Strategies to Enhance Student Learning and Motivation based on Principles of Cognitive Science

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Goals of Cognitive Science

• Understand the mind

• Develop theories that explain and predict human thought and behavior

• My group’s research aim is to understand basic cognitive mechanisms of learning, motivation, and transfer

• Develop and test applications of these theories for instruction
Knowledge-Learning-Instruction (KLI) Framework

Instructional events
- Text, practice, writing, discussion

Assessment events
- Informal: Feedback, questions
- Formal: Exam, survey

Learning events
- Acquisition: e.g., induction, sense-making
- Application and adaptation

Knowledge Components
- Representation: e.g., concepts, skills

Koedinger, Corbett, & Perfetti, 2012
Motivation additions to Knowledge-Learning-Instruction

Instructional events
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Assessment events
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Learning events

Knowledge Components

Motivation Beliefs and Goals

Domain-level

KEY
- Ovals – observable
- Rectangles - inferred
- Arrows – causal links
Starting Questions

- What is a problem of practice that you are working on in your teaching?
- What do you hope to gain from today’s workshop?
- First write out answers on your worksheets then discuss with people at your table
- Someone from the group reports out to the larger group
Outline

- **Problem**: training students to become more like experts
- Three interrelated theories of student motivation
  - expectancy-values, interest, and achievement goals
- Learning challenges and solutions based on cognitive science
  - Basic memory effects
  - Practice testing and spaced practice
  - Explanation and analogical comparison
- Conclusions and questions
Problem

- How can we facilitate students’ learning?
- We want students to develop the understanding and problem solving approaches of experts

**Students**
- Perceive surface features
- Rely heavily on examples
- Little transfer

**Experts**
- Perceive deep structure
- Forward-working strategies
- Transfer to new contexts

Nokes, Schunn, & Chi, 2010
Problem

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*Nokes, Schunn, & Chi, 2010*
Experts  

Schwartz, Bransford, & Sears, 2005

- Adaptable and efficient
- Adaptable, but not efficient
- Efficient, but not adaptable
- Neither efficient nor adaptable

Problem solving skills

Motivation

Understanding

Innovation

Efficiency
Student Motivation

- Expectancy-value
- Interest
- Achievement goals
Expectancy-value

Eccles & Wigfield, 2002

- Choice of a challenging task
- Expectancies of success (self-beliefs)
- Value of the task
  - Intrinsic, attainment, utility, and cost
Interest

• Consists of both cognitive and affective components (Hidi & Harackiewicz, 2000; Renninger, 2000)

• Most theories hypothesize two types: situational and individual

• Four phase model (Hidi & Renninger, 2006)
  1. Triggered situational interest
  2. Maintained situation interest
  3. Emerging individual interest
  4. Well-developed individual interest
Achievement Goals

**Mastery**

**Approach**

*My goal is to learn as much as possible.*

**Avoidance**

*My aim is to avoid learning less than I possibly could.*

**Performance**

*My goal is to perform better than the other students.*

*My goal is to avoid performing poorly compared to others.*

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Self-report AGQ-R questionnaire: Elliot & Murayama, 2008
Writing interventions

- Brief writing tasks have been shown to improve interest and achievement

- Utility-value intervention (Hulleman & Harackiewicz, 2009)
  - Encouraged students to make connections between their lives and what they were learning in their science courses
Writing interventions

*Harackiewicz et al., 2016*

- Utility Value intervention in a college Biology course
  Can it help close achievement gaps?

**Utility Value**

Write an essay addressing this question and discuss the relevance of the concept or issue to your own life. Be sure to include some concrete information that was covered in this unit, *explaining why this specific information is relevant to your life or useful for you.* Be sure to explain how the information applies to you personally and give examples.

**Control**

Select the relevant information from class notes and the textbook, and write a one to two page response to your question. You should attempt to organize the material in a meaningful way, rather than simply listing the main facts or research findings. Remember to summarize the material in your own words.
Writing interventions

Harackiewicz et al., 2016

• Utility Value intervention in a college Biology course
  Can it help close achievement gaps?
Writing interventions

- Mastery goals and interest intervention (Bernacki et al., 2016)

**Motivation Prompts**

Take some time to think about how well you understood today’s lesson. In the box below, name one part of it you feel like you understood very well. How do you know that you understand it? Explain.

Name one concept or idea you learned today that you found interesting and explain why it was interesting.

**Summary**

Describe one thing you learned in today’s lesson. Give as many details as you can.
Procedure and design

Goal
Survey

Interest
Survey

Summary prompts
M=10.67; SE=.65

10 minutes each

Motivation prompts
M=9.92; SE=.58

pretest
3rd quarter

intervention, approx. 1 a week

posttest
end of 4th quarter

Bernacki et al., 2016
Results - Goals

Adjusted Posttest Scores

KEY: Summary  Motivation

Bernacki et al., 2016
Results - Interest

Adjusted Posttest Scores

KEY: Summary  Motivation

Situational Interest  Individual Interest

d=.59

Bernacki et al., 2016
Promoting Mastery Goals

Adapted from Figure 1: Ames, C. (1992). Classrooms: Goals, structures, and student motivation. *Journal of Educational Psychology, 84 (3), 261-271.*

**Structure**
- **Task**
  - Focus on meaningful aspects of learning
  - Design for novelty and student interest
  - Design tasks that offer reasonable challenge
  - Establish short-term, self-referenced goals
  - Support the use of effective learning strategies

- **Authority**
  - Help students participate in decision making
  - Provide choices where decisions are based on effort not ability
  - Provide opportunities to develop responsibility and independence
  - Support self-management and monitoring skills

- **Evaluation/Recognition**
  - Focus on individual improvement, progress, and mastery
  - Make evaluation private, not public
  - Recognize students’ effort
  - Provide opportunities for improvement
  - Encourage view of mistakes as a part of learning

**Instructional Strategies**
- **Task**
  - Focus on meaningful aspects of learning
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**Motivation Patterns**
- **Task**
  - Focus on effort and learning
  - High intrinsic interest
  - Attributions to effort
  - Use of effective learning and other self-regulatory strategies
  - Active engagement
  - Positive affect
  - Feelings of belongingness
  - “Failure tolerance”
Motivation Reflections

• Have you used these or other ways to support task value, interest, and mastery approach goals? Describe them.

• What opportunities are there to support student motivation in your teaching?
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Challenges for STEM Learning

Mestre et al., 2009

• Problem: Conceptual understanding AND problem solving skills
• Cognitive research: *Specialized systems*
  • declarative and procedural memory
• **Implication:** Practice assessing and applying conceptual knowledge
• Problem: Reliance on surface features
• Cognitive research: *Specificity of Knowledge*
• **Implication:** Unpack how principles are applied in example; give more than one example, support analogy and explanation
Basic memory effects

- Three demonstrations to show effects of cognitive processing and prior knowledge on memory
- Hope is to illustrate some basic concepts upon which the later strategies build
- These focus on two aspects: elaboration and prior knowledge (schemas)
You will memorize a list of words

First, I am going to give half the class one set of directions and the other half another

Split class (left and right sides)

LEFT look first, RIGHT close your eyes
Instructions:

• Rehearse the list over to yourself again and again. Simply rehearse, silently.

• For example, if the list was apple, car, table you would say the list repeatedly to yourself silently.

apple, car, table,   apple, car, table,    apple, car, table, etc...
• Left close your eyes

• Right open
• Instructions:
  
  • Relate the words to yourself, your likes and dislikes. Think of a personal example for each.
  
  • For example if the list was apple, car, table then you might think that you like apple pie, you own a Chevrolet car, and you like antique tables, etc.
boat
coffee
paper
soccer
friends
hat
robin
glasses
book
pizza
shoes
phone
chocolate
bus
dog
Encoding: elaboration

- In short-term memory, elaborative rehearsal leads to better later memory recall
- “Elaborate” - explain and connect to prior knowledge
- Many types of elaboration - making a story, imaging together, relating to self, explanation …
Demo 1

- I am going to show everyone a picture to remember, it will appear very briefly.

- But first, I am going to show the RIGHT a caption.

- LEFT close your eyes, RIGHT keep them open.
• A little boy playing a trombone in a phone booth
Now draw an image of your office

Now draw the picture
• I am going to show everyone another picture to remember, it will appear very briefly

• But first, I am going to show the LEFT a caption

• RIGHT close your eyes, LEFT keep them open
The early bird gets the worm
Now draw an image of your friend

Now draw the picture
Results

• Which picture did you remember better?
• How many remembered the first picture better?
• How many remembered the second picture better?
Encoding: elaboration

• Droodles with or without explanation  
  (Bower, Karlin, & Duek, 1975)

• After looking at a set of them, draw  
  - Without explanation 51%  
  - With explanation 70%

• Why?  
  - Provides a way of connecting information into a coherent whole based on prior knowledge
Demo 2

Recall the words

- Remember the words from demo 1
Check your accuracy

boat
coffee
paper
soccer
friends

hat
robin
glasses
book
pizza

shoes
phone
chocolate
bus
dog
Results

• Raise your hand if you remembered 1 word, 2 words ...
• LEFT simply rehearsed the list
• RIGHT related to personal likes and dislikes
• Judgments about self lead to better recall than other common tasks.

• Particularly good type of elaboration because we know a lot about ourselves.

Elaboration

• Easier to remember by relating it to what we know

• Helps to augment and interpret the information we have

• Helps to build a coherent representation using information from memory

• One type of deeper, constructive processing
Demo 3

based on Bransford & Johnson, 1972

- RIGHT close your eyes, LEFT keep them open
LEFT

washing laundry
The procedure is actually quite simple. First you arrange items into different groups. Of course one pile may be sufficient depending on how much there is to do. If you have go somewhere else due to lack of facilities that is the next step; it is better to do too few things at once than too many. In the short run this may not seem important but complications can easily arise. A mistake can be expensive as well.
At first, the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to foresee any end to the necessity for this task in the immediate future, but then, one can never tell. After the procedure is completed one arranges the materials into different groups again. Then they can be put into their appropriate places. Eventually they will be used once more and the whole cycle will have to be repeated. However, this is part of life.
Analyzing the results

- Write down everything you remember about the paragraph
- Count how many words
- Write down the topic of what the paragraph was about
- Raise your hand if you remembered 20 words, 30, 40 ....
Typical results

Number of Words

No topic

Topic
Schemas

• Definition:
  - An active organization of past experiences and knowledge (what typically happens)
  - Lists what parts to expect, lists default values (steps in washing clothes)

• Schemas effect:
  - Our comprehension of new events
  - How we encode events
  - How we retrieve information later
Memory summary

- **Elaboration** can help memory encoding
- Provides connections to what one already knows, creating a coherent, organized representation
- Deeper constructive processing: self-explanation and analogical comparison
- **Schemas** are powerful for memory
  Can help encoding, understanding, and retrieval of information
- Hypothesized knowledge organization and representation of experts
Experts

Schwartz, Bransford, & Sears, 2005

Schemas

Adaptable and efficient

Problem solving skills
• Practice test

• What is elaboration? Give an example.

• What is a schema? Why is it helpful for learning?
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Practice testing

- Testing that is completed as a formative assessment
- Many studies have shown that it improves learning and retention compared to restudy
- Why?
  - Direct effects: generative versus passive; elaborative retrieval processes (activates related info)
  - Indirect effects: figure out what one does not know; opportunity for future study, elaborative encoding processes
Learning facts and concepts

Butler, 2010
Classroom results

Spaced practice

• Spacing practice is better than massed practice for long-term retention

• Why?
  • Deficient processing, studying so close together leads to shallow studying the second and third time around
  • Spacing practice leads to reminding of the earlier instances which improves learning (practice testing)
  • Consolidation
Example experiment

Bahrick, 1979
Classroom results

Bude, Imbos, vn de Weil, & Berger, 2011
Knowledge-Learning-Instruction (KLI) Framework

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Retrieval & Spaced Practice

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Koedinger, Corbett, & Perfetti, 2012

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Self-Explanation

- Explanation of worked examples or expository text (Chiu & Chi, 2014; Fonseca & Chi, 2011)

- Why?
  - Generating inferences from prior knowledge (Chi, 2000)
  - Helps to repair mental models (Chi, 2000)
  - Explanation helps identify sub-goals (Catrambone, 1996)

- Laboratory evidence across a number of domains: physics, biology, mathematics, electronics
Berry, 1983
Analogies can facilitate learning and problem solving (Gentner, Holyoak, & Kokinov, 2001)

Why?

- Facilitates abstraction, acquisition of a problem schema, and a focus on the underlying concept (e.g., Gick & Holyoak, 1983; Nokes-Malach at el al., 2013)

What is similar across the problems?
Demo 5

- Q1. What is a schema?
- Q2. Why is it helpful for learning?
- Q3. Compare the testing effect to spaced practice.

What is similar what is different?
Conclusions

• Helping novices to become more like experts
• Three interrelated theories of student motivation
  • Expectancy-values, interest, and achievement goals
• Writing intervention to improve - interest and achievement
• Instructional features to highlight class mastery goals
• Can provide the motivational fuel for constructive cognitive processing
Conclusions

- Memory effects:
  elaboration (process) and schemas (representation)

- Five learning strategies:
  1.) Relating new info to prior knowledge (e.g., self, domain)
      Reading book in advance helps learn from lecture
  2.) Practice testing
  3.) Spaced practice
  4.) Self-explanation
  5.) Analogical comparison

- Implementing these learning strategies in instruction promotes conceptual learning and transfer

- Helps to build a bridge to adaptive expertise
More reading


Questions?