# Assessment Lessons From K-12 Education Research: Knowledge Representation, Learning, And Motivation

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**Abstract.** Research on teaching to the test in K-12 settings has documented the lack of generalized understanding of underlying principles in tested subjects. This is similar to the experience of physics students who can complete computational problems without conceptual understanding. The PER community is well aware of the importance of explicit representations of learning goals as well as the role of the formative assessment process, especially feedback and self assessment, in promoting or deterring students' engagement and willingness to take responsibility for their own learning. Key principles from socio-cultural learning theory and research on motivation are summarized and used to identify instructional and assessment practices that hold the most promise for engaging students in developing deep conceptual understanding.

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## INTRODUCTION

To be effective in furthering student learning, classroom assessment must be exemplary in two fundamentally important ways. First, its form and content must fully represent not only important ideas, but also the specific practices in each of the disciplines. In K-12 education research, this idea was first introduced in the late 1980s, under the banner of "authentic assessment," to counteract the negative effects of multiple-choice accountability tests. Second, assessment processes and purposes must support learning and a learning orientation. These ideas are pursued within the framework of formative assessment [1,2].

The physics education research (PER) community has focused on assessment reforms in both categories, developing context-rich tasks to better elicit students' conceptual understanding [3] as well as curricula and activities that build on students' prior knowledge [4]. Physics education researchers are increasingly directing attention to formative assessment as a means to further student learning, especially if enacted in ways that are consistent with socio-cultural learning theories, e.g. activity theory, cognitive apprenticeship, etc. Here I recapitulate briefly the arguments for conceptually rich tasks, but my main focus is on key principles from cognitive and motivational research and the implication of these theoretical perspectives for instructional and assessment practices.

## CONCEPTUALLY-RICH ASSESSMENT TASKS

Developing assessment tasks that fully embody learning goals is not just a matter of accurate measurement. Assessment tasks convey what is important to learn. In the short run, the character of assessment shapes how students focus their study efforts, but over time, it determines their understanding about the very nature of subject matter.

In K-12 settings in the 1980s, researchers studying reading recognized the need to focus instruction explicitly on "meaning making" after documenting that high-performing students had inferred from the feedback they received that reading was about understanding the story. This was in contrast to struggling readers who thought that they should be trying to read fast without making mistakes. Similarly, physics students tend to believe that physics knowledge is a collection of isolated facts and laws, and when asked to solve a problem turn to their notes or textbook to try to find the right formula [5].

Conceptually-rich problems set the direction for learning and engage students in meaningful practice with the kinds of thinking and reasoning abilities that we want them to develop. "Context-rich problems are designed to focus students' attention on the need to use their conceptual knowledge of physics to qualitatively analyze a problem before beginning to manipulate equations. They are essentially short stories that include a reason for calculating some quantity [3]." Such problems are consciously not formulaic. The unknown to be solved for is not directly identified, students may need to use additional information that is common knowledge or make assumptions.

Some conceptually-rich problems have an especially important instructional role to play, if they draw out student intuitions that are not consistent with scientific ideas. By selecting critical tasks that elicit known student difficulties, teachers can help students test their thinking and see how and why various ideas might need to be modified or extended [6].

The importance of challenging problem types that adequately capture learning goals is well recognized in the PER literature. Let me emphasize additionally that these good assessment tasks are interchangeable with good instructional tasks. We ought not develop powerfully rich instructional activities and then assess only with a traditional post-test. Nor should rich problem types be encountered for the first time on the test. Rather, students should have plenty of practice on an array of problem formats so that they are comfortable with new applications of what they have learned on an exam. We have evidence that "teaching to" this kind of problem – that ensures the more fulsome representation of real learning goals – improves learning.

## DISTILLED LEARNING PRINCIPLES

The knowledge base for formative assessment is closely tied to contemporary theories of learning that describe how knowledge is organized in the mind and how participation in communities of practice shapes understanding. The National Research Council reports, *How People Learn* [7] and *Learning and Understanding* [8] serve as curriculum guides for our learning about how to teach for understanding. The following are examples of distilled learning principles [8], which have implications for effective instruction and assessment strategies.

- Expert knowledge is organized around key concepts and principles and is "conditionalized," meaning that part of mastering a concept includes knowing when and how to use it.
- Learners use what they already know to construct new knowledge. (Prior knowledge may help or impede new learning.)
- Metacognitive strategies – e.g. checking for sense and explaining to one's self – facilitate learning.
- Motivation and sense of self affect effort and willingness to persist with difficult problems.
- Practices and activities engaged in while learning shape what is learned. (Hence the "plug-and-chug" complaint.)

Learning principles in turn lead to principles for curriculum, instruction, and assessment aimed at deep understanding [8]. The list is long, but a few examples illustrate the logical connections to findings from learning research. To promote learning with understanding curricula should:

- "Focus on depth of understanding rather than breadth of content coverage by providing students with multiple opportunities to practice and demonstrate what they have learned in a variety of contexts [8]."

Instruction for conceptual understanding:

- "Structures learning environments in which students can work collaboratively to gain experience in using the ways of thinking and speaking used by experts in the field."
- "Focuses on detecting, making visible, and addressing students' often fragile, underdeveloped understandings and misconceptions [8]."

Consistent with socio-cultural theory, these principles evoke an interactive and apprenticeship – learning-by-doing – model for instruction.

## MOTIVATION AND LEARNING

Historically, research on motivation was entirely separated from research on learning. These divisions, however, began to break down as cognitive psychologists came to recognize that the disposition to use one's knowledge and skills required development as much as the skills themselves. At the same time, social psychologists who studied motivation discovered that beliefs about intelligence were closely tied to students' willingness to put forth effort, which strongly influenced their academic achievements [9]. Instead of self esteem being off to the side and having the pejorative connotation of being pursued *instead of* achievement, anthropologists studying the development of identity helped us see that motivation and meta-cognition were so entwined that they could not be separated.

Recognizing the motivational aspects of learning is especially important in the context of assessment because traditional assessment practices have so often undermined intrinsic motivation to learn. Consider the following characteristics of performance-oriented students versus those with a learning orientation, (which corresponds roughly to the distinction between extrinsic and intrinsic motivation [10]). Extrinsically motivated students:

- tend to believe in fixed ability.
- work toward "performance goals," i.e., for grades, to please the teacher, and to *appear* competent.
- pick easy tasks and are less likely to persist once they encounter difficulty.

Note poignantly that girls are overrepresented in this category.

By contrast, students with a mastery or learning orientation, who are intrinsically motivated:

- attribute success to their own efforts.
- work toward "learning goals," i.e., to increase a sense of mastery and to become competent.
- are more engaged in schoolwork, use more self-regulation, and develop deeper understanding of subject matter.

Importantly, students are not born with these dispositions. They can have high intrinsic motivation in one context and not in another. Witness the example of kids who do poorly in school math but who can compute real-time updates of basketball averages.

Grading practices in schools can, and often do, foster a performance rather than a learning orientation. Fortunately, the same kinds of classroom strategies that support deep cognitive development also encourage intrinsic motivation – a sense of purpose in learning the material, internalization of what it takes to get better at the task, and increasing self-regulation.

## CHANGING CLASSROOM DISCOURSE AND SOCIAL NORMS

Today, socio-cultural theory brings together cognitive and social development. We now understand that intellectual abilities and an identity of mastery are socially and culturally developed. Children develop their abilities to think and reason in the same way that they learn language, gestures, interpersonal behaviors, manners, and tastes through their social interactions with family and community. How did your ability to explain your reasoning develop at your dinner table growing up? How did you learn to talk like a scientist?

Currently, classroom norms often encourage students to pretend to know. As a consequence, reform requires a conscious effort to negotiate new norms that encourage risk-taking and learning from mistakes. In a community of learners, students help one another solve problems, build on each other's knowledge, ask questions to clarify explanations, and suggest ways that the group can make progress toward its learning goals [11]. In K-12 contexts, it is interesting to note that schools have had more direct success in teaching students conflict resolution techniques, with related strategies summarized in colorful posters in the gym, than they have had in creating new discourse patterns for learning science and math.

At the college level, physics education researchers have considered explicitly how new classroom interaction patterns and expectations can be established. Heller and colleagues [3,12] have structured specific problem-solving steps emphasizing conceptual understanding: visualize the problem, describe the problem in physics terms, and so forth. And, they have assigned roles to help members of groups think like physicists: manager, skeptic, checker/recorder. In the same vein, Beichner and his SCALE-UP colleagues [13] also explicitly teach students conceptually-oriented problem-solving steps (gather information, organize your approach, analyze the problem, learn from your efforts) and establish formal group contracts governing group participation.

This is not to say that there is one best way to do this nor that such ideas are not sometimes implemented badly (as when grade points are given to motivate participation). Nonetheless, it is clear that for norms to change explicit attention must be given to new roles and new expectations – and students must be provided with feedback about how well they are contributing in these new learning environments.

## LINKING FORMATIVE ASSESSMENT TO LEARNING THEORY

Making it normative to explain one's reasoning, provide evidence, and engage in critique is one way to ensure that students receive real-time feedback. There are other *formative assessment* strategies as well that follow directly from an understanding of learning and motivation research.

The PER community knows well the idea that new learning is shaped by *prior knowledge*. This includes both prior school learning and self-taught interpretations of the physical world. Therefore, classroom practices should include assessment of students' relevant knowledge and experience not only to inform teaching but also to draw students into the habit of reflecting on their own knowledge resources. In K-12 classrooms, teachers strive to use knowledge activation routines, such as instructional conversations with students, to help both the teacher and the student become aware of the student's initial ideas.

*Feedback* improves learning but only if it provides guidance about how to improve. Surprisingly, a meta-analysis [14] of controlled studies found that feedback actually worsened outcomes in one-third of studies. Consistent with research on motivation, negative effects are most likely to occur if feedback is focused on the person (or normative comparison) rather than task evaluation.

*Transfer* is controversial in the PER community. Of course, no one should imagine that an elaborate knowledge structure is constructed in one context and then hauled intact to a new context. However, if we have learned anything from teaching-the-test research, which demonstrated the non-generalizability or non-transferability of concepts mastered by rote in one context but unusable and inaccessible in another, even highly similar context – it is that real learning means that one's knowledge must be flexible, robust, and relevant in new contexts.

In K-12 settings we are reminded of the importance of "teaching for transfer" when we encounter elementary children who cannot connect their knowledge of fractions with what they know about decimals. In physics, we have the famous "pit problem [15]." The standard motion problem given in class has a boy dropping a balloon from a window. "If it takes .8 seconds to hit his friend, who is 5 feet tall, how high is the window?" On the exam, a stone is kicked into a well, and a student calls foul, because "We never did any Pit problems in class."

Teaching for transfer is closely related to the principles of teaching for deep understanding. It means routinely asking students to draw connections, as with prior knowledge routines, and calling for new applications and extensions so that ultimately students are expected to look for the relevance of old knowledge in new contexts. Expanding the range of applications should be a part of both classroom problem solving and an expectation for exam questions. Expect to use knowledge from the pit problem in a new context and in a new way.

In the formative assessment literature, there is a hoped-for progression from feedback to self-monitoring. The idea of qualitative rubrics is not to justify grades but to help students internalize the features of quality work, which serves both meta-cognitive and intrinsic motivation purposes. Coming to understand what makes a good argument, good problem solving, good writing, good experimentation is part of becoming expert in that field. *Self assessment*, then, is a strategy that, if used properly, can help move students away from a focus on grades and toward a more substantive focus on the quality of their work.

## CONCLUSION

The kinds of classrooms envisioned, based on the *How People Learn* and *Learning and Understanding* [5,6] principles, require profound cultural shifts, changing both the substance of classroom work and the nature of student interactions. Formative assessment processes are closely linked to effective learning strategies, but because of the negative history of assessment being about grades rather than learning, explicit attention must be paid to negotiating new classroom norms. Socio-cultural theory, which brings together cognitive and motivational research, is an important resource for generating promising innovations and for analyzing both successes and disappointments.


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