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ABSTRACT

This paper discusses a model of integrated instruction and assessment called SMART (Special Multimedia Arenas for Refining Thinking). SMART involves interactive use of the Internet and multimedia software. The Internet serves three important functions: it acts as a formative assessment tool by providing individualized feedback to students, creates a learning community by displaying data submitted by participating classrooms, and promotes discussion and reflection on important concepts. This paper discusses design features of the SMART model, including the Internet tools, and describes an example from middle-school science. Two figures present an excerpt from the SMART WWWeb macroinvertebrate catalog and an excerpt of student feedback from SMART WWWeb. (Author/DLS)

A Smart Curriculum for Middle-School Science Instruction: A Web-Based Curriculum Integrating Assessment and Instruction

Cognition and Technology Group at Vanderbilt
Vanderbilt University
United States of America
vyenj@ctrvax.vanderbilt.edu

Abstract: This paper discusses a model of integrated instruction and assessment called SMART (Special Multimedia Arenas for Refining Thinking). SMART involves interactive use of the internet and multimedia software. The internet serves 3 important functions: It acts as a formative assessment tool by providing individualized feedback to students, creates a learning community by displaying data submitted by participating classrooms; and promotes discussion and reflection on important concepts. We discuss design features of the SMART model, including the internet tools, and describe an example from middle-school science.

A primary focus of current research on alternative assessment involves the investigation of performance assessments for summative purposes, in particular for school- and system-level accountability [Baker & O'Neill 1994]. In this context, researchers have largely been concerned with the psychometric properties of performance assessments, notably, with issues that have arisen with respect to scoring, reliability, and validity.

While these issues are important, this paper concerns a different, often overlooked, function of assessment--to inform ongoing instruction and learning. There are several reasons for our focus on formative assessment[1]. One derives from our goal to transform classrooms into exciting learning communities that encourage students to achieve high levels of learning. We assume that teachers will make better instructional decisions by engaging in formative assessment, leading to improved student learning. We also assume that students will learn more and learn more deeply if they routinely engage in reflection and revision [Brown 1987].

In addition, formative assessment is fundamental to the new standards for instruction recommended by groups such as the [National Research Council 1996] and the [National Council of Teachers of Mathematics 1989]. These standards, based on social constructivist principles of learning, emphasize the importance of teaching in ways that promote deep understanding by students. Learning is no longer viewed as the accretion of new information. Instead, it is viewed as transformational process wherein concepts slowly evolve. In this milieu, teachers are being asked to adopt a more "cognitive" stance to teaching, for example, to be aware of the preconceptions that their students bring to new learning situations, to teach in ways that make students' thinking "visible" to other students and to help students reflect on and reconcile their conceptions with those of others. Formative assessment is an important part of this new repetoire of teaching behaviors.

In this paper we discuss a model of integrated instruction and assessment that we call SMART (Special Multimedia Arenas for Refining Thinking). SMART involves interactive use of the internet and multimedia software for assessment and instruction. In SMART the internet functions as both a teaching tool and an assessment tool. We first describe design features of the SMART model, and then discuss an example from the area of science. In this context we elaborate on details of the tools we developed for the internet.

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[1] We use the term "formative assessment" to refer to reflective practices by both teachers and students. Formative assessment by students is synonymous with self-assessment activities where students reflect on their conceptions. Formative assessment by teachers involves ongoing monitoring of students' knowledge and skills for purposes of instructional decision-making.

EVOLUTION OF THE SMART MODEL

The current SMART model derives from close to 10 years of research with students and teachers on ways to motivate and assess exceptional learning [Barron, Vye, Zech, Schwartz, Bransford, Goldman, Pellegrino, Morris, Garrison, & Kantor 1995] [Cognition and Technology Group at Vanderbilt 1994]. Our initial work focused on mathematics, and was concerned with an approach to instruction that we call "anchored instruction." In anchored instruction, teaching and learning are focused around complex problems or "anchors." The anchors are stories on videodisc (or CD-ROM) that each end with a challenge to solve. All of the data needed to solve the challenges are contained in the stories. The problems (a) are complex and require extended effort to solve (at a minimum, in the range of 3-5 hours for most middle school students); (b) are relatively ill-defined and require significant formulation prior to solving; and (c) have multiple viable solutions. The anchors are designed to engage students in authentic problem solving activities that highlight the relevance of mathematics to the world outside the classroom.

Our initial research on anchored instruction was conducted using "The Adventures of Jasper Woodbury", a series of video anchors developed by members of our Cognition and Technology Group at Vanderbilt. Findings indicated that working on multiple Jasper anchors over the course of a school year resulted in significant improvements in fifth and sixth grade students' problem formuation and problem solving skills. In addition, students showed positive changes in their attitudes towards mathematics [Pellegrino, Hickey, Heath, Rewey, Vye, & Cognition and Technology Group at Vanderbilt 1991]. Nonetheless, reports from teachers and students were unanimous in their strong dislike for our assessments (these assessments were conducted as part of our research and consisted of traditional paper and pencil mathematics story problems).

In thinking about how to re-design our assessments, we focused on assessment as it occurs outside of school settings. This was a valuable thought experiment in that it pointed to some important differences between assessment in and outside of school. First, in contrast to assessment in schools, assessment in professional contexts is usually external, and the products that are assessed are designed to contribute in some way to the profession. For example, when we write a paper or prepare a proposal for a presentation, our work is examined by expert individuals who are external to our department. Further, evaluation is not the sole purpose for generating products. Hopefully, papers and presentations contribute to knowledge, research and development in the field. In designing SMART we have tried to emmulate these features. Students' learning is directed toward culminating challenges that are evaluated by experts and have tangible consequences. For example, in some of our early work, students from different classes participated in live satellite programs in which they responded in real time to challenges related to Jasper [Kantor, Moore, Bransford, & Cognition and Technology Group at Vanderbilt 1992]. In recent work, the culminating challenges relate to project activities that follow Jasper. In one of the Jasper anchors students learn to design blueprints and a scale model of a playground and playground equipment, and in the project that follows, students are challenged to design blueprints and a scale model of a playhouse for kindergarten-aged children. Students present their designs to expert builders, and designs that meet prespecified evaluation criteria are entered into a random drawing. Designs selected during the drawing are built and donated to local kindergarten classes.[2]

Another way in which assessment in school and professional settings differs relates to opportunities that are available for improving one's work. In professional settings, there is a comittment to creating the very best product that is possible. We solicit input from people both internal and external to our organization, and we pay careful attention to performance standards set by experts in the field. We rely on this information as we draft and re-draft our work; reflection is a critical part of the process. Regrettably, in most classrooms, opportunities for feedback, reflection, and revision are almost non-existent. When students do receive feedback, it is usually in the form of a grade--rather than something that could help them enhance their understanding--and opportunities to improve their work are rare.

To promote self-assessment and reflection in SMART classrooms, instruction is explicitly organized around cycles of work and revision, and we have designed technology-based tools to that provide feedback to students and help them improve their work. Our research indicates that students who use these tools learn significantly more than students who go through the same instructional sequence for the same

amount of time, but who do not use the tools [Barron et al. 1995]. Initially, our tools consisted of videodisc programs and stand-alone computer applications. More recently, we have used the internet. In the sections below, we describe a just-completed experiment using our SMART WWWeb.

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[2] Space constraints preclude a comprehensive review of our research on SMART. We refer interested readers to [Barron, et al. 1995] and [Cognition and Technology Group at Vanderbilt 1994] for more information.

THE WEB AS A TOOL FOR TEACHING AND ASSESSMENT

As mentioned, in SMART students iterate through cycles of problem solving and revision. Students access our internet site, SMART WWWeb, during the revision phase. Essentially, SMART WWWeb serves 3 functions: First, it provides individualized feedback to students. In this way, the Web serves as a formative evaluation tool. The feedback suggests aspects of students' work that are in need of revision, and classroom resources that students can use to help them revise. The feedback does not tell students the 'right answer.' Instead, it sets a course for independent inquiry by the student. The Web feedback is generated from data that individual students enter. Essentially, data that is submitted by students in the brower is collected in a database on our server. Responses in the database are subsequently tagged with feedback that is sent back to the browser for students to print out.

The second function of SMART WWWeb is to collect, organize and display the data collected from the distributed classrooms. Data displays are automatically up-dated as new data are submitted to the database by students. We call this section, SMART Lab. The data in SMART Lab consist of students' answers to problems and explanations for their answers. Each class' data are displayed separately from the distributed classroom's data. This feature enables the teacher and her/his class to discuss different solution strategies, and in the process, address important concepts and misconceptions. These discussions provide a rich source of information for the teacher on how her/his students are thinking about a problem, and are designed to stimulate student reflection as well.

The third section of SMART WWWeb is Kids Online. Kids Online consists of explanations by student-actors. The explanations are text-based with audio narration. Still pictures of the presenters are also available. The explanations are errorful by design. Students are asked to critically evaluate the explanations,

and provide feedback to the student-actor. By including errors we are able to seed thinking and discussion on concepts that are frequently misconceived by students. At the same time, students learn important critical evaluation skills.

AN EXAMPLE FROM SCIENCE

Our current work on SMART is focused around a video anchor on CD-ROM entitled, 'Stones River Mystery' (hereafter SRM). SRM is an episode in the series "Scientists in Action" developed by Bob Sherwood and his colleagues at Vanderbilt [Sherwood, Petrosino, Lin, Lamon, & Cognition and Technology Group at Vanderbilt 1995]. SRM tells the story of a group of high school students who, in collaboration with a biologist and hydrologist, are monitoring the water in Stones River. The video shows the team visiting the river and conducting various water quality tests. (In our work we focus on benthic macroinvertebrate sampling and dissolved oxygen testing.) Students in the classroom are asked to assess the water quality at a second site on the river. They are challenged to select tools that they can use to sample macroinvertebrates and test dissolved oxygen, to conduct these tests, and to interpret the data relative to previous data from the same site.

When students begin working on macroinvertebrates, they are given a catalog of sampling tools/instruments. Many of these are "bogus" and collect the wrong kind of sample; others are 'legitimate' and will gather a representative sample of macroinvertebrates. The catalog items are specially designed to include contasting cases that help students discover the need to know certain kinds of information. For example, to use macroinvertebrates as indicators of water quality, one needs to collect a sample that represents the river's biodiversity, and as such, all types present need to be sampled. The following is the actual description of one of the items in the catalog, the TetraBen Laser Counter:

"Knowing the number of macroinvertebrates in your water is an important way to determine the health of your river. Collecting and counting these organisms can be a slow, tedious process. Modern science has revolutionized this process. The TetraBen Laser Counter lets you count macroinvertebrates without getting your hands wet! Simply scan the laser beam slowly over the water. The laser beam automatically counts the macroinvertebrates, and shows the total number on a built-in screen. The laser is completely waterproof and won't harm anything, living or non-living (and that includes macroinvertebrates and humans!) Simple, safe, and completely accurate!"

This is an example of an item that would collect the wrong kind of information; it counts the macroinvertebrates and ignores information about the types of macroinvertebrates in the sample.

Students are asked to choose and justify their choice of tool. To help them make their choices, they are provided with resources, some of which are on-line, that they can use to find out about river ecosystems, macroinvertebrates, and water quality monitoring. Once students have made an initial set of choices, they use SMART WWWeb. They enter their catalog choices (yes or no), and select justifications for their choices (why or why not choose that catalog tool). Figure 1. shows a portion of the internet "order form."

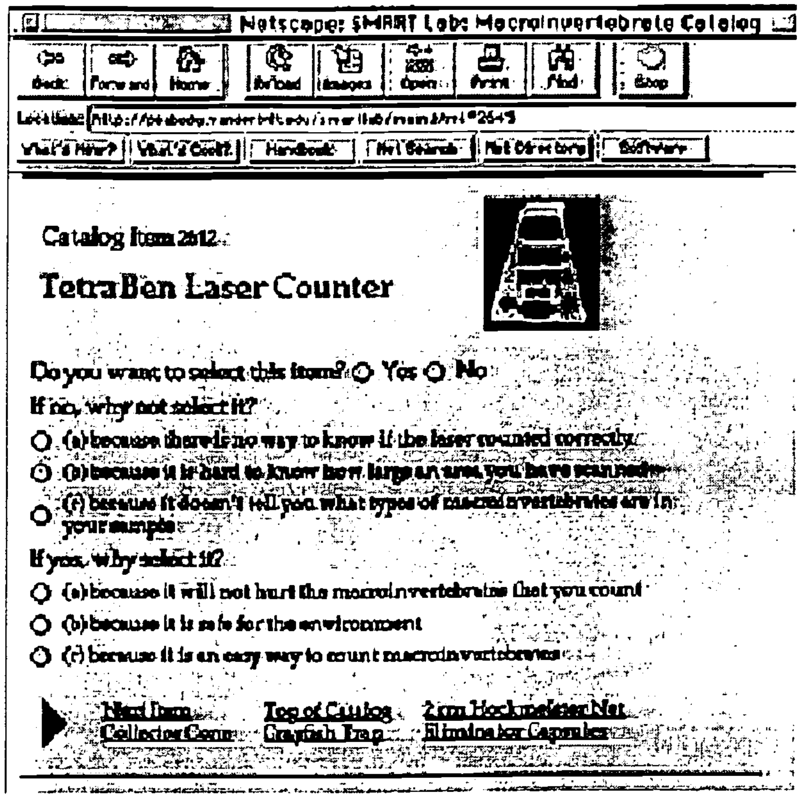

Figure 1: Excerpt from SMART WWWeb macroinvertebrate catalog

An important feature of the catalog and internet order form is that they are designed to reveal common misconceptions about ecosystems and pollution. For example, our pilot research on science showed that many students think that bacteria is harmful and pollutes rivers. We have tried to include catalog items and foils that expose particular misconceptions. In our macroinvertebrate catalog, we have a 'Super Collector Cone' that promises to collect macroinvertebrates and bacteria, and if students decide to order the Cone, one of the justifications that they can use is that 'bacteria pollute the water so it is important to catch them.'

Once students have submitted their catalog order on-line, SMART WWWeb sends them individualized feedback. Figure 2. shows a segment of SMART WWWeb feedback.

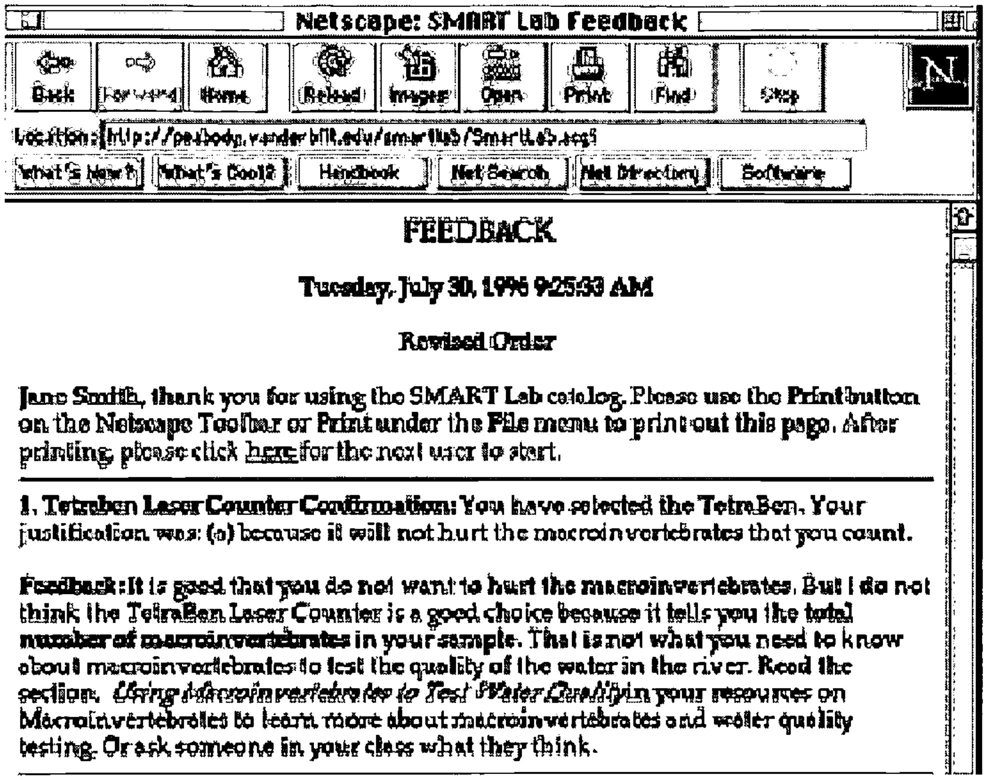

Figure 2: Excerpt of student feedback from SMART WWWeb

The feedback that students receive from SMART WWWeb highlights why the selected tool is problematic, and suggests helpful resources (sections of on-line and off-line resources, hands-on experiments, and peers). This form of feedback is similar to the feedback that we used in our work on mathematics, and that our research suggests can be an effective stimulus for guided inquiry and revision by students.

SMART Lab and Kids Online are accessed next. Teachers use these sections to engage their classes in critical discussions. In the process, teachers and students discover how class members are thinking about issues. For example, SMART Lab summarizes the catalog choices and justifications submitted by each class and displays these data with the same data aggregated across all classes. Classes can discuss how their data are similar and different from the distributed class' data. Or they can discuss whether they agree with the most popular reasons given for choosing catalog items. In Kids Online, student-actors discuss their own catalog choices. We purposefully include reasoning errors in these presentations, and target common misconceptions that students have about river science. In the course of discussing Kids Online, students confront and hopefully debunk these misconceptions.

After visiting the internet, student work to revise their catalog selections. They have opportunities to look up text-based resources that provide more in-depth information about science content relevant to various choices. For example, the text resources explain the need to break macroinvertebrates into categories, namely, pollution tolerant, somewhat pollution intolerant, or pollution intolerant. Students can use this information to understand why the TetraBen Laser Counter, which counts all macroinvertebrates but does not sort them, does not provide the kind of data they would need.

After revising their thinking, students again visit the SMART WWWeb and make new choices of catalog items and new justifications. They can then see summarized data from their class and other classes and see how the data have changed. Following the correct choice of an appropriate object (in this case the .5mm Hochmeister Kick Net), students work with a CD-ROM simulation that allows them to 'see' a sample of macroinvertebrates, calculate a water quality index, and compare their results with baseline data from previous years. Although each student gets a different sample of macroinvertebrates, each set of data shows that there is a serious absence of pollution sensitive macroinvertebratesóhence something is wrong.

The SMART Challenge continues by next having students choose items for doing an oxygen test. Again, they make their choices via the Web and see data that summarizes the choices of other classes. Also, students gain access to text-based resources (which sometimes reside in other internet sites) that help them understand the science underlying various choices. And they eventually do some experiments on their own. For example, students are encouraged to test the amount of dissolved oxygen in a tank of water prior to putting fish in it and after the fish have lived in it for at least one day. With appropriate testing instruments, data show that there is less dissolved oxygen in the water after the fish have been there. For classrooms that cannot do actual tests, simulated, computer-based tests are available. All of these activities are preliminary to project-based activities in which students conduct water quality testing at a local river and present and publish their findings for the local Water Quality Management Department.

As noted above, our work with SMART WWWeb challenges is just beginning: The Stones River Mystery challenge is the first we have attempted. By providing students and teachers with frequent opportunities for formative assessment and revision, we believe that we can better help them reach the goals of the National Standards in areas such as science and mathematics. Our plans are to create additional internet-based challenges that focus on 'big ideas' in areas such as mathematics, social studies, and literature.

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