/felder-public/Learning_Styles.html*>.

- Everybody is both sensor and intuitor, but everyone has a preference that may be mild (close to balanced), moderate, or strong.
- Most undergraduates are sensors. Most professors are intuitors, and many professors who are sensing learners teach intuitively (emphasizing "fundamentals," theories, mathematical models). The result is a mismatch between the teaching style and the learning style of most students.
- The balance between S and N varies from one field to another, and an individual's preference in a situation varies from one situation to another. However,
- Both may make excellent professionals, in all professions.

Visual (Vs) Learners	Verbal (Vb) Learners
• "Show me." – pictures – diagrams – sketches – schematics – flow charts – plots	• "Explain it to me." – spoken words – written words, symbols (seen, but translated by brain into their oral equivalents)

- *Bias dominance.* Visual and verbal information are processed differently by the brain. You learn more when information is presented in your preferred modality (visual or verbal), even more if you get it in both channels.
- Most people are visual learners, while 90–95% of most course content is verbal (lectures, readings) except in art and architecture. Mismatch!

Active (A) Learners	Reflective (R) Learners
• Tend to process actively (doing something physical with presented material, then reflecting on it) • Think out loud • "Let's try it out and see how it goes." • Tend to jump in prematurely • Like group work	• Tend to process reflectively (thinking about presented material, then doing something with it) • Work introspectively • "Let's think it through and then try it." • Tend to delay starting • Like solo or pair work

- All classes have both active and reflective learners. Most classes (except for labs) are passive—the active learners don't get to act on the material presented and the reflective learners don't do much reflecting during the lectures. Mismatch!

Sequential (Sq) Learners	Global (G) Learners
• Build understanding in logical sequential steps	• Absorb information randomly, then synthesize the big picture
• Function with partial understanding of information	• Need the big picture (interrelations, connections to other subjects and personal experience) in order to function with information
• Make steady progress	• Large leaps in understanding with little progress between them
• Explain easily	• Can't explain easily
• Good at analytical thinking (the trees)	• Synthesis, holistic thinking (the forest)

- Most students, instructors, courses, curricula, and textbooks are sequential. Not strictly a mismatch. BUT
- The global minority is
  - extremely important (multidisciplinary thinkers, systems thinkers, top administrators)
  - at risk in school if their learning needs (help in seeing the big picture & the lateral connections to other subjects) are not met

Exercise: Who's Talking?

Identify the learning style dimension indicated by each student comment. Dimensions may be used more than once. Some statements may have more than one possible answer.

_____ 1. I don't see what this math garbage has to do with the real world.

_____ 2. I go crazy when I have to sit still through a class—I need to do stuff and talk about it to learn it.

_____ 3. I can't do the homework unless I see how it all fits together.

_____ 4. I hate all this plug and chug—it's boring!.

_____ 5. Lectures don't do a thing for me. You want me to understand something, show me a picture.

_____ 6. Even when I know how to do the problems, I always run out of time on tests.

_____ 7. Everyone around me can do the problems and I can't and I fail. Then I get it, but by then the teacher is on to something else. I can never win.

_____ 8. Don't just lay stuff on me—tell me why I should care about it.

Consequences of Learning and Teaching Style Mismatches

- Many students can't get what's being taught. They may then
  - — become bored, inattentive, or disruptive in class
  - — do poorly on tests
  - — get discouraged about the course, the curriculum, and/or themselves
  - — change to another curriculum or drop out of school

- Professors observe low test scores, unresponsive or hostile classes, poor attendance, dropouts—know something's wrong. They may
  - — get defensive or hostile (making things even worse)
  - — question whether they're in the right profession

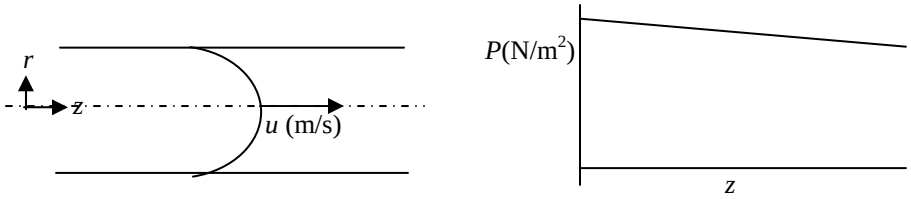
- Society loses potentially excellent professionals.
  - — visual, active learners (most students)
  - — sensing learners
  - — global learners

Example (Fluid Dynamics).

Derive the velocity profile and pressure drop of a newtonian fluid in a circular pipe. (Takes about two weeks at the beginning of the course.)

Plan 1. Conventional approach.

- Derive the differential mass and momentum balance equations for a fluid flowing in a pipe—coupled partial differential equations in cylindrical coordinates. [*Intuitive, verbal, sequential*]
- Express the shear stress in terms of velocity using Newton's law. [*Intuitive, verbal, sequential*]
- Solve the equations for velocity [$u(r)$] and pressure [$P(z)$] in the pipe. [*Intuitive, verbal, sequential*]
- Show plots of the solutions. [**Visual**, *sequential*]



- Homework: Have students calculate velocities, pressure drops, stresses at the pipe wall, and derive comparable formulas for a rectangular flow channel. [*Intuitive*, **active**, *reflective, sequential*]

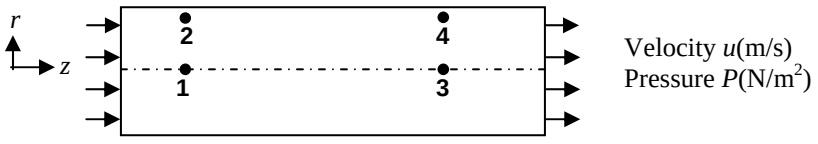
Two weeks have just gone by, in a manner that is almost entirely

1. *Intuitive:* Concepts, variables, formulas, words
2. *Verbal:* Spoken and written words, formulas (except for two plots)
3. *Passive:* The only meaningful student activity is homework
4. *Sequential:* Step-by-step, no effort to make the material relevant to other subjects and personal experiences.

The sensing, visual, active, and global learners might as well stay home and copy someone else's lecture notes for all they will get out of attending class during this two-week period.

Plan 2: Approach designed to address the full spectrum of learning styles

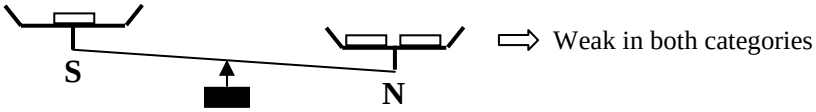
- If possible, show a video or animation demonstrating the phenomena to be studied (laminar flow of a newtonian fluid in a circular pipe). [*Sensing, visual*]
- Divide the class into groups of two and three at their seats. Sketch a horizontal pipe with a liquid flowing in it, and label four points—two on the axis, and two near the wall.



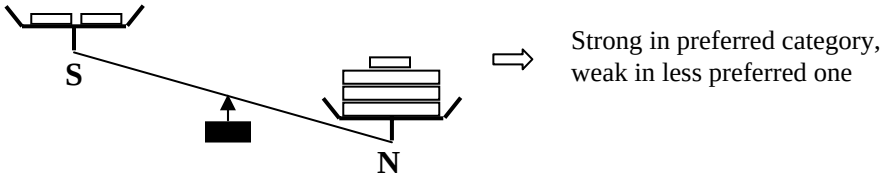
- Ask groups to speculate on differences between u and P at the four points. Allow about a minute, collect responses. Collectively infer that u should vary with r and P should vary with z. [*Sensing, Visual, Verbal, Active, Reflective*]
- Ask groups for everyday situations that involve fluid flow in channels. [*Sensing, intuitive, verbal, active,* **global**]
- Sketch and describe devices to measure $u(r)$ and $P(z)$. Sketch plots of u vs. r and P vs. z. [*Sensing, visual, verbal*]
- Reconsider the circular pipe. Write a force balance on a cylindrical fluid element, derive formulas for $u(r)$ and $P(z)$. Compare them with the results obtained experimentally.
- Exercise: Suppose $u(r)$ and $P(z)$ are measured & the results don't agree with the derived formulas. Ask groups to brainstorm possible explanations. (Mistakes in measurements, instrument error, mistakes in calculations, violation of assumptions in derivation,…) [*Sensing, intuitive, verbal, active, global*]
- Derive the differential balances that Plan 1 began with, solve them to confirm the results obtained with the force balances. [*Intuitive, verbal, sequential*]

Summary and Recommendations

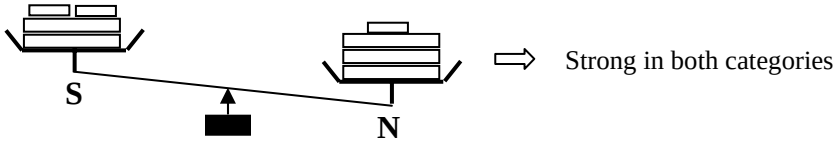
- Students may be sensors or intuitors, visual or verbal, active or reflective, sequential or global. *All types are needed in every profession.*
- Most teaching is abstract (intuitive), verbal, and sequential, and most classrooms are passive. *We need to address all 16* (2^4) *styles, not just one.* The key to doing that is *balance.*
- Professionals need to function sometimes as sensors (careful, methodical, practical, observant,…) and sometimes as intuitors (analytical, critical, creative); they need to receive and understand verbal information and visual information, etc.
- If students are taught only in their less preferred modes, they will be too uncomfortable to learn effectively and will not gain skills in either mode.



- If they are taught only in their preferred modes, they will gain skills in those modes but will not develop equally important skills in their less preferred modes.



- <u>Solution</u>: Teach to both sides of each dimension.



Recommendations

- Establish relevance and provide applications for all course material. Before presenting theoretical material, provide graphic examples of the phenomena that the theory describes or predicts. *(sensing, global)*
- Balance concrete information (facts, observations, data) *(sensing)* and abstract information (principles, theories, models) *(intuitive)* in all courses.
- Integrate labs and lectures to the greatest extent possible. *(sensing, intuitive)*
- Make extensive use of pictures, schematics, graphs, and simple sketches before, during, and after presenting verbal material. *(sensing, visual)*
- Use multimedia presentations. *(sensing, visual)* Provide demonstrations *(sensing, visual)*, hands-on if possible.
- Use some numbers in illustrative examples, not just algebraic variables. *(sensing)*
- Give students time to think about what they have been told. Assign "minute papers" (Write the main point of this lecture and the muddiest point) or learning logs. *(reflective)*
- **Give small-group exercises in class** ("active learning")**.** *(active, reflective)*
- Use computer-assisted instruction if you have software that allows for experimentation and provides feedback. *(sensing, active)*
- Assign some drill exercises in homework *(sensing, active)* but don't overdo it *(intuitive, reflective).*
- Assign some open-ended problems and exercises that call for creative thinking and critical judgment. *(all styles)*
- **Have students cooperate on homework** using techniques that promote positive interdependence, individual accountability, face-to-face interaction, interpersonal skills, and self-assessment of team functioning ("cooperative learning")**.** *(all styles)* This one is not trivial—find out about cooperative learning methods before trying it.
- Recognize and encourage creative solutions. *(all styles)*
- **Tell students about their learning styles or let them assess their own style.** Click on the *Index of Learning Styles* at ***http://www.ncsu.edu/felder-public.***
- **Try a few of these suggestions at a time.** If an idea doesn't work, go back to the notebook and see if you're forgetting something. Adopt the ideas that work and drop the others. Then try a few more.

To find out more about learning styles, go to Richard Felder's Web page at ***http://www.ncsu.edu/felder-public*** and click on the link to *Learning Styles.*