...Speed Networking...

You have:

• 1 MINUTE each to explain what you will be teaching at St. Olaf and your research area
• 2 MINUTES to ask questions/talk. Try to find an area where your professional lives at St. Olaf might intersect
• Then move one chair clockwise and start again...
How Learning Works: Seven Research-Based Principles

Gary Muir, CILA

Dr. Michele DiPietro
Executive Director,
Center for Excellence in Teaching and Learning
Kennesaw State University

mdipietr@kennesaw.edu
http://www.kennesaw.edu/cetl
Quick Problem to Solve

There are 26 sheep and 10 goats on a ship. How old is the captain?

Adults: Unsolvable
5th graders: Over 75% attempted to provide a numerical answer.

After giving the answer “36” one student explained “Well, you need to add or subtract or multiply in problems like this, and this one seemed to work best if I add.”

(Bransford & Stein, ’93)
The Moral:

We must really understand how students process what we teach them!!
How Learning Works: Seven Research-Based Principles

Synthesis of 50 years of research

• Constant determinants of learning
• Principles apply cross-culturally
  – Translations to Mandarin, Korean and (forthcoming) Japanese
Objectives

Following this workshop, you should be better able to consider pedagogical strategies to support learning based on the seven principles.
What is Learning?

One definition:

“Learning is a *process* that leads to change, which occurs as a result of experience and increases the potential for improved performance and future learning.”
7 Learning Principles

1. Students’ **prior knowledge** can help or hinder learning.
2. How students **organize knowledge** influences how they learn and apply what they know.
3. Students’ **motivation** determines, directs, and sustains what they do to learn.
4. To develop **mastery**, students must acquire component skills, practice integrating them, and know when to apply what they have learned.
5. Goal-directed **practice** coupled with targeted **feedback** enhances the quality of students’ learning.
6. Students’ current level of **development** interacts with the social, emotional, and intellectual **climate** of the course to impact learning.
7. To become **self-directed** learners, students must learn to monitor and adjust their approaches to learning.
“I consider that a man's brain originally is like a little empty attic, and you have to stock it with such furniture as you choose.” (Sherlock Holmes, A Study in Scarlet)
1. Prior Knowledge can help or hinder learning

HELPs Learning

Prior Knowledge

When Activated Sufficient Appropriate and Accurate

When Inactive Insufficient Inappropriate or Inaccurate

HINDERS Learning
Prior knowledge can hinder learning

If it is:

• Inappropriate
• Insufficient
• Inaccurate
Some examples of inaccurate prior knowledge (*misconceptions*)

When the switch $S$ is closed, do the following increase, decrease, or stay the same?

- a) The intensity of A & B
- b) The intensity of C
- c) The current drawn from the battery
- d) The voltage drop across each bulb
- e) The power dissipated in the circuit

Bricks A & B are identical. The force needed to hold B in place (deeper than A) is

- a) Larger than
- b) The same as
- c) Smaller than
- d) the force required to hold A in place

Mazur (1996)
What are some misconceptions students have in *your* field?
Some other misconceptions....

**Science:** Seasons happen because the earth orbits the sun elliptically (Schneps and Sadler, 1988)

**Statistics:** Association implies causation

**Psychology/Neuroscience:** People use only 10% of their brains
But even if prior knowledge is correct…

- Each card has a letter on one side and a number on the other.
- Rule: If a card has a vowel on one side, it must have an even number on the other side.
- Questions: What is the minimum number of cards that must be turned over to check whether this rule is being followed? Which cards are they? (Wason 1966, 1977)
Each card represents a student at a bar. The age of each student is on one side and what she is drinking is on the other.

- Rule: If a person is drinking a beer, then she is over 21
- Question: Which card(s) must be turned over to check whether everyone’s behavior is legal? (Griggs & Cox, 1982)
The moral

• Prior knowledge lies *inert* most of the time
• Prior knowledge must be *activated* to be useful
What we owe our students

Learning environments that:

• Value and engage what students bring to the table

• Actively confront and challenge misconceptions
2. How students organize knowledge influences how they learn and apply what they know.
How is information processed?

(Atkinson and Shiffrin 1968; Baddeley, 1986)
Memorize the following list:

TSXCOBCAFTNB

Try again:

FOXABCTNTCBS
A Statistics Example

Memorize the following formula:

\[ f(x) = \frac{1}{\sqrt{2\pi \cdot 5}} e^{-\frac{1}{2} \left(\frac{(x-10)^2}{5}\right)} \]
A Chemistry Example

Memorize the following formula:

\[
\begin{align*}
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} \quad \text{C} \quad \text{O} \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H}
\end{align*}
\]
Knowledge Organization

We all “chunk” knowledge and organize it by connecting new information to existing knowledge.

The same knowledge can be organized in multiple ways.

Experts have mental structures very different from novices/students.
How Novices & Experts Differ
(Chi, Feltovich & Glaser, 1981)

Novices’ Groupings

Novice 1: “These deal with blocks on an inclined plane”
Novice 6: “Blocks on inclined planes with angles”

Experts’ Groupings

Expert 2: “Conservation of Energy”
Expert 4: “These can be done from Energy considerations”
How Novices & Experts Differ

- Experts have a higher density of connections
- Experts’ structures rely on deep underlying principles
- Experts have more flexible structures

These features affect memory, meaning-making, and transfer.
An Example…

If the balloons popped, the sound wouldn't be able to carry since everything would be too far away from the correct floor. A closed window would also prevent the sound from carrying, since most buildings tend to be well insulated. Since the whole operation depends on a steady flow of electricity, a break in the middle of the wire would also cause problems. Of course, the fellow could shout, but the human voice is not loud enough to carry that far. An additional problem is that a string could break on the instrument. Then there could be no accompaniment to the message. It is clear that the best situation would involve less distance. Then there would be fewer potential problems. With face to face contact, the least number of things could go wrong. (p. 719)

Bransford & Johnson, 1972
Try now 😊

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Bransford & Johnson, 1972
What we owe our students

Learning environments that not only transmit knowledge, but

• Help students organize their knowledge in productive ways

• Actively monitor students’ construction and transfer of knowledge
3. Students’ motivation determines, directs, and sustains what they do to learn.
Goals/Value

• If students cannot find any value in what we are offering them, they won’t find motivation to do it
• Students value multiple goals
• Some goals are in competition
What do students value in your field?
Goals/Value

- Rewards & Punishments
- Learning
- Competence
- Performance approach/avoid
- Social
- Affective
- Purpose/Integrity/Authenticity
Expectancy: expectation of a successful outcome

Three main components of this positive expectation:

1. **Outcome expectancy**: beliefs that certain behaviors are causally connected to desired outcomes

2. **Efficacy expectancy**: that one has the ability to do the work necessary to succeed (*self-efficacy*)
   e.g., You “have it” or you don’t vs. the mind is like a muscle; I’m no good at math vs. I lack experience in math

3. **Environmental expectancy**: that the environment will be supportive of one’s efforts.
   e.g., Perceptions of: Instructor’s fairness; Feasibility of the task; Instructor’s approachability/helpfulness; Team members’ ability and effort
Effects of Value, Self-efficacy, & Environment on Motivation

The Environment is **NOT SUPPORTIVE**

- **DON’T SEE Value**
  - Rejecting
  - Evading

- **SEE Value**
  - Hopeless
  - Defiant

The Environment is **SUPPORTIVE**

- **DON’T SEE Value**
  - Rejecting
  - Evading

- **SEE Value**
  - Fragile
  - Motivated

Student's efficacy is...

**LOW**

**HIGH**
What we owe our students

Learning environments that:

• Stay up-to-date with what students value
• Engage multiple goals
• Build self-efficacy
• Are responsive and helpful
The next two principles pertain to learning skills
4. To develop *mastery*, students must acquire component skills, practice integrating them, and know when to apply what they have learned.

**Mastery**

- Acquire Component Skills
- Practice Integrating Skills
- Know When to Apply Skills
5. Goal-directed *practice* coupled with targeted *feedback* enhances the quality of students’ learning.
“It’s not teaching that causes learning. Attempts by the learner to perform cause learning, dependent upon the quality of feedback and opportunities to use it.” -- Grant Wiggins

<table>
<thead>
<tr>
<th>Goals</th>
<th>Practice</th>
<th>Feedback</th>
</tr>
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<tbody>
<tr>
<td>• Explicit</td>
<td>• Scaffolded</td>
<td>• Frequent</td>
</tr>
<tr>
<td>• Before the performance</td>
<td>• Zone of Proximal Development (Vygotsky 1978)</td>
<td>• Timely</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Constructive</td>
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</table>
An important caveat

The Stroop Effect (1935)

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<thead>
<tr>
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</tr>
</thead>
<tbody>
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<td>BLUE</td>
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</tbody>
</table>
An Example – Learning to Drive

Initially
- students rely on very general rules and problem-solving skills, e.g. following a step-by-step example, matching variables in equations
- working memory load is very high
- performance is very slow, tedious and error-prone

With some practice:
- very general rules are instantiated with discipline-specific details to make new, more efficient productions
- performance becomes faster
- many errors are detected and eliminated with feedback

With a great deal of practice:
- related steps are compiled and “automatized” by collapsing steps
- less attention is needed to perform
- performance continues to speed up
- experts may lose the ability to verbalize all steps
The Expert Blindspot

Movement to Mastery

Sprague and Stuart (2000)
Where are your expert blindspots?
What we owe our students

Learning environments where educators
• Actively hunt down their expert blindspots

Learning environments that:
• Emphasize both individual skills and their integration
• Explicitly teach for transfer
• Provide multiple opportunities for authentic practice
  • Oriented toward clear goals
  • Coupled with targeted feedback
6. Students’ current level of development interacts with the social, emotional, and intellectual climate of the course to impact learning.
Developmental Theories

• Describe how our views of certain concepts (e.g., knowledge, morality, culture, identity) evolve over time from unsophisticated positions to ones that embrace complexity.
• Development is described as a response to intellectual, social, or emotional challenges, where students begin to question values and assumptions inculcated by parents and society, and start to develop their own.
• Development can be described in stages.
• It describes students in the aggregate, not individually.
• Development is not always forward.
Intellectual Development

I. **Dualism/Received/Absolute Knowledge**

- Knowledge: viewed as received Truth
- What matters: facts—things are right or wrong
- Teacher: has the answers
- Learning: Memorizing notes for tests, getting the A is what counts

**Frustration:** Why won’t the teacher answer my questions?
Intellectual Development

II. Transitional Knowledge

- Knowledge: partially certain, partially uncertain
- What matters: facts—things are right or wrong
- Teacher: has the answers
- Learning: Memorizing notes for tests, getting the A is what counts

Frustration: Why won’t the teacher answer my questions?
Intellectual Development

III. Multiplicity/Subjective/Independent Knowledge

- Knowledge: a matter of opinion
- Teacher: not the authority—just another opinion
- Learning: a purely personal exercise

Frustration: How can the teacher evaluate my work?
Intellectual Development

IV. Relativism/Procedural/Contextual Knowledge

- Knowledge: based on evidence
- What matters: supporting your argument with reasons
- Teacher: Conversation partner, acts as a guide, shows the direction
- Learning: depends on the context—what we “know” is colored by perspectives and assumptions

Questions asked: What are more sources of information?
Intellectual Development by Year

Baxter-Magolda (1992)
Classroom Climate

Students work out these developmental challenges in the context of the classroom environment.

Perceptions of a “chilly” climate affect student learning, critical thinking, and preparation for a career (Pascarella et al. 1997; Whitt et al 1999).

Climate is best understood as a continuum:

Explicitly Marginalizing  Implicitly Marginalizing  Implicitly Centralizing  Explicitly Centralizing

DeSurra & Church (1994)
What factors contribute to climate?

- Content
- Interactions
  - Faculty-student and student-student
    e.g., stereotype threat
- Tone
  - Syllabus study—punishing vs. encouraging (Ishiyama and Hartlaub 2002)
    - Punishing: “If for some substantial reason you cannot turn in your papers or take an exam at the scheduled time you must contact me prior to the due date, or test date, or you will be graded down 20%”
    - Rewarding: “If for some substantial reason you cannot turn in your papers or take an exam at the scheduled time you should contact me prior to the due date, or test date, or you will only be eligible for 80% of the total points.”
Results

• Significant difference in perceived approachability (p=.04)
  ✓ Instructor with punishing wording rated as less approachable
  ✓ Students less likely to seek help from the punishing instructor
  ✓ First & second year students most affected by wording
What we owe our students

Learning environments that:

• Use the tools of the disciplines to engage and embrace complexity

• Are explicitly inclusive in methods and content
7. To become *self-directed learners*, students must learn to monitor and adjust their approaches to learning.
Metacognition: Definitions

“Metacognition refers to one’s knowledge concerning one’s own cognitive processes or anything related to them, e.g., the learning-relevant properties of information or data. For example, I am engaging in metacognition if I notice that I am having more trouble learning A than B; if it strikes me that I should double check C before accepting it as fact.”—J. H. Flavell (1976, p. 232).

“The process of reflecting and directing one’s own thinking.”—National Research Council (2001, p. 78).
Evidence from research on metacognition

Students don’t!
(NRC 2001; Fu & Gray 2004)

Students overestimate their strengths
(Dunning 2007)

Self-explanation effect
But students don’t do it!
(Chi et al. 1989)

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Research on beliefs about learning

- Quick  Gradual
- Intelligence as Entity Intelligence Incremental

Beliefs about learning influence effort, persistence, learning and performance (Schommer, 1994; Henderson & Dweck, 1990)
Metacognition can be taught

- Early research found it was EXTREMELY hard
- More recent research is a little more optimistic

In particular:
- Students can be taught to monitor their strategies, with greater learning gains as a result (Bielaczyc et al., 1995; Chi et al., 1994; Palinscar & Brown, 1984)
- Students can be taught more productive beliefs about learning and the brain (Aronson et al., 2002)
What we owe our students

Learning environments that foster:
• metacognitive awareness
• a lifelong learning disposition
Teaching strategies

2 in particular:
• Guided self-assessment (Appendix A):
• Exam Wrappers (Appendix F):
  http://www.cmu.edu/teaching/design/teach/examwrappers/

Two über-strategies:
• Modeling Your Metacognitive Processes
• Scaffold Students’ Metacognitive Processes
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References


National Research Council (2001) *Knowing what students know: The science and design of educational assessment*. National Academy


