ClemsonThinks^2: Promoting Metacognition and Self-Regulated Learning

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Why metacognition and self-regulated learning? (Why not critical thinking?)

Part of the working definition of critical thinking for this Faculty Institute is "…the intellectually disciplined *process* of actively and skillfully conceptualizing, applying, analyzing, synthesizing..." So critical thinking is, by definition, a *process*. How do you assess a process? By looking for evidence that it is happening.

This is where **metacognition** fits in. Instructors will be structuring learning experiences for their students to teach the elements of the "critical thinking" process. If metacognition – basically thinking about thinking - is part of these learning experiences, students will provide evidence of their development as "critical thinkers". It will also improve the chances of students sustaining their critical thinking practices throughout their college career (and beyond) – of becoming self-regulated learners.

Self-regulated learning can be defined as the process of taking control of and evaluating one's own learning and behavior. There are two critical points for students' success in self-regulation: 1) meta-cognition (awareness), and 2) strategies and techniques. Students must be aware that their strategies are not working to change or improve. Once they are aware, they are only as successful as their repertoire of techniques and strategies, and their knowledge about when to employ which technique and strategy.

In this session of the CT^2 Faculty Institute, participants will learn ways to structure instructional materials and activities to promote metacognition, and to develop assessments that will provide evidence of desired students outcomes for the CT^2 program.

Metacognition and Self-regulated learning

Meta-cognition: the ability to think about how the self learns and changes

- Metacognitive processes: planning, setting goals, organization, self-monitoring

Self-regulation: the ability to control and regulate thoughts and actions

- Academic tasks encompass four phases of self-regulation (Winne and Hadwin, 2008):

- Task perception
    - Gather information, personalize it
    - Perceive self-efficacy (how well you will be able to do a task)
    - All learners do this, but self-regulated learners are aware of the relationship between processes and desired learning outcomes, and use strategies such as goal setting and selective attention to achieve outcomes
- Setting goals, planning
    - Depends on task perception to a degree
    - Related to behaviors, cognitive engagement, motivation
- Self-monitoring, enacting
    - Use of strategies and skills
    - Activating prior knowledge
- Self-evaluating, adapting
    - Evaluate performance, adapt to improve
    - A "self-oriented feedback loop", both negative (reducing differences between goals and outcomes) and positive (raising the bar in response to observed outcomes)

- Student strategies to promote self-regulated learning (Zimmerman, 1990; Boekarts, 1999):

- Self-instruction
- Verbal elaboration; Self-recording
- Text comprehension monitoring (quizzing yourself)
- Goal setting and planning
- Environmental structuring
- Resource management (manage and control materials and resources)
- Rehearsing; Memorizing (developing automaticity)
- Seeking help from others (peers, teachers, other adults)

Examples of Instructional Approaches to Facilitate Metacognition

1. General Design: Learning Progression

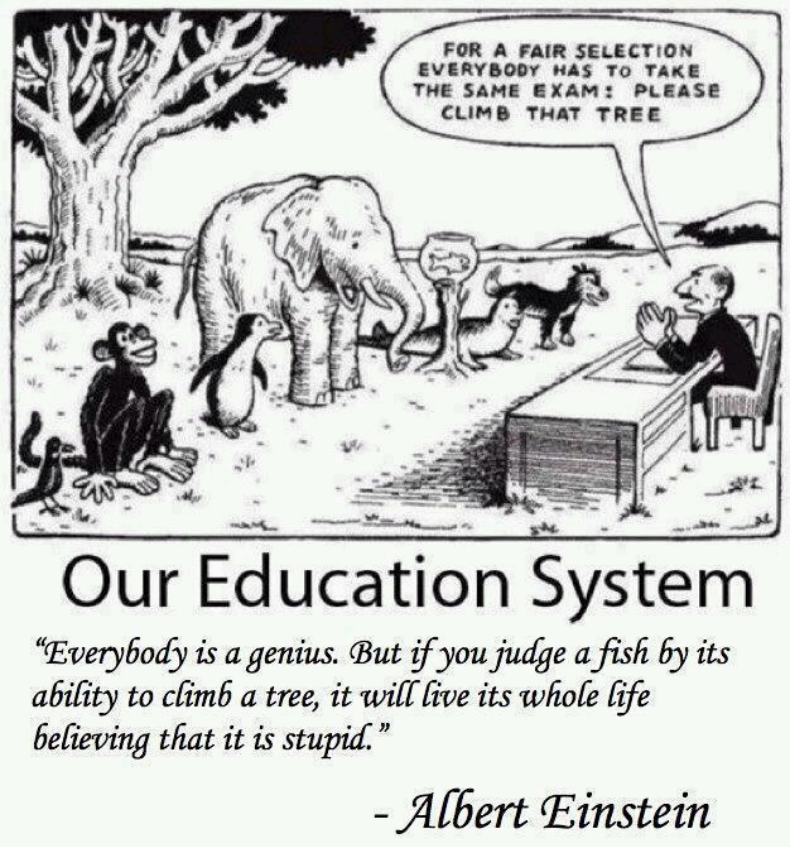
- "Descriptions of successively more sophisticated ways of thinking about an idea that follow one another as students learn: they lay out in words and examples what it means to move toward more expert understanding." (http://www.cpre.org/ccii/images/stories/ccii_pdfs/learning%20progressions_heritage.pdf)

- Characterized by these features:
    - Learning is envisioned as a development of progressive sophistication in understanding and skills within a domain
    - Students experience vertical development over an extended period of time
    - Learning is conceived as a sequence or continuum of increasing expertise
- Construction using a "top-down" approach (developed from the perspective of an "expert" in terms of domain knowledge) centers on three questions:
    1. What should be assessed?
    2. What type of learning performances will best illustrate students' knowledge?
    3. What tasks, questions or situations will bring about the appropriate type of response?

2. Specific Activity: Contrasting Cases

In science, engineering and mathematics, contrasting cases can be used to help students cognitively engage with the subject matter by doing things such as making decisions about what procedure to use when solving a particular type of problem, comparing features of different designs or cases, etc. The instructor presents two cases/problem solutions/designs/etc. side by side, poses questions about specific features, and has students discuss questions in small groups. Groups present summaries of their discussions to the class; this is followed by instruction about the content, which can be brief, touching on important take-home lessons. This cycle can be repeated through a class period, or interspersed with regular class activities. This method is described as part of the "Preparation for Future Learning" approach developed by Dan Schwartz and others.

Assessing Metacognition



To promote metacognition, from a constructivist perspective, instruction should

- Focus on making connections between facts and fostering new understanding in students.
- Use teaching strategies that are tailored to student responses and encourage students to analyse, interpret, and predict information
- Rely on open-ended questions and promote extensive dialogue among students.

It follows that assessment should involve more than grades and standardized testing (i.e. summative assessment). Assessment becomes part of the learning process so that students play a larger role in judging their own progress (i.e., formative assessment).

Examples of assessing students' understanding and integration of concepts and mastery of problem-solving processes are on the following pages.

Example of assessment of knowledge integration for open-ended responses (from Lee and Liu, 2009)

Electrical energy is used to power a lamp. Is the amount of light energy produced more than, less than, or the same as the amount of electrical energy used? — *Item context description*

The amount of light energy produced is

____ more than, ____ less than ____ the same as

the amount of electrical energy used. — *Multiple-choice part*

Explain your choice. — *Explanation part*

Ideas:

- Energy dissipation idea: Some energy is lost in the circuit or through heat.
- Energy transformation idea: Some energy is transformed to light energy or used to light the lamp.
- Energy conservation idea: The total amount of energy is conserved.

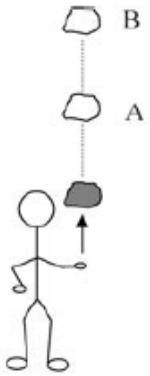
Link:

- Energy dissipation-transformation link: Electrical energy is used to both heat and light the lamp.

Knowledge Integration Level (score)	Criteria	Examples
Irrelevant: Off-task (1)	Wrote some text unrelated to the item.	• Because I think so.
No-link: Nonnormative ideas (2)	Elicited nonnormative ideas or restated the multiple-choice answer chosen.	• Light energy is less needed than electrical energy and because of that the electrical energy is greater. • Because the system would eventually overload if it was too much and it wouldn't work if it was less.
Partial-link: Normative ideas (3)	Elicited one of the energy dissipation, transformation, and conservation ideas	• The light produced does not use all of the electrical energy that goes into the light bulb. Some of the energy is used for the production of the light, but it doesn't actually cause the light to be brighter.
Full-link: Single link between two normative ideas (4)	Made a link between energy dissipation and transformation ideas	• Some of the electrical energy dissipates into heat and is absolutely lost. The remaining energy is converted to heat and used as light energy.
Complex-link: Two or more links among three or more normative ideas (5)	Made a link among energy dissipation, transformation, and conservation ideas.	• A lamp works by charging a filament, which produces both light and heat. Because of conservation of energy, the light energy must be less than the total energy used.

Figure 1. Light item (IEA, 1995b) and knowledge integration scoring rubric.

Example of assessing conceptual understanding by incorporating common misconceptions; iterations of multiple-choice questions were based on responses to open-ended responses and think-aloud interviews (from Alonzo and Steedle, 1999)



Derek throws a stone straight up into the air. It leaves his hand, goes up through point A, gets as high as point B and then comes back down through A again.

a) Original item

When the stone is on its way up through point A, what force(s) are acting on it?	**Level**
A. Only gravity is acting on the stone.	Level 4*
B. Only the force from Derek's hand is acting on the stone.	Level 3*
C. A force inside the stone is keeping it moving upward.	Level 2*
D. Both gravity and the force from Derek's hand are acting on the stone, but the force of gravity is smaller.	Level 3*
E. There are no forces acting on the stone because nothing is touching it.	Level 1*

b) First revision (in response to students' OE answers)

C. The stone carries the force from Derek's hand.	Level 2*

c) Second revision (in response to changes in the learning progression, students' OE answers)

Ignoring air resistance, what force(s) are acting on the stone when it is moving <u>up</u> through point A?	**Level**
A. Only gravity is acting on the stone.	Level 4
B. Only the force from Derek's throw is acting on the stone.	Level 2A
C. Both gravity and the force from Derek's throw are acting on the stone.	Level 3A
D. There are no forces acting on the stone because nothing is touching it.	Level 1

d) Third revision (in response to students' think-aloud responses)

D. There are no forces acting on the stone.	Level 1

* Original learning progression level.

Figure 1. Revisions to a force and motion OMC item.

Example of assessing problem solving processes for engineering students (from Grigg et al., 2013)

Grader:		Student ID:				
	Problem Solving Process/ Category	**Explicit Tasks Performed**	**Level of Completion**			**Error(s) Committed**	**Process Score**
			Missing	**Inadequate**	**Acceptable**		
			0 points	**1 point**	**2 points**	**(-1 point)**	**(0 to 2 each)**
Conceptual -->	Identify Problem and System Constraints	□ Identified unknown □ Restated problem □ Identified system constraints □ Communicated assumptions	Did not explicitly identify or define the problem/system	Completed some problem/system definition tasks	Clearly identified and defined the problem/system	□ Incorrect unknown □ Incorrect assumption □ Ignored or incorrect problem constraints	
	Represent the Problem	□ Drew a visual representation □ Relate variables/values	No representation drawn, no relationships indicated	Drew a representation or related variables, but not both	Drew a representation and indicated variable relationships	□ Incorrect representation □ Incorrect relate variables	
	Organize Knowledge	□ Identified known values □ Identified equation(s) □ Identified conversion factor	Did not explicitly organize information about the problem	Completed some information organization tasks	Fully organized information needed to solve the problem	□ Incorrect known values □ Misused governing equation □ Incorrect conversion factor	
<-- Analytical	Allocate Resources (Execution)	□ Manipulated equation □ Derived units □ Used conversion factor □ Documented math	No work shown	Partially documented execution tasks (Work showed some evidence of relevant tasks)	Fully documented execution tasks (Work showed evidence of relevant tasks)	□ Incorrectly manipulated equation □ Incorrect calculation □ Incorrect unit derivation □ Inconsistent transcription □ Inconsistent units □ Incorrect unit assignment □ Missing units throughout □ Used irrelevant information □ Other _____	
	Evaluate the Solution	□ Checked accuracy □ Indicated final answer □ Justified final answer	Did not evaluate solution	Explicitly evaluated the solution, but flawed in some way	Adequately evaluated the solution	□ Incorrectly manipulated equation □ Incorrect calculation □ Incorrect unit derivation □ Inadequate reasoning	
	Final Solution Accuracy		Missing Answer	Incomplete Answer	Complete Answer	□ Missing units □ Incorrect units □ Incorrect value □ Did not answer the question	
						Total Score	

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