Use of Technology to Support Scientific Inquiry and Reflective Assessment

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Introduction

Our model of learning scientific inquiry through reflective assessment is implemented in a dynamic website called the Web of Inquiry. The main purpose of the website is to provide spaces for teachers to create and score science inquiry projects, for students to complete and self-assess science inquiry projects, and for researchers to analyze project and assessment outcomes. Grades 5-8 science classes are currently targeted, although the website can accommodate any grade level. The functional design of the website is based on constructivist and constructionist principles (Papert and Harel, 1991), essentially giving students as much control over their learning as possible, providing flexible and adjustable scaffolding (in the form of advice and tools for learning), accounting for individual differences such as learning goals or advice preferences, and providing students with projects to complete or things to build.

Two previous prototype systems were developed and tested with middle school science classrooms. The SCI-WISE system was a stand-alone multimedia program using modifiable "advisors" (software agents) that allowed students to modify and select advice while working on science inquiry projects in an online workbook (Shimoda, White, and Frederiksen, 2002). One result showed that students with knowledge-oriented goals learned more and used the modifiability more those with task-completion goals. The Inquiry Island/Many Minds system was a stand alone Java-based system that integrated in-depth "advisors" and tied advice to self assessment while students worked in an online notebook (White, Frederiksen, Frederiksen, Eslinger, Loper, and Collins, 2002).

Figure 1, the Web of Inquiry home page, shows the main links. These include user log in, the main home pages for each user type, information, links, and contacts. The four main user types are teachers, researchers, individual students, and project teams (one or more students). When logged in, the users are taken directly to their home page which presents the links and workspaces available to that user. On their home page, all users can update personal information, which varies according to user type. Teachers and researchers can create or modify project templates, set up and administer a class, set up projects for that class, respond to student discussions, and view and score projects. Teachers and researchers, if approved, can create and modify inquiry advice and tool help. Students can sign up for a class, start a project, and go to projects they have previously started. Project teams can go to the tasks and subtasks for their project, see advice, and use inquiry tools.

The Web of Inquiry is implemented on a set of servers running SQL Server 2000 (a relational database), JavaScript, and ColdFusion (tag-based, markup-language middleware). ColdFusion integrates templates, user input, and the results of SQL (Structured Query language) queries to the database to create HTML pages which are displayed on the user browser. Privacy is assured through user login and password

control. The main modules in the Web of Inquiry are a suite of advisors and advisor editor, a project template builder, a project workspace, a set of inquiry tools, and a project assessment workspace. Each is described in more detail in the following sections.

Project templates

Project templates are a set of elements that student teams use to complete their projects. A template consists of top-level, task, and subtask instructions; assessment items and rubrics or text boxes; and links to advisors and advice. The Web of Inquiry's project template builder provides forms and selection options (Figure 2).

Top-level, task (e.g., Figure 3) and subtask information and instructions provide the basic requirements for completing the project. Any number of tasks may be created, and under each task, any number of subtasks. For example, the six tasks for the template named "Revised Workbook Sept 2005" are: Question and Theorizing, Forming Hypotheses, Investigating Our Hypotheses, Analyzing Our Data, Synthesizing, Extending Our Theories. Subtasks under Question and Theorizing are: Our Research Topic, Our Theories, Possible Questions, Our Specific Question.

Template builders can choose advice for each project template element, including assessment items and rubric items, from a pre-developed suite of advisors (described in the following section). In general, each advisor corresponds to an inquiry task (see Figure 4), or to a cognitive or social skill. For the project top level and each task, a primary advisor and any number secondary advisors can be selected. For example, Quentin Questioner is the primary advisor for the Questioning and Theorizing task, secondary advisors might be Ingrid Inventor who helps with brainstorming and Keiko Collaborator who helps with teamwork in developing a research question. For selecting specific advice from an advisor, a list of all the advisor's advice is presented.

For each top-level, task, and subtask element, assessment items can be created. Assessment items include goal achievement, standards-based, analytic, or open. Goal achievement assessments are selected from an advisor's goal criteria, for example, one of Quentin Questioner's goal assessments is, "Have you chosen a question that is possible for you to investigate, and will help you test your theories?" Standards-based assessments are usually taken from an established set of state or federal standards. Analytic assessments are usually specific to the project. Open assessments can be of any origin or purpose.

Assessment formats can be radio button (one item selection), checkboxes (selection of multiple items), or text/media (open-ended text or non-text media such as images, sound, or video). Assessment items are assigned to one or more of the assessors or scorers, including self-assessment of student teams or individuals, peer assessment, and teacher and researcher assessment. Figure 5 shows a partial page used in modifying assessment items.

Inquiry advisors and advice

The Web of Inquiry advice currently available includes task advisors based on the inquiry cycle (e.g. Quentin Questioner), cognitive advisors (e.g., Ingrid Inventor), social advisors (e.g., Keiko Collaborator), metacognitive advisors (e.g., Ricky Reflector), and system development advisors (e.g., Imogene Improver). Advisors' advice includes goals, strategies, motives, examples, concepts, and plans. Each advisor has a top-level page with links to main categories of advice, and also an "autobiographical" About Me. The About Me narrative presents a personal dialogue about the skill incorporated in the advisor. Figure 6 shows an example of the advice format. An advisor editor allows advisors to be created and modified. Rules for establishing when advisors or advice is displayed are created in the project template builder. The current set of advisors are found in a virtual space called "Inquiry Island."

Project workspace and tools

Students record their work on science inquiry projects in the project workspace. As students work on a task or subtask, they have access to specific advice selected for the context. Figure 7 shows the project instructions, project work, navigation, advisors, advice, and some of the tool icons.

For each task or subtask, students or teams can enter and modify text. Also displayed in the project workspace are a team's links to non-text media including images (JPEG, GIF, PNG), video (QuickTime, MPEG, WAV), sound (MP3 or video formats), and PDF documents. Currently, these types of files must be sent to Web of Inquiry administrators who check the files for format, size, and viruses before and uploading them to the server. This procedure will eventually be automated so students can upload their own files.

Other features of the workspace include advice icons that link to relevant advice. The advice title is displayed when rolling the cursor over an icon. Clicking on the main and secondary advisors for the task opens the advisor's top-level page. Two navigation lists allow students to link to other tasks or subtasks, or go to higher level pages such as the class home page.

A set of tools help students complete tasks and assess their work. The tools currently available include:

- Thinker Tool
- Project Progress Tool
- Discussion Tool
- Project Report Tool
- Data Entry and Table Tool
- Graph Tool
- Inquiry Island link

The Thinker Tool (Figure 8) is essentially a blog builder. Students can enter text, which is date stamped and displayed in reverse chronological order, that is, the latest entry first. This tool allows students to record thoughts, problems, solutions, or other documentation not intended to be included in the actual project work. The Thinker Tool

entries are intended for team member use only, although the entries can also be read by teachers and researchers scoring the projects.

The Project Progress Tool (Figure 9) tracks team progress through tasks and assessments. If a student workspace contains text, media, or data links, the progress is noted with a check mark. Obviously, the program doesn't know if the task or subtask is completely finished, only if something has been done. If any self-assessment items have been completed, they are also indicated with a check mark.

The Discussion Tool (Figure 10) provides project teams with a space for threaded discussion with other teams in the same class and the class teacher. Teams create "discussion starters," which can be any form such as requests for feedback or help. The discussion starters may also be specified by the teacher or other project template developer. Other teams or the teacher can reply to discussion starters. The main purpose of the Discussion Tool is to provide another means of reflective assessment, as well as to facilitate communication and interactive aspects of scientific inquiry. Researchers or other scorers can view the discussion threads but can't participate in the dialogue.

The Project Report Tool (Figure 11) creates a printable report of student work. The report includes task and subtask text, images, tables, and graphs. Versions of the report can be saved, however, they are HTML pages that can't be modified. In other words, only the current project work can be modified. A team's current report can be viewed by other teams in the class, accessed through the Discussion Tool. Teacher and researcher scorers can also view the reports. In the Project Report Tool, students can also view a single-page compilation of all the project instructions, so that they can see the entire project on one page. .

The Data Entry and Table Tool (Figure 12) allows teams to create variables, enter data, and build data tables. Any number of variables can be created, and can be numeric or non-numeric variables. For numeric data, a running average is calculated. Data tables are simply created by selecting which variables are to be included in the table. A heading or title for the graph must be added. Similarly, the Graph Tool (Figure 13) is used to create bar or line graphs from data tables. Axis labels and gridline information for formatting the graphs must also be entered.

A link to Inquiry Island (Figure 14), the virtual location of the advisors, is also part of the tool set. The Inquiry Island link goes to a graphic that displays the island with click-able areas for each task advisor and areas for cognitive, social, metacognitive, and system advisors. A text list of the advisors is also available.

The tools are supplied with a link to Help, which provides more detailed instructions on using the tools. Other tools being developed include an Inquiry Dictionary, a Model Builder, and an Argument Constructor.

Assessment workspace and project scoring

The assessment workspace (Figure 15) contains the self-assessment items created in the template builder for the top-level project workspace and each task and subtask. For each assessment item, the main instructions are displayed. When the students work on the item, the rubric items or text entry box is displayed. Advice icons are available for an assessment item, as well as for each rubric item for radio button or checkbox formats, if

established in the project template builder. If the students have previously completed the item, the previous selection or text is displayed. The previous assessment can be modified. As students complete self-assessment items, the results are also available in the Project Progress Tool.

Teachers and researchers score projects by accessing classes and projects through a "project scoring" link found on the teacher and researcher home pages. Scoring is accomplished through an assessment tool that displays all assessment items, or group by type (i.e., goal, standards, analytic, or open). Assessment items are not necessarily the same for teams and teachers and researchers, as each may have different items created in the project template builder. After scoring, data from the all assessments can be selected and formatted for use in statistical software.

Conclusion

The Web of Inquiry provides a set of tools and functionality that allows a constructivist approach to learning scientific inquiry. The first dimension, giving students as much control over their learning as possible, is accomplished through providing an open system allowing students to explore, to use their own initiatives, and to use the reflective assessments to evaluate their progress. Of course, the amount of student and instructor control can vary from classroom to classroom, depending on the teacher's use of the system.

The second dimension, providing flexible and adjustable scaffolding, is accounted for in the form of advice and tools for learning. Inquiry Island allows students to explore the entire space of advice, while offering suggestions for relevant, specific advice, for each task or subtask. Also, collaboration between teams members, between teams, and between teams and teachers are facilitated through the Thinker Tool, the Discussion Tool, and scoring and assessment functions.

The third dimension, accounting for individual differences such as learning goals or advice preferences, is accomplished through the flexibility of the workspaces and tools. A wide range of advice is available, allowing students to choose the most relevant for their current situation. The tools allow student control over their use in time and in extent, for example, the Discussion Tool is available whenever the students feel the need to communicate, rather than at specific points on the project.

The fourth dimension, providing students with projects to complete or things to build, is the basis of the Web of Inquiry's focus on learning through science inquiry projects. Within the projects, the students are not only building understanding and science knowledge through inquiry, but building cognitive and social tools to learn in other contexts.

References

Papert, S. & Harel, I., (1991). *Constructionism*. Bristol, UK: Ablex Publishing Corporation.

Shimoda, T. A., White, B. Y., & Frederiksen, J. R. (2002). Student goal orientation in learning inquiry skills with modifiable software advisors. *Science Education*, *86*, 244-263.

White, B., Frederiksen, J., Frederiksen, T., Eslinger, E., Loper, S., & Collins, A. (2002). Inquiry Island: Affordances of a Multi-Agent Environment for Scientific Inquiry and Reflective Learning. In P. Bell, R. Stevens and T. Satwicz (Eds.), *Proceedings of the Fifth International Conference of the Learning Sciences (ICLS).* Mahwah, NJ: Erlbaum.

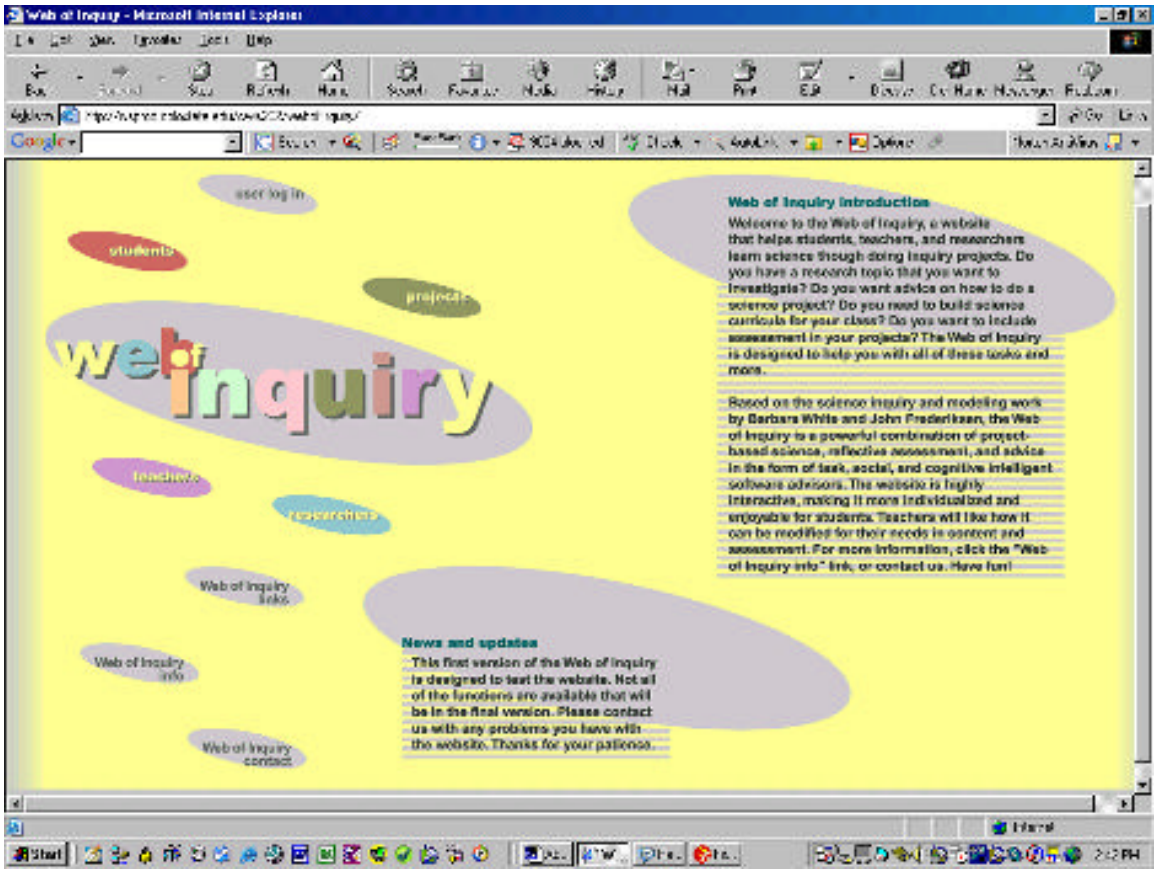

Figure 1. Web of Inquiry home page (http://wsprod.colostate.edu/cwis232/webofinquiry/)

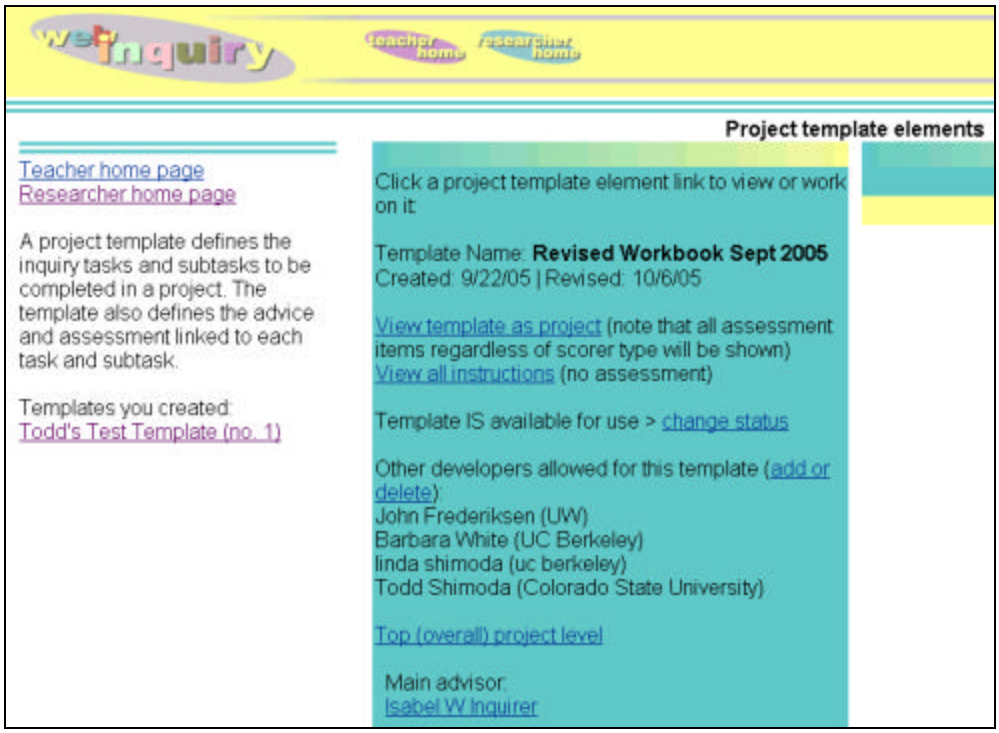

Figure 2. Project Template Builder main page

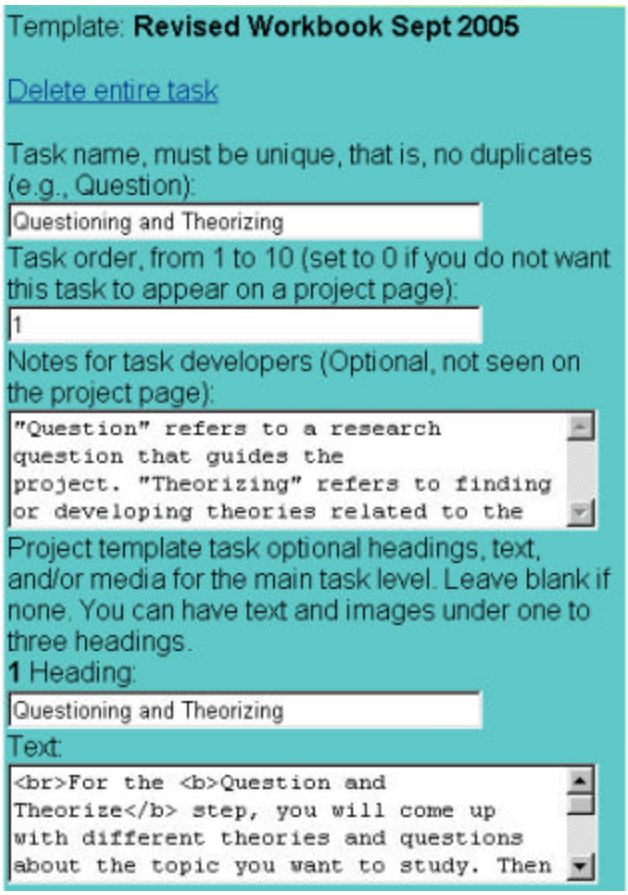

Figure 3. Project Template Builder task

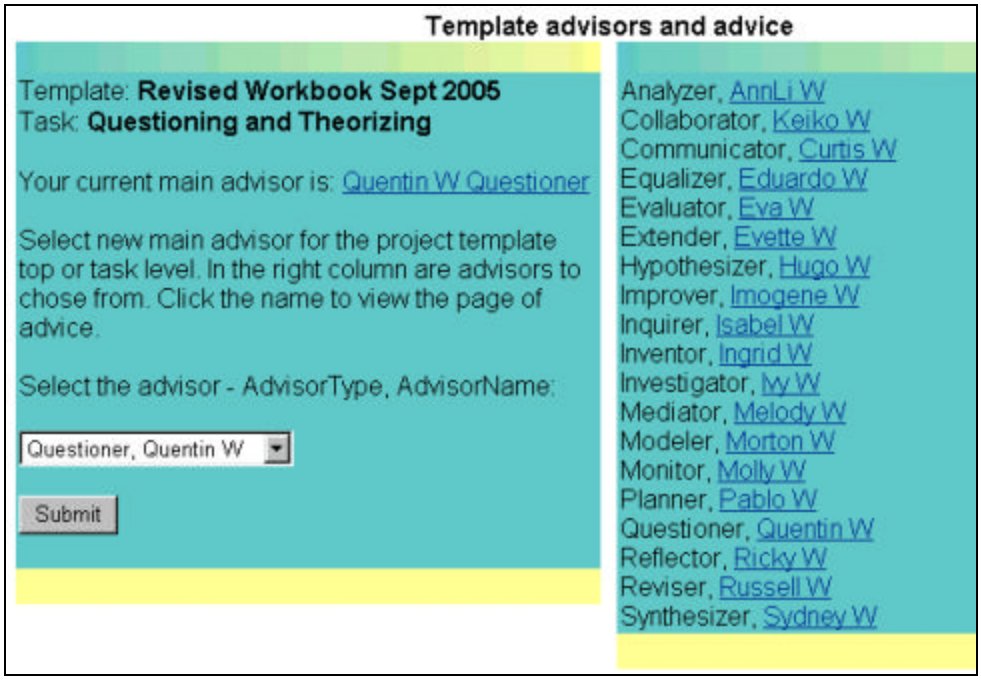

Figure 4. Project Template Builder advisor selection

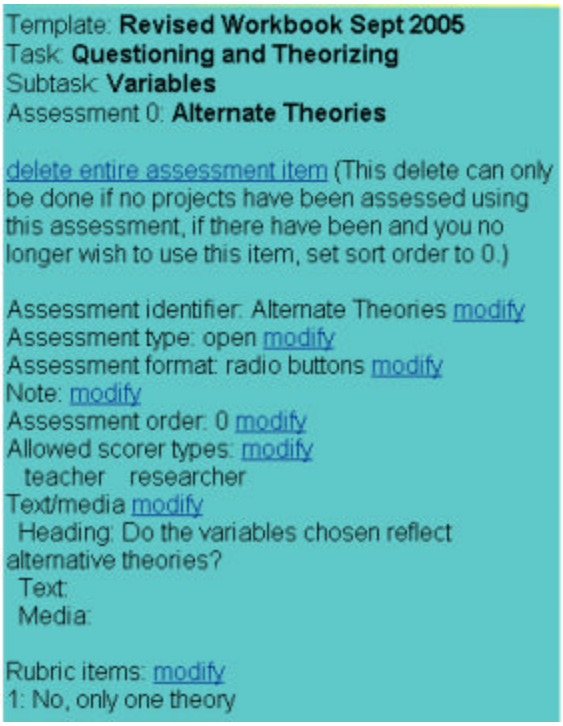

Figure 5. Project Template Builder assessment modification

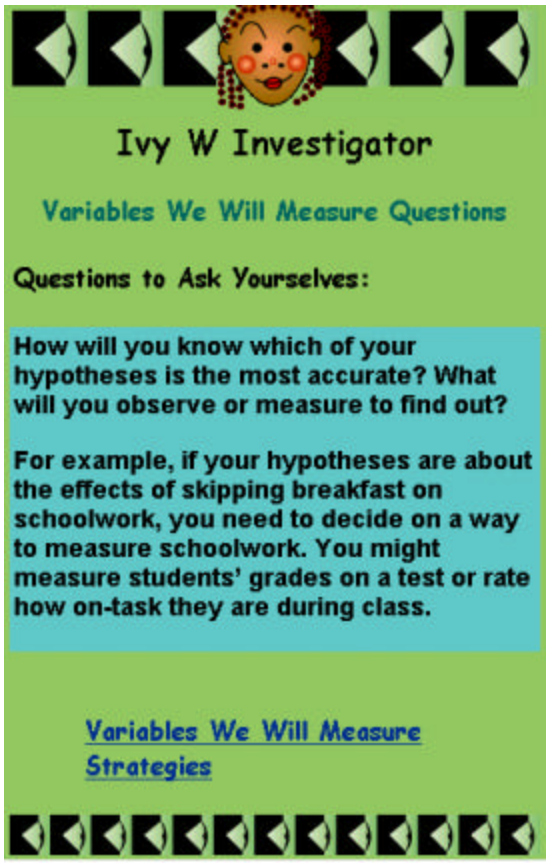

Figure 6. Advice format

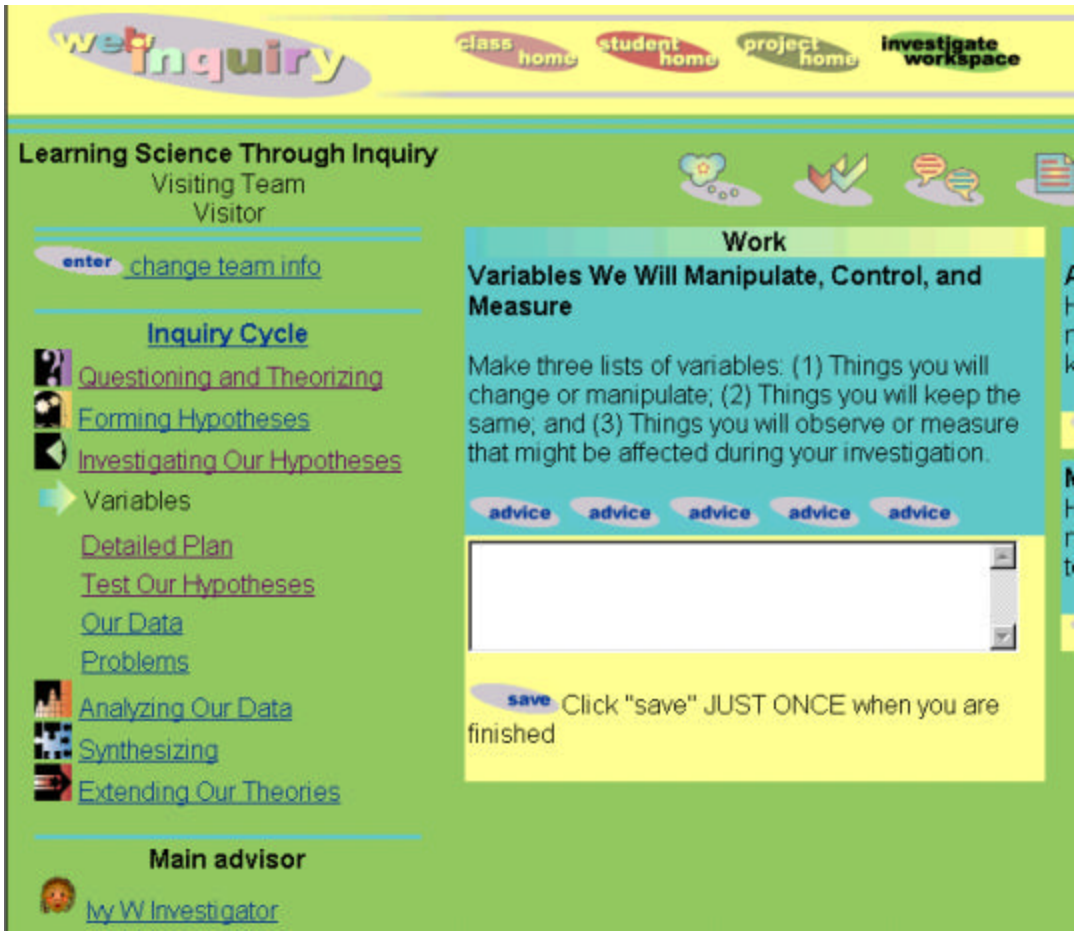

Figure 7. Project workspace

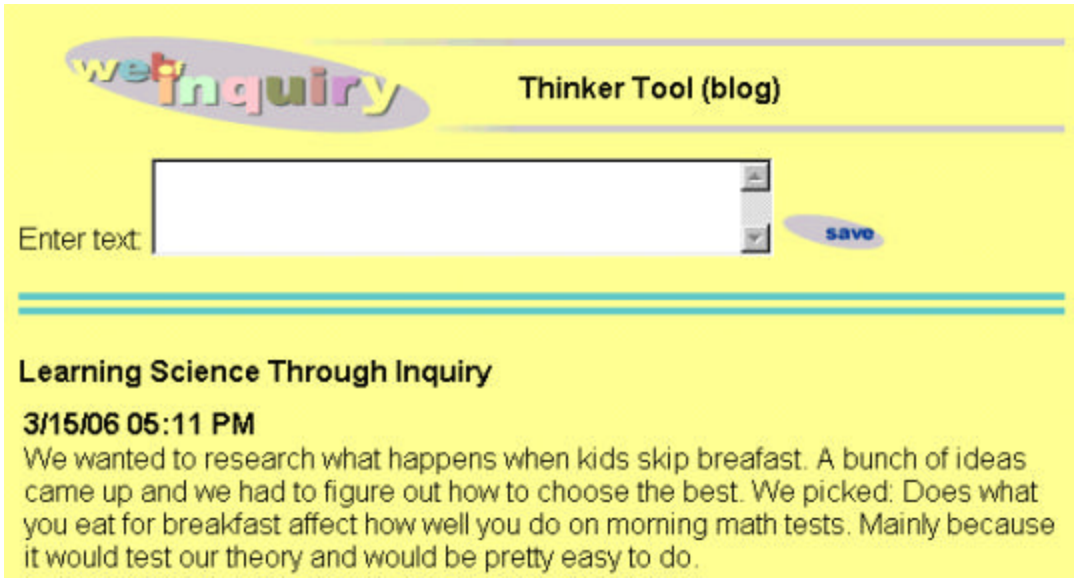

Figure 8. Thinker Tool

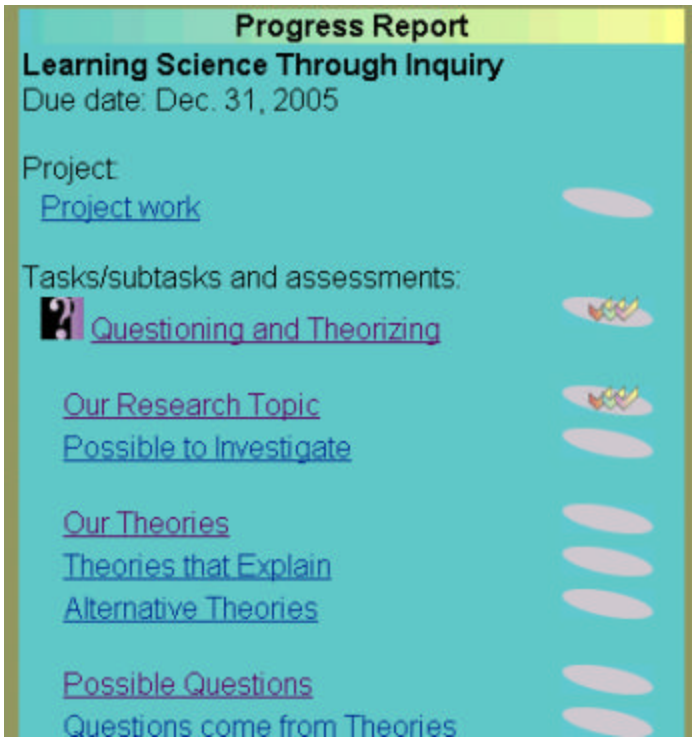

Figure 9. Project Progress Tool

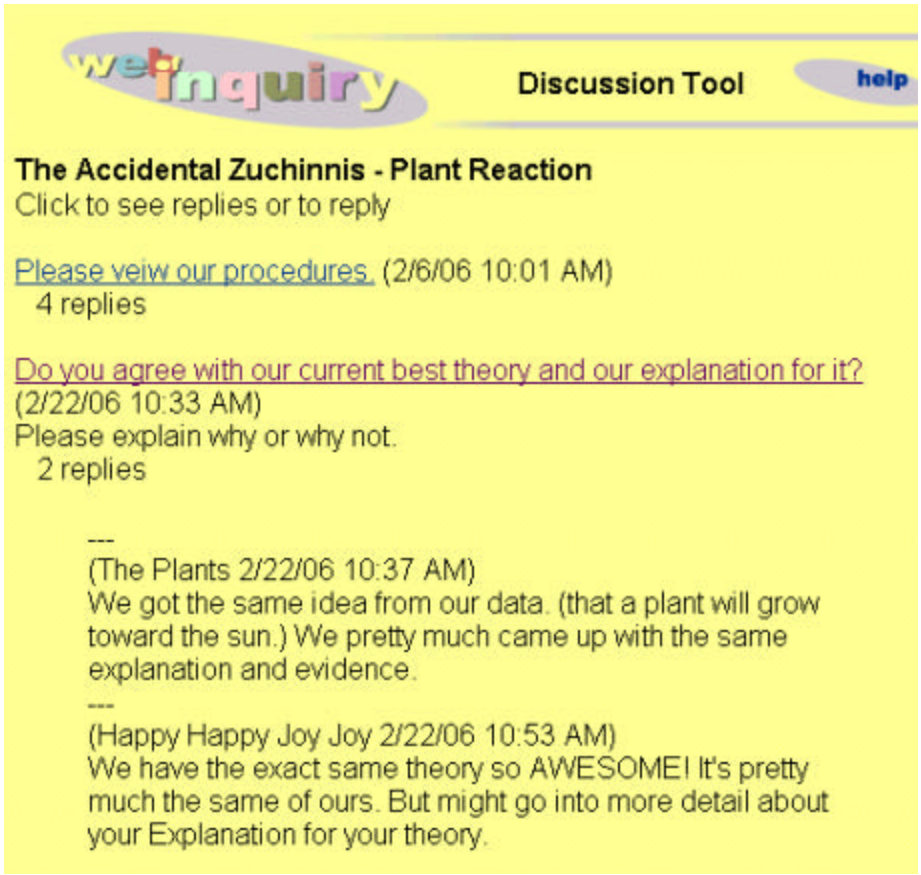

Figure 10. Discussion Tool

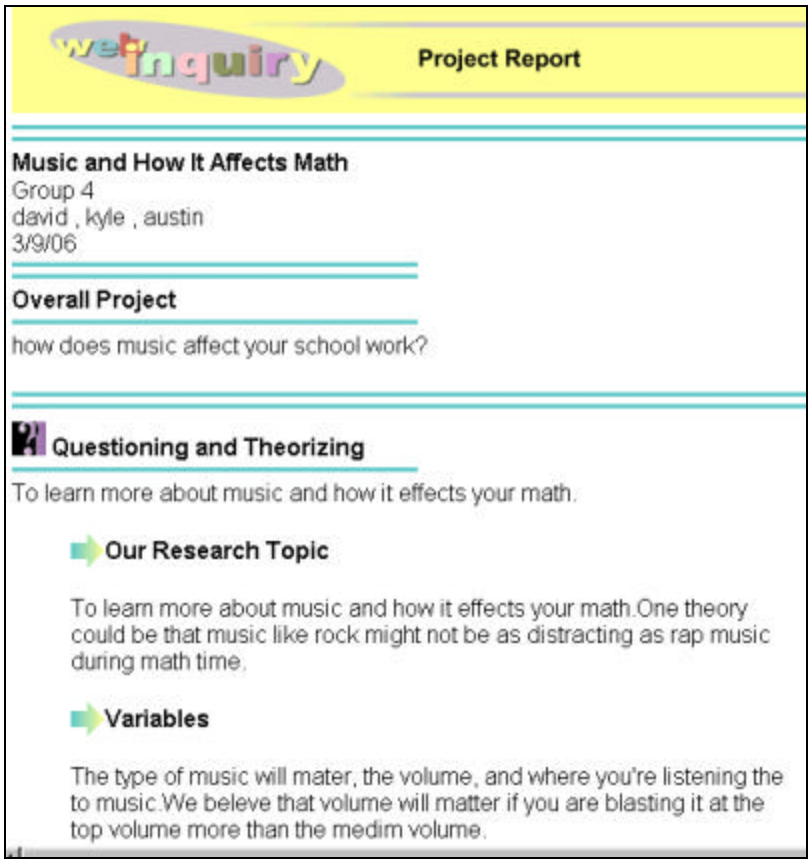

Figure 11. Project Report Tool

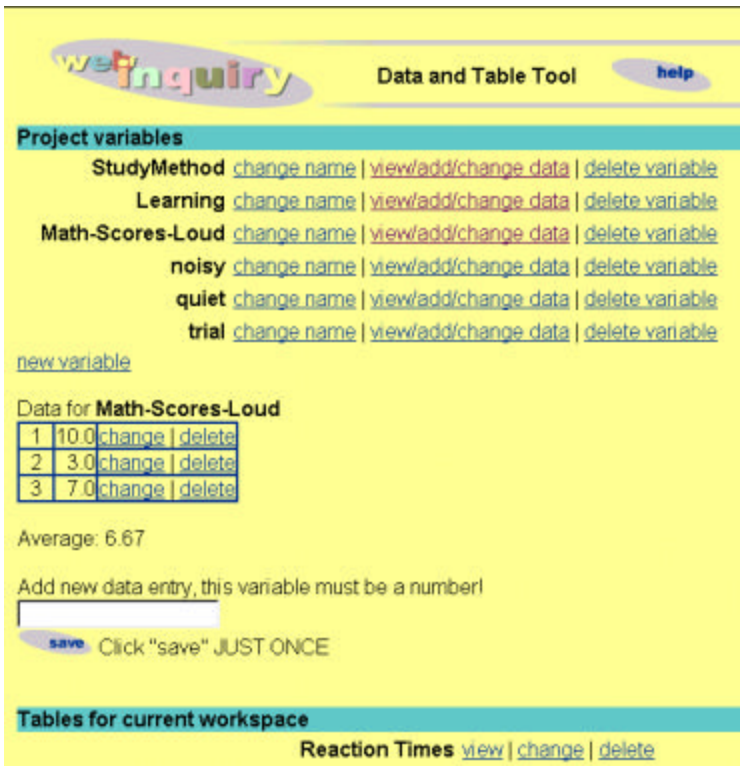

Figure 12. Data Entry and Table Tool

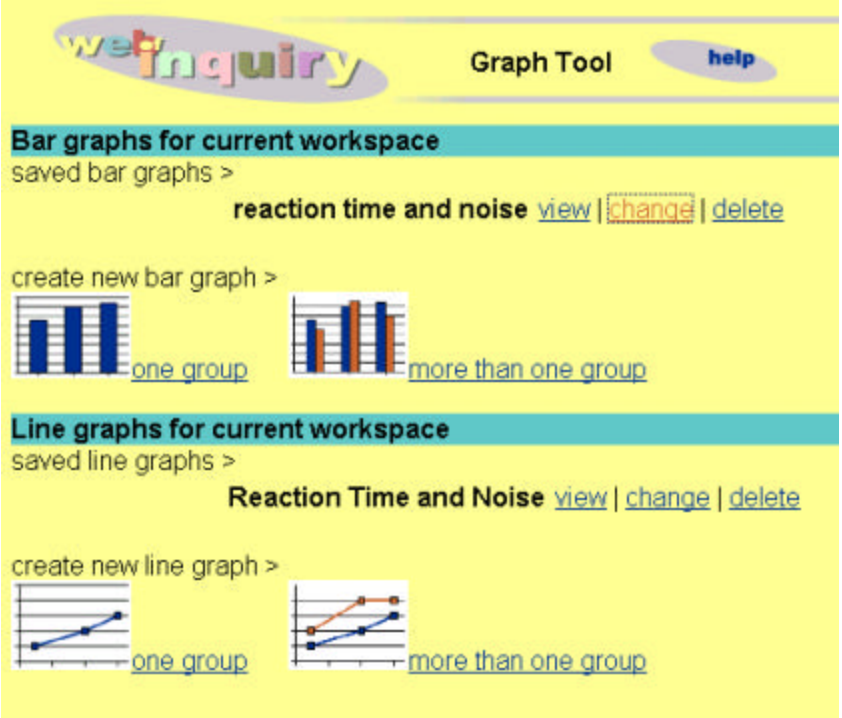

Figure 13. Graph Tool

Figure 14. Inquiry Island

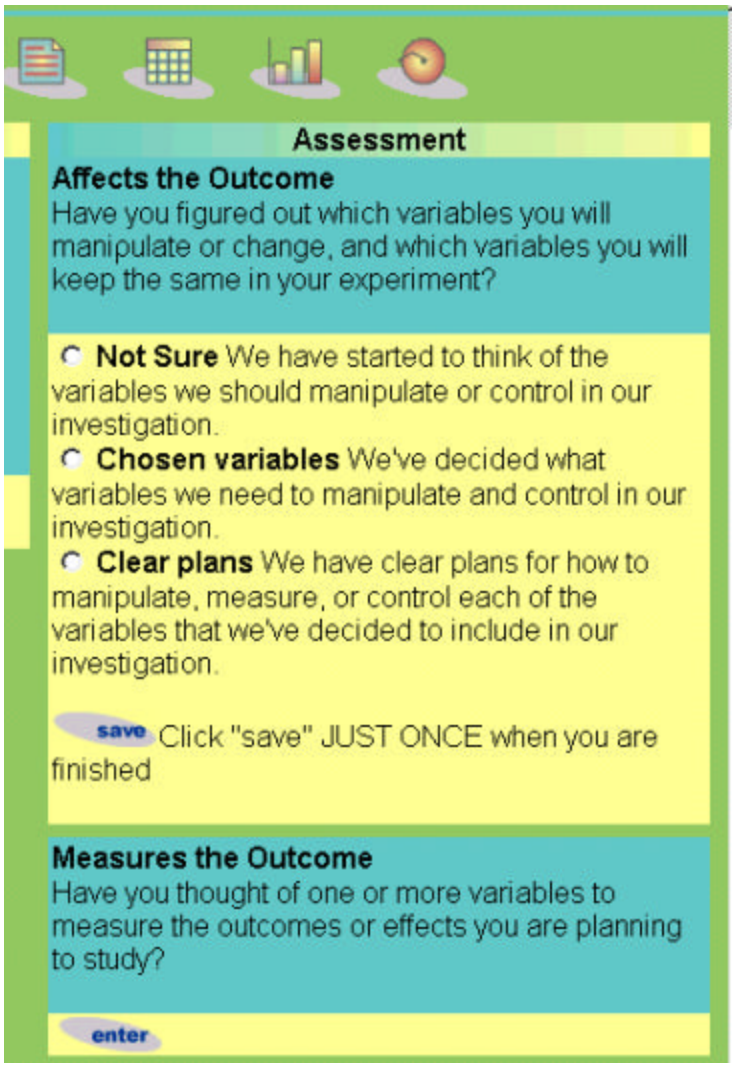

Figure 15. Project assessment space