Tell me and I forget. Teach me and I remember. Involve me and I learn.

-Chinese Proverb as quoted by Benjamin Franklin
JUST-IN-TIME TEACHING, WORKED EXAMPLES AND FLIPPED LEARNING
Gregor Novak - USAFA and IUPUI
EDUCATION RESEARCH

• Cognitive Science
• Educational Psychology
• Discipline - Specific Issues
• SoTL
Interactive Engagement - Active Learning
Passive vs Active
An Experiment at UBC

Experienced, award-winning, charismatic lecturer
vs
Two trained inexperienced instructors with research-based highly structured lessons

pre-class reading  pre-class reading quiz

in-class clicker questions with student-student discussion SSD

small group active learning task ALT

targeted instructor feedback TIF

SSD1 2 min  TIF 4 min
SSD2 2 min  TIF 4 min  SSD2 (cont) 3 min  TIF 5 min  SSD2 (revote) 1 min
SSD3 3 min  TIF 6 min
ALT 6 min  TIF (demo) 6 min  ALT (cont) 4 min  TIF 3 min
Research Suggested Teaching Strategies

• Student-perceived relevance of the subject matter

• Clear expectations, practice, and feedback

• Appropriate tests

• Reasonable workload

• Choice over learning tasks
JUST-IN-TIME TEACHING, WORKED EXAMPLES AND FLIPPED LEARNING
Gregor Novak - USAFA and IUPUI

2009

Worked Examples
Online Preclass Assignements
Flipped Learning
JUST-IN-TIME TEACHING, WORKED EXAMPLES AND FLIPPED LEARNING
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From Novice To Expert

Decoding the Disciplines: Helping Students Learn Disciplinary Ways of Thinking
David Pace
Joan Middendorf
EDITORS

Number 98 • Summer 2004

Joan Middendorf - David Pace

IVY TECH, INDIANAPOLIS, MAY 14, 2016
http://jittdl.physics.iupui.edu/WE2016_WORKSHOP/
Research Suggested Student Activities

Predicting outcomes

Interpreting and modeling physical phenomena

Generating ideas and brainstorming

Identifying problems and troubleshooting

Formulating procedures for solving complex problems

Formulating problems

Making judgments and decisions and justifying them
The "Ersatz Learning vs Genuine Learning" Challenge

- Students are motivated by the desire to survive rather than excel.
- If the course structure permits, it is more effective to cope than to learn.
- Students can study and pass without learning.
- Knowledge does not transfer.

**Authentic Testing vs. Inauthentic Testing**

An authentic test requires that the student performs some real task, similar to what that practitioners in the discipline perform.
Arteries
a. Are more elastic than veins
b. Carry blood that is pumped from the heart
c. Are less elastic than veins
d. Both a and b
e. Both b and c

VS

Imagine being asked to design an artificial artery--would it have to be elastic? Why or why not?
Research-Based Pedagogies

Inductive vs Deductive
• Students grapple with content before instruction
• Pre-class work
• Student-response-based lessons

Active Learning
• Students actively participate in class

Collaborative Learning
• Students work in teams
Inductive Pedagogies

Just-in-Time Teaching - JiTT
Students do lesson preparatory work that becomes the basis for in-class activity. There is a lot of flexibility in how the JiTT assignments are constructed. There are, however, two critical JiTT requirements:
1. There must be a carefully constructed assignment for students to complete before every lesson.
2. Student work must have a prominent role in the lesson activities.

Inquiry-based
Students are presented with a challenge – a question, an observation, a data set, a hypothesis to be tested. They accomplish the learning by responding to the challenge.

Problem-based (PBL)
Students, working in teams, are presented with an ill-structured open-ended real-world problem to solve. They formulate and evaluate alternative solutions, select the best one and make a case for it. Instructor acts as a guide.

Project-based
Students work an assignment to produce a product; a process or product design, a computer code or simulation. The outcome is a report.

Case-based
Students study historical or hypothetical cases involving scenarios likely to be encountered in professional practice.

Discovery
Students are confronted with a challenge and left to work out the solution on their own. The instructor provides feedback but little or no direction.
A variant is guided discovery.
Peer Instruction and Group Learning

Cooperative Learning
Students work in teams on structured assignments

Process Oriented Guided Inquiry Learning (POGIL)
A research based learning environment where students are actively engaged in mastering course content and in developing essential skills by working in self-managed teams on guided inquiry activities.

Studio Approach
Student work at workstations, supervised by graduate students. There may be an occasional lecture. This is similar to Cockpit Physics that we tried at USAFA in 1995.

Peer Led Instruction (pioneered at Dickenson as Workshop Physics, not to be confused with Peer Instruction)
Students work in small groups on very structured assignments. The groups are led by specially trained undergraduates from previous semester classes.

Peer Instruction (pioneered at Harvard by Eric Mazur)
Students vote on answers to a question, discuss in small groups and re-vote. Can get very sophisticated with clicker software and clever questions.

Tutorials (pioneered at University of Washington)
Groups of students, led by a trained graduate students, interact in Socratic dialogues. Can be watered down to group worksheet work with little or no supervision.
Cooperative Learning

TEAM WORK UNDER CONDITIONS THAT MEET THE FOLLOWING CRITERIA:

Positive interdependence. The team members must rely on one another to accomplish the goal.

Individual accountability. Each team member is held accountable for doing his or her share of the work and for all of the material in the assignment, regardless of who was principally responsible for it.

Face-to-face interaction, at least part of the time. Some or all of work must be done by members working together (as opposed to parceling out the assignment to individual members and putting the completed pieces together without discussion).

Appropriate use of interpersonal skills. Team members must practice and receive instruction in leadership, decision-making, communication, conflict management, and other critical teamwork skills.

Regular self-assessment of group functioning. The team members periodically reflect on what they are doing well as a team, what they could improve, and what (if anything) they will do differently in the future.
JiTT

Timely pre-instruction warmup assignments inform the upcoming lesson and encourage the students to examine their prior knowledge and to get informed about the upcoming topic, before coming to class.

There is much flexibility as long as two crucial criteria are met:

The assignments are

• thoughtfully constructed and

• constitute an integral part of the lesson
What is a good JiTT question?

- yields a rich set of student responses for classroom discussion
- requires an answer that cannot easily just be looked up
- encourages the student to examine his/her prior knowledge and experience
- requires that the student formulate the response, including the underlying concepts, in his/her own words
- contains enough ambiguity to require the student to supply some additional information not explicitly given in the question. (This feature enriches the subsequent classroom discussion.)
Mathematics

In some sections of the textbook, "the derivative" refers to a specific number. In other sections, "the derivative" refers to a function. Explain the difference.
Fine Arts - Photojournalism

After two short readings on “The Fallen Soldier”

• Summarize in your own words the argument that the photo was staged, then summarize in your own words the argument that the photo is authentic.
• Which argument do you find more convincing? Why?
• In your opinion, does it matter whether or not this photograph was staged? Why or why not? This is chance to explore and articulate your ideas about the truth value of photography.
Physics

Please explain in your own words what a focal point is. Do this without referring to any particular device.
Worked Examples
and
Self Explanation
• New material is introduced via carefully crafted worked examples of problems.

• Students study worked examples and try to construct a rudimentary version of the conceptual knowledge.

• In-class time is spent in elaborating on the self-constructed knowledge and firming it up.

• After the lesson students work additional homework problems
A self-explanation is a comment about an example statement that contains domain-relevant information over and above what was stated in the example line itself.

In an intervention study, Chi et al. found that high-ability and average-ability students benefited equally from being prompted to generate self-explanations.
Cognitive Load

History - From Miller to John Sweller Cognitive Load Theory to Instructional Design

Why Some Material is Difficult To Learn?

Working Memory vs Long Term Memory

Cognitive Load

Expert Problem Solving - Novice Problem Solving

Schemas - Chunking - Automation

Instructional Design Implications

Element Interactivity

Task: Plot P(x,y)

1. Algebraic vs Geometric System
2. P(x,y) refers to point in both systems
3. x refers to location x on x-axis
4. y refers to location y on y-axis
5. Draw a line from x perp to x-axis
6. Draw a line from y perp to y-axis
6. The meeting of point of lines is P(x,y)
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Instructional Design Implications

SHORT TERM WORKING MEMORY
• limited to about seven information units
• engaged in processing instructional material
• encoding it into long term memory

LONG TERM MEMORY
• essentially unlimited store of knowledge
• factual data
• processing instructions
Cognitive Load

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Instructional Design Implications

COGNITIVE LOAD
• quantity and complexity of elements to process
• instructional design influences both

INTRINSIC LOAD
• quantity and complexity are interrelated
• minimally influenced by instructional design

EXTRANEOUS LOAD
• how information is presented
• at the heart of instructional design

GERMANE LOAD
involved in organizing information and integrating with prior knowledge
Cognitive Load

History - From Miller to John Sweller Cognitive Load Theory to Instructional Design

Why Some Material is Difficult To Learn

Working Memory vs Long Term Memory

Cognitive Load

EXPERT vs NOVICE

The purpose of Instruction is to turn a novice into an expert.

Experts store in long term memory procedures to deal with information presented to the working memory.

With practice these procedures become automated

Expert Problem Solving - Novice Problem Solving

Schemas - Chunking - Automation

Instructional Design Implications
Cognitive Load

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Why Some Material is Difficult To Learn

Working Memory vs Long Term Memory

Cognitive Load

Expert Problem Solving - Novice Problem Solving

SCHEMAS - CHUNKING - AUTOMATION

Schema: Organizes information according to the manner in which it will be dealt

Chunk: Multiple pieces of information and their interactions treated as one element

Automatic recognition of appropriate schema bypasses working memory
Self-Explanation

History - Classic Study 1989 by Michelene Chi and colleagues

What is self-explaining?

Trainable learning activity where students
• generate fill-in missing information
• integrate information within the study material
• integrate new information with prior knowledge
• monitor and repair faulty knowledge

Types of self-explanation

Contrast with Instructional Explanations

Good learners tend to be
• principle-based explainers
• anticipative reasoners

Prompting Self-explanation

Instructional Design Implications

Self-explaining can be successfully prompted or trained rather than spontaneously generated with similar learning benefits
Self-Explanation

History - Classic Study 1989 by Michelene Chi and colleagues

What is self-explaining?

Types of self-explanation

Contrast with Instructional Explanations

Prompting Self-explanation

Instructional Design Implications

We would like the students to know:
• what are the consequences of an action
• when the action is applicable
• what is the relationship of actions to goals
• what is the relationship of goals and actions to principles

Explanation Statements
• Interpretative
• Monitoring
• Mathematical Elaborations
• Strategic
**Self-Explanation**

History - Classic Study 1989 by Michelene Chi and colleagues

What is self-explaining?

Types of self-explanation

Contrast with Instructional Explanations

Efficacy of prompts depends on matching the response to the prompt to recall and modification of prior knowledge and the progress towards understanding and solving problems
PROMPT CATEGORIES
1. Procedure Focused

1a. Step elaboration
   (elaborate – provide detail)

1b. Deconstructing the analysis
   (Call attention to the subtle features of the step – probe for mathematical maturity – provide the missing steps and/or details)

1c. Checking mathematical maturity
   (Are the more obscure consequence of a particular mathematical step understood? – Ask about the consequences of a subtle change in the mathematical expression. – Ask about a non-obvious extension.)
2. Metacognition Focused
(understanding the concepts in the step – understanding the procedure used – understanding the mathematical language used – understanding the translation physics -> mathematics – understanding the translation mathematics -> physics)

2a. Verbalizing the physics involved in a mathematical step
(What does the equation say about the physics involved? Verbalize the change in physics resulting from a change in an expression.)

2b. What is behind the concept?
(Call attention to the subtle properties of a newly defined concept. Illustrate with a concrete example)

2c. Step justification
(How does this step follow logically from the preceding step? Is the mathematics justified? Is the physics justified? How?)
2d. Relating to other sources of knowledge
(Previous knowledge – text book – peers)

2e. Intuition
(Conceptual Intuition—Does the concept make intuitive sense - build an intuitive feel for a concept – Can you recognize an instance of the concept if you see it?
Procedural intuition – Does the step make intuitive sense?
Mathematical intuition – Is the mathematical result what is intuitively expected?
Real world check – is the final outcome what one would expect?

2f. Extending the example
(How would the procedure used in the example have to be changed to accommodate an obvious extension of the example? A non-obvious extension?)
Acceptance is easier if the new concept is
• intelligible (student is able to understand)
• plausible (makes sense)
• fruitful (having the potential to solve new problems)
How concepts develop?

explorations to intuitive rule-based reasoning to explicit rule-based understanding

If I add a bulb in a series circuit all bulbs will shine less brightly.

At a node in circuit the current splits into several paths.

Whenever an object changes its movement a force is exerted on the object.
HOMEGROWN

Lightning never strikes the same place twice

Color is inherent to an object, e.g. a red book.

Current is a substance, stored in a battery, consumed by a lamp (like a fuel.)

Most body heat is lost through a person's head.
PICKED UP IN SCHOOL

ARTICLE NO.0021
DESA Working Paper No. 35
ST/ESA/2006/DWP/35
September 2006

Globalizing Inequality: ‘Centrifugal' and ‘Centripetal' Forces at Work

“An interesting model of economic geography must include both centripetal and centrifugal forces. The corresponding spatial equilibrium is then the result of a complicated balance of forces that push and pull consumers and firms until no one can find a better location.”
RESEARCH GUIDE TO INTERVENTION STRATEGIES

Scientific explanations are counterintuitive.

Directly confronting misconceptions typically fails

If instruction wants students to understand a particular concept, the students need to discover this concept at least intuitively before they are likely grasp related conceptual information.

Some misconceptions explicitly point to misleading or missing experiences which, in turn, have to be made during instruction.

To simply start presenting basic physics concepts through nonmaterialistic representations (e.g. electric fields) may strip the students of all the tools and experiences they have constructed to make sense of things.
A Worked-Example Learning Unit

For student:
• A worked-out problem (two if it is a comparison example)
• A matched near transfer problem
• A set of self-explanation prompts
• A matched pre-class web assignment - warmup
• An in-class near-transfer problem
• An in-class far transfer problem
• Extra study resource (e.g. website)

For instructor:
• learning objective
• known bottleneck/difficulty/misconceptions
• suggestions for in-class follow-up
• extra study resource (e.g. website)
Pre-class Assignment

• WarmUp
• Pre-Instruction Worksheet

In-Class Follow Up

• Discussion of examples
• Mini-lecture
• In-class worksheets

Post-instruction

• Graded homework
Benefits - Student Perspective

• The pre-class assignment creates a structured study environment.
• Students monitor their own learning processes and develop metacognition skills.
• Daily practice helps with time management, reduces anxiety and test prep time.
Benefits - Instructor Perspective

• Students prepared for the lesson
• Instructor aware of the bottlenecks
• Improved classroom climate
Implementation - Course Design Perspective

· A high percentage of the course grade is based on the instructor’s assessment of the student’s preparation for class.

· Materials must be consistent across all sections and all parts of the course: examples, warmups, worksheets.

· It has to be clearly specified what must happen in all classrooms and where the instructor has some flexibility.

· Credit given for student work must be consistent across all sections.

· All activities and materials must be aligned with learning objectives and tests.
• Decoding Cycle
• The Arons List
• Learning Taxonomy
• Learner Maturity
Step 1: Identify a Bottleneck to Learning

Step 2: Identify the Mental Operations that Students Must Master to Get Beyond the Bottleneck

Step 3: Model These Operations for Students

Step 4: Give Students Opportunities to Practice These Operations

Step 5: Deal with Potential Emotional Bottlenecks to Learning

Step 6: Assessing Learning
The Arons List

Unrealistic expectations that students can

• Perform Qualitative, Phenomenological Reasoning or Thinking
• Paraphrase a Paragraph of Text
• Understand the Need for Operational Definitions
• Translate Words into Written Symbols and Written Symbols into Words
• Draw Inferences from Data and Evidence
• Discriminate Between Inductive and Deductive Reasoning
• Check Inferences, Conclusions, or Results
BOTTLENECK

**Vague**: Students have difficulty moving from fact learning to a deeper understanding of biological processes.

**Useful**: Students have difficulty visualizing chromosomes, appreciating the distinction between similar and identical chromosomes (i.e., homologs and sister chromatids), and predicting their segregation patterns during mitosis and meiosis.

- Strome, 2004
Mental Operations - Hidden Expert Knowledge

Make explicit the tacit mental operations that students must master to overcome bottlenecks to learning. This involves slowing down so that steps that are automatic are accounted for and breaking large, ill-defined tasks into their component parts.
Allison is driving with her parents when they get in a serious car accident. At the emergency room, her doctor tells Allison that her mother is fine, but her father Bob has lost a lot of blood and will need a blood transfusion. Allison volunteers to donate blood, and you tell her that her blood type is AB. Bob is type O.

(a) Can Allison donate blood to Bob? Why or why not?

(b) Allison, who is a biology student, begins to wonder if she is adopted. What would you tell her and why?
The conducting wires W1 and W2 are made of different materials, the first one with resistivity $\rho$, the second with resistivity $\frac{1}{2} \rho$, have lengths and cross-sectional areas as marked. Which of the following pairs of wire segments will have equal resistances?

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## Cognition and Knowledge Taxonomy

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LEARNER MATURITY

Baxter Magolda

Absolute knowing. Knowledge is viewed as certain. Teachers are the authorities; learning is about facts; all points of view are either right or wrong. Teachers must communicate knowledge and the students must memorize and repeat.

Transitional knowing. Some knowledge is uncertain. Authorities don’t know everything and are expected to provide more information about the applicability of knowledge. Learners are focused on understanding knowledge rather than simply acquiring it.

Independent knowing. Knowledge is mostly uncertain. The learning environment is supposed to reward thinking and logic over particular views and opinions.

Contextual knowing. The legitimacy of knowledge claims is depends on the context. The learner constructs a point of view, but must have supporting evidence.”

Just-in-Time Teaching (JiTT)

World Wide Web

Homework

Classroom

Assignment Design
Example

• **Question:** Is it possible to add heat to an ideal gas without changing its temperature? If it is possible, please explain how it is done.

  – “It is not possible because the internal energy of an ideal gas only depends on the temperature.... the internal energy will increase when the temperature rises....”

  – “If you add heat to a system while the system is doing the corresponding amount of work, the temperature will not change.”

  – “It is possible to add heat to an ideal gas without it changing it’s temperature by the gas receiving the heat, and the atoms of that gas getting excited enough to disperse that heat as fast as they receive it...”
What makes a good Warmup?

• Based on a “big idea”
• Provokes students to think about the reading
• Gets students engaged and anticipating class
• Illuminates misconceptions about topic
• Provides fodder for class discussion or activities
• Connects subject to “real life.”
Question stems

• Explain what <jargon> means in your own words.
• Explain the similarities and differences between the terms <jargon 1> and <jargon 2>
• <Key Idea> is used to describe <situation>. What can you say about <this example>
• <key idea> is similar in some ways to <previous key idea>. What are the similarities and differences?
• Unusual thing happens in certain circumstances. How does <key idea> explain this?
• Give an example of how <key idea> applies to your daily life.
• Under what circumstances can we use <important skill>? What are some circumstances in which <important skill> does not apply?

• Rank the following <things> in order of <property>. Explain how you determined your ranking.

• Applied properly, <key idea> has the potential to help millions of people. Are there also disadvantages to <key idea>? What are the most serious?

• We have solved problems before using <old idea>. What new problems can <new idea> solve that <old idea> could not?
Chemistry example

This picture depicts matter at the submicroscopic level. Describe what you see and take a guess as to what the identity of the substance is.

- “The particles are well spaced out so I would guess the substance to be a gas. The substance is a gas composed of 2 elements that are in an equal ratio.”
- “After reading Chapter 1 in the book I would guess that the substance is water in the form of a solid because the atoms are in order. However, I could be wrong because I think the atoms in a solid might be closer together.”
Choosing and using student responses

- Always say something positive
  - This is true, but what if something else occurs simultaneously…
  - This makes sense, but something is missing…
  - This is a great response… how would we know how much heat to add?
  - This is correct, but the reasoning isn’t quite right…
  - This has a great beginning, but more could be added…
Choosing and using student responses

- Peer Instruction/Think-Pair-Share
  - Here’s a clicker question based on the warmup
  - Question 3 on the last warmup was pretty tough. Now that we’ve talked about it, let’s do it again with clickers
  - Here are three answers to last night’s warmup, Which do you think is the best?
Worked Examples

- Focus on “big idea”
- Require MINIMAL background
- Must model “good behavior”
- Easy to moderate difficulty
- Intersperse self-explanation questions
Tips and Pitfalls

• Explain methods and purpose on first day
• No need to review all responses before class: sample for “useful” quotes, grade later
• Focus on students strengths, too, not just misconceptions and other problems.
• Use answers from many students: not favorites.
• Do not “isolate” warmups – use throughout session
• Must be routine. Don’t start/stop mid-semester
• Upper level students can handle more “exploratory” questions, connections to prerequisites
• Faculty cedes some control!
More Examples

• In a few sentences, explain what an "impulse" is, and how it can be calculated.

• A ford Mustang weighs about 3500 pounds, and can accelerate from 0-60 MPH in about 5 seconds. What force is responsible for this acceleration? What is its approximate magnitude?

• In a sentence or two, please describe the difference between "gauge pressure" and "absolute pressure? When would you want to use each?
Impulse responses

- Impulse is the change in momentum over time. It can be calculated by integrating force as a function of time.
- ...it's the force integrated over the time period or the change in momentum in that time period.

- An impulse is a large amount of force that acts on an object of a short amount of time.
- An impulse is the moment at which two objects initially collide and exert enormous force upon each other.
What does the book say?

**IMPULSE**

When two objects collide, they usually exert very large forces on each other for a very brief time. The force exerted by a baseball bat on a ball, for example, may be several thousand times the weight of the ball, but this enormous force is exerted for only a millisecond or so. Such forces are sometimes called *impulsive forces*....