

Tools for Ubiquitous Assessment in Discussion-Based Pedagogy*

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1 Introduction

Our research is founded on the idea that ubiquitous, non-intrusive, concept-centric student assessment is an important way for teachers to gain insight into the educational needs of their students. Ubiquitous assessment means that assessment is an integral part of students' everyday activities, thus allowing for a detailed temporal understanding of the students' progress. In order for ubiquitous assessment to work, it must also be non-intrusive. In most situations, it's unrealistic to have students take tests every day. Not only would it be onerous, but it detracts from time spent actually learning new material. Therefore, we argue for integrating assessment into learning activities. This allows teachers to understand what notions the students begin an activity with, and how the activity has helped them revise and improve upon that understanding.

While ubiquitous assessment represents a fine-grained approach to assessment with respect to frequency, we believe that assessment should also be fine-grained with respect to the type of knowledge being assessed. While a homework assignment or test question might determine whether a student understands a concept well enough to accomplish the assigned task, detailed knowledge of the concept may still be erroneous.

In order to provide this type of continuous, detailed tracking of student knowledge, we have developed a set of tools, collectively called INFACT. These tools are particularly suited for use with an instructional methodology in which students to build knowledge through small group collaboration and group discussion. In this paper, we discuss this pedagogical technique, its application to teaching math and computer programming concepts, and some of the computational methods that underly the tools.

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2 INFACT Forum and the Discussion-Based Pedagogy

We use a discussion-based teaching methodology. We first divide the class into groups of two to five students and prompt an on-line discussion of the subject matter within each group. The students make an initial blind post without reading posts from the other people in their group. Then all posts are made visible and the students discuss one another's answers. Finally, at the end of the unit, the students must each post a final answer, again without access to each other's final posts. This methodology allows us to obtain the students' initial understanding of the topic, follow the evolution of the students' knowledge during the unit and then get a final assessment of their conceptualization. This is all done in the context of normal classroom activities, lectures, in-class assignments, homework and testing. However, the discussion groups reinforce and supplement the other activities. They give the students a chance to express their understanding, teach each other and develop communication skills. The contents of the discussions can then be mined for evidence of particular misconceptions and how those misconceptions are (hopefully) changed into correct understanding. This evidence can then be reported to the teacher in a variety of ways.

The INFACT-Forum is the web-based discussion software we have developed in order to facilitate the pedagogy-via-discussion process. It has most of the features common to other discussion systems. Students and teachers can make posts, follow-up existing posts, view posts by thread, author, subject, etc. In addition there are a number of additional features that make INFACT-Forum particularly well-suited for the classroom. These include a tool for group-management, the ability to control the visibility of posts and both textual and graphical modalities.

In addition to textual posts, INFACT-Forum also includes a graphical posting mechanism called the "sketch tool". This is a simple drawing tool with functions such

as free-form drawing, circles, rectangles, lines, etc. Objects can be selected, moved or deleted after being drawn. Furthermore, sketches can be quoted in the forum, in a manner similar to quoting the text of a previous post. When sketches are quoted, each level of quotation is denoted by the color of that poster's additions to the sketch. Thus color in the sketch tool is analogous to the '>' prefix used by many text-based discussion systems. Finally, unlike other drawing tools, the result of a sketch tool session is a log of all the student's actions in the session, rather than a snapshot image. This allows the assessment process to include the use of information about false starts a student might have made in her sketch, as well as temporal ordering and gap information. False starts can give information about how a student is reasoning through a problem. Timing information can give an indication of what parts of a sketch the student considers first or believes to be more important.

3 Automatic Assessment

While INFACT-Forum and the sketch tool can provide a rich source of raw data from which to infer student concept development, it would be unreasonable to expect a teacher to go through all of the text and sketches produced by her students over a semester, searching for evidence of concept formation and transition. In order to reduce this burden, we have created a language for specifying "markup rules" that can be used to automatically assess posts, selecting pertinent parts of the text and associating them with common misconceptions from a pre-existing database. This rule language is a variant of regular expressions and allows for the specification of required keywords, ordering constraints and unordered combinations. For example, if a student posts about looping constructs, "I think if $N < 5$ the loop will go over it again", the rule learner might combine that with other posts to learn a rule like " $N < 5$ " AND "LOOP GO ... AGAIN" where ... indicates that some wildcard words can be skipped.

In addition, we are developing a system to learn markup rules. The system takes hand-assessed posts as input and uses machine learning to create the markup rules. The learning algorithm we use is a variant of the version space algorithm. It creates rules by generalization as new examples are seen and can learn rules from just a handful of examples. We have demonstrated that it is able to improve upon straight multiple choice tests in classifying student writing into different "common concept" classes. We are currently looking at ways to incorporate more sophisticated linguistic information to improve our performance in classifying text. We are also currently working on extending both the rule language and the learning algorithm to allow for assessment of student sketches.

We believe that the combination of INFACT-Forum and

the ability to learn markup rules for automated assessment provides a powerful means for teachers to get a better grasp on their students' understanding and therefore to teach more effectively. While we haven't done experiments to determine whether this has particular application to educationally disadvantaged students, it would seem that these students may have a harder time communicating their needs to teachers through traditional means, and may respond negatively to standardized tests. It stands to reason that an automated assessment technique specifically designed to give a teacher a detailed picture of the student's understanding would be especially valuable in this situation. While we haven't done experiments to test this hypothesis, we have used the system in a math and programming class for educationally disadvantaged students.

4 Application to Programming for Educationally Disadvantaged Students

We have used INFACT in a class that teaches mathematical and programming concepts using image processing. The class used another program we developed, called PixelMath. PixelMath is a calculator-like interface that allows students to enter mathematical formulae and Scheme programs and then observe how the image changes. For example, the formula $destination_pixel = source_pixel \times 2$ produces contrast enhancement, while $destination_pixel = source_pixel + 50$ results in a general brightening of the image. Using PixelMath, we teach about many mathematical and programming concepts and areas, such as polar coordinates, looping, cryptography, etc. Students respond well to pixelmath because they can immediately see the results of their work in a way that is fun, visually meaningful and aesthetic. It also provides with a means to express themselves creatively and come up with self-motivated tasks. A typical INFACT exercise might involve presenting students with a formula or program and ask them to discuss what they think it will do before running it, and explain how it actually works after running it.

The Pixelmath and INFACT systems are currently being used in GEAR-UP, a federally funded outreach program that encourages educationally disadvantaged students to aim to attend college. We have started doing manual assessment of PixelMath discussion logs and will soon begin using our rule learning system to generate assessment rules. We believe that with the ability to easily present teachers with detailed information about students' conceptual progress, teachers in schools with a large percentage of educationally disadvantaged students will be able to teach their students more effectively.