Assessing-to-Learn Physics (A2L)

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Project Description

Overview

Original project goal

Our *initial* intent was to work with in-service teachers to develop prototype formative assessment materials for use with a classroom response system in high school physics instruction. We collaborated with participating teachers to create collections of questions ("items") to be posed, pondered, answered, and discussed in class with the use of a classroom response system.

Realization

During this collaboration, we discovered that our approach was not viable for impacting teachers or improving instruction (see the **Summary of Findings** column).

Modified project goal

Consequently, we broadened the scope of the project to investigate issues affecting teachers' adoption and implementation of formative assessment practices. In particular, we explored pedagogical aspects of classroom response system use, as well as the professional development support required by teachers.

Results

Experiences and findings from this project led us to formulate a comprehensive pedagogical model for using classroom response systems to teach science, *Technology-Enhanced Formative Assessment* (TEFA), and criteria for conducting effective professional development to support it. Both are central to our subsequent project, *Teacher Learning of Technology-Enhanced Formative Assessment* (ESI-0456124, TPC program).

Developing Formative Assessment "Items" (Questions)

Focus on developing expert-like conceptual structure

See the **Five Stages of Cognitive Development** column.

Focus on developing process skills

See the **Twelve Habits of Mind** column.

Model students and tune items accordingly

See below.

New Roles and a New Classroom Dynamic

New roles for teachers

Instead of being content experts and presenters, teachers become engineers of productive learning situations and coaches of learning.

New roles for students

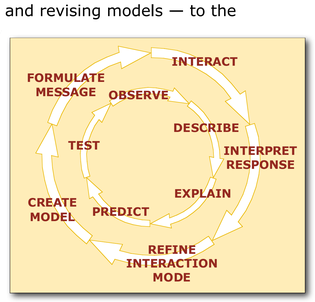
Students take greater responsibility for their own learning, modeling the physical world, becoming aware of their world views and those of their classmates, reflecting on their learning, relying on classmates for assistance, and structuring their own knowledge.

The classroom dynamic

As students practice the scientific paradigm — observing, modeling, experimenting to test models, and revising models — to the physical world, teachers apply that same paradigm to the students.

"Formative assessment" means seeking information about students' thinking and learning in order to adjust instruction and help students optimize their learning activity.

Doing this effectively requires building and updating mental models of the students.



teachers modeling students modeling the world

Targeting Cognitive Development

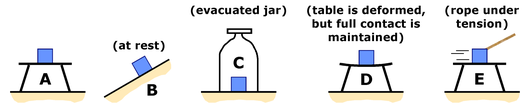
Overview

- Developing formative assessment items and using information about students' understanding to make real-time teaching decisions poses a number of challenges.
- In facing these challenges, we have found it useful to employ two classification schemes inspired by PER.
- One scheme describes students' cognitive development within a domain and defines a set of 5 cognitive goals.

Five Cognitive Goals

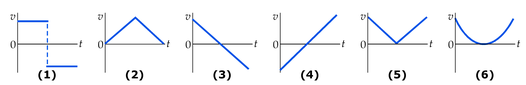
Goal 1: Exploring students' existing concepts

Q1. For which situation(s) below is the normal force on the block largest? (Choose ALL that apply.)



Goal 2: Honing, linking, and clustering concepts

Q2. Which of the velocity vs. time plots below might represent the velocity of a cart projected up an incline?



Goal 3: Developing analysis and reasoning skills

Q3. Predict what you think will happen when oil is poured onto a ball floating in water as shown.

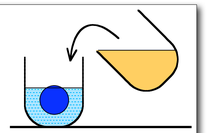
a) The ball will sink farther into the water.

b) The ball will stay at the same height relative to the water.

c) The ball will rise out of the water.

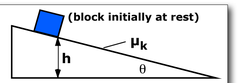
d) I don't know.

e) Not enough information.



Goal 4: Structuring the knowledge store

Situation: A block is released from rest on an incline.
Goal: Find its speed at the bottom of the incline.



Q4. Which principle would you use to solve this problem MOST EFFICIENTLY?

a) Kinematics only

b) F = ma or Newton's laws

c) Work-Energy theorem

d) Impulse-Momentum theorem

e) Not enough information

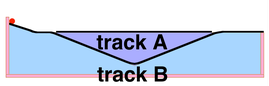
Goal 5: Developing problem-solving skills

Q5. Two identical steel balls are released from rest from the same height, and travel along tracks as shown. Which ball reaches the end of its track first?

a) Ball on track A

b) Ball on track B

c) They reach the end at the same time.



Targeting Process Skills

Overview

- Formative assessment attempts to monitor and interact with the thinking and learning processes of students.
- A desirable outcome of formative assessment activities is the stimulation of mental processes needed for active engagement and intellectual growth. We refer to these mental processes as "habits of mind."
- The 6 "basic" habits of mind are slightly more fundamental than those labeled as "advanced." They are also more widely applicable, because they can be encouraged during all stages of learning.
- The 6 "advanced" habits of mind are more easily applied to later stages of learning.
- To reach the stage of being a proficient, flexible problem solver, students need to develop all 12 habits of mind.
- Formative assessment activities occupy the space defined by the 5 cognitive goals and 12 habits of mind.

Twelve Habits of Mind

Basic

- Seek alternative representations
- Compare and contrast
- Explain, describe, draw, etc.
- Predict & Observe
- Extend the context
- Monitor and refine communication

Advanced

- Generate multiple solutions
- Categorize and classify
- Discuss, summarize, model, etc.
- Plan, justify, and strategize
- Reflect, evaluate, etc.
- Meta-communicate

Habits of mind vs. cognitive goals

Each item should target one (or more) cells in the matrix.

Habits of Mind	Cognitive Goals				
	exploring existing concepts	honing & linking concepts	developing analysis & reasoning	organizing & structuring knowledge	developing problem solving
seek alternative representations	✧	✧	✧	✧	✧
compare & contrast	✧		✧		✧
explain, describe, draw, etc.	✧	✧	✧	✧	✧
predict & observe	✧	✧	✧	✧	✧
extend the context	✧	✧	✧		
monitor & refine communication	✧	✧		✧	
generate multiple solutions			✧	✧	✧
categorize & classify	✧	✧	✧	✧	✧
discuss, model, summarize, etc.		✧	✧	✧	✧
plan, justify, and strategize	✧	✧	✧	✧	✧
reflect, evaluate, etc.			✧	✧	✧
meta-communicate	✧	✧	✧	✧	✧

Summary of Findings

There is no single "right way" to implement formative assessment (FA).

Teachers vary so significantly in their skills, perspectives, contexts, and needs that a "one size fits all" approach to formative assessment, and especially to curriculum development for it, is not feasible.

Creating high-quality FA questions is difficult for teachers.

Due to time constraints and unfamiliarity, teachers have great difficulty creating curricular materials of sufficient quantity and quality to support a comprehensive formative assessment program, even with our assistance.

Implementing or adapting high-quality FA questions is also difficult for teachers.

Teachers have difficulty making effective use of high-quality formative assessment materials created by others (such as us), both because they do not fully understand the design logic of the materials and because they (often inaccurately) feel these materials do not fit their students, curriculum, context, and "style." Often, this results from a mismatch between the designer's instructional goals and the teachers' implicit goals while using the materials.

Teachers are not always able to align everyday FA practice with long-term FA goals.

Although most teachers identify with the stated goals of formative assessment, their practice of it is often inconsistent with those goals.

In practice, many FA activities are less "formative" than they were intended to be.

Although teachers and students seem to enjoy doing formative assessment activities and express their belief that the activities are valuable learning experiences, few teachers use the information they receive during formative assessment to make real-time teaching decisions. As a result, the activities are less "formative" than they could be and are intended to be.

It can take as long as 3 years for a teacher to become an expert practitioner of FA.

Approximately three years of sustained effort is required for a teacher to become "fluent" — facile and comfortable — with the formative assessment approach being promulgated.

To help teachers incorporate authentic formative assessment into their practice, we must provide intensive professional development in the wide-ranging skills and pedagogy needed to succeed with it.

Overall, it became clear that while a highly tuned set of formative assessment activities might ultimately be useful for improving a classroom's dynamic, such materials are generally insufficient to induce teachers to adopt authentic formative assessment practices. The project's major findings, therefore, address pedagogy and professional development as well as curriculum.

We began formulating *Technology-Enhanced Formative Assessment*, a coherent pedagogical model for teaching science with formative assessment and classroom response technology. We also developed a sustainable teacher professional development model that addresses effective use of classroom response system technology, teacher creation of formative assessment questions, new roles for students and teachers, goals and practices of formative assessment, and pedagogical principles underlying the complex decision making necessary for continuous formative assessment.

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