

## Chapter 1: The TRE Construct Domain and Problem-Solving Scenarios

### The TRE Construct Domain

There is no existing NAEP framework for the domain of “Problem Solving in Technology-Rich Environments.” As a result, that construct domain needed to be defined by the TRE team—i.e., the research scientists, test developers, and a Development Committee of technology and science education advisors who worked on the project (see appendix A for Development Committee membership). The domain definition process involved drawing upon a variety of sources, including national education standards in technology and science, relevant research literature, and the expertise and experience of the Development Committee. The resulting domain conceptualization, described below, served as the basis for creating the experimental measures used in this demonstration project. Readers should recognize that this conceptualization process did not involve the broad representation of diverse constituencies typical of NAEP assessment frameworks, and the conclusions drawn from TRE study results should, therefore, be limited accordingly.

The domain of “Problem Solving in Technology-Rich Environments” (TRE) was conceptualized as the intersection of content areas and technology environments. Problem solving with technology can occur in a range of content areas, such as biology, physics, economics, and history. Similarly, various technology environments such as databases, text editors, simulation tools, dynamic visual displays of information, spreadsheets, and presentation tools can be used to solve problems in these content areas.

The TRE team chose to sample from the universe of content areas and technology environments so that one content area—the physical science associ-

ated with helium gas balloons used for space exploration—carried through different technology environments. Using the same content across technology environments is consistent with the emphasis in the research literature on extended problem solving because the student remains situated in the same context throughout the assessment and, thus, has greater opportunity to apply response processes that might not be engaged by presenting a series of more elemental, unrelated tasks (Baxter and Glaser 1998; Nichols and Sugrue 1999). In addition, emphasizing content expresses the view that, in real-world settings, problem solving with technology is driven by the problem, and not by the technology.

Science was chosen as a content area because computers are used routinely as scientific problem-solving tools in advanced academic and work environments, and because these tools are increasingly being used in secondary school for instructional purposes. Further, a range of state middle school science standards, the National Education Technology Standards, and the National Science Education Standards typically cite scientific inquiry, problem solving with technology, and the use of simulation as key proficiencies (International Society for Technology in Education 1998; National Academy of Sciences 1996). The topic of helium gas balloons was selected because it is a working application of fundamental physical principles, like buoyancy and its relationship to mass and volume, in a context expected to be engaging to middle school students.

Figure 1-1 represents the TRE conception of problem solving with technology. In the figure, the TRE measure is indicated within the content area of phys-

**Figure 1-1.** Domain conception for problem solving in Technology-Rich Environments, grade 8: 2003

Content area	Database	Text editor	Simulation	Dynamic visual display of information <sup>1</sup>	Interactive feedback	Spreadsheet	Presentation and communication tools
Biology							
Ecology							
Physics							
Balloon science <sup>2</sup>							
Economics							
History							

<sup>1</sup> A dynamic display changes in real time.

<sup>2</sup> The shaded area indicates the coverage of the scenarios.

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2003 Problem Solving in Technology-Rich Environments Study.

ics. The specific scenarios developed for the current study incorporate several technology uses within the same problem context, denoted by the shaded area. Note that very different measures would have resulted if the focus had been on a single technology use across different content areas. Also note that, because the measure is an example, it covers only a small portion of this hypothetical problem-solving domain, too small for any inferences to be made from study results to performance in problem solving in technology-rich environments generally.

In developing the Simulation scenario, the TRE team drew on the research of Glaser and associates, as well as that of others (Raghavan, Sartoris, and Glaser 1998; Schauble et al. 1991, 1992; Shute and Glaser 1990, 1991; White and Frederiksen 1998). The common theme running through this research is the “discovery environment.” A discovery environment is a “microworld” where a student can experiment to construct an understanding of some underlying phenomenon, often physical in nature. Although these environments have primarily been used for instructional purposes, they also hold promise for assessment.

Among the more compelling models of such environments were the “Deformed Frog” scenario from the Knowledge Integration Environment (KIE) project at the Graduate School of Education at the University of California at Berkeley, which involves students in researching web-based information and testing hypotheses about what is causing deformation among frogs in North America (KIE 1997), and “Smithtown,” developed at the University of Pittsburgh (Shute and Glaser 1990). In Smithtown, students learn basic macroeconomics concepts and scientific inquiry skills by conducting experiments in a simulation setting. Therefore, Smithtown was very helpful as a model for how to organize and present a computer-based tool for making and testing hypotheses. The “Jasper” series, developed by the Cognition and Technology Group at Vanderbilt University (although not a computer-based microworld), was an interesting model in which students must discover underlying mathematics and science concepts to solve hands-on design problems (Learning Technology Center 1992). While these projects are set in a variety of content areas, all of them offer students opportunities and sufficient context to form and test hypotheses and draw conclusions about underlying phenomena.

Research done by Schauble was particularly informative for the kinds of reasoning and strategies the TRE team wanted to measure, and what the team sought to avoid, namely, laboratory exercises in which

students “follow prescribed procedures and hope to achieve the right answer” (Schauble et al. 1995, p. 133). This kind of activity is also criticized in the NAEP Science Framework:

Many...so-called performance assessment scenarios...[are] reduced to “follow-the-instructions” problems. No inferences about a student’s knowledge of science or its tools and procedures can be drawn from such exercises. (National Assessment Governing Board 2000, p. 33)

Instead, the TRE team sought to design scenarios that would feature (as far as possible in a large-scale assessment—versus a classroom—context) the kind of exploration characteristic of real-world problem solving.

Finally, the Search scenario was based on research about proficient and novice electronic information-finding behaviors of adolescents and adults (Fidel et al. 1999; Klein, Yarnall, and Glaubke 2001; Salterio 1996; Schacter, Chung, and Dorr 1998). Of particular use was a web-search study carried out by the National Center for Research on Evaluation, Standards, and Student Testing (CRESST), which suggested behaviors that might be used as markers of search proficiency (Klein, Yarnall, and Glaubke 2001, 2003). As with the Simulation scenario, the various documents describing standards for students’ science and technology skills were also relevant because of their references to electronic information search as a desired proficiency (ISTE 1998; Riley, Holleman, and Roberts 2000).

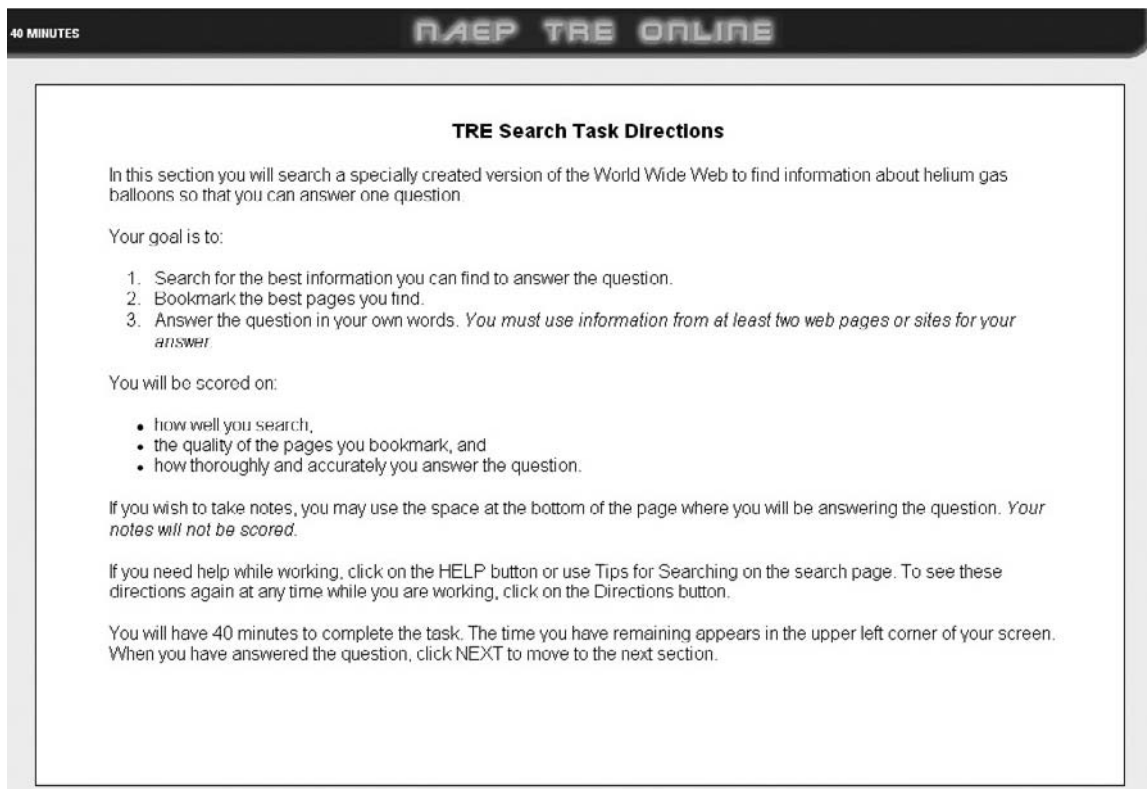
### **The TRE Problem-Solving Scenarios in Detail**

The following section presents the two TRE scenarios in detail as a context for understanding the study. The discussion of the design and components of each scenario is accompanied by selected screen shots.

#### **The TRE Search Problem-Solving Scenario**

Figures 1-2 through 1-5 display the progression through the Search scenario. Students first received a set of prior science and computer knowledge questions (shown in appendix D) and worked through a brief (5 minute) tutorial (not shown) to introduce them to the Search interface. They were then shown the scenario directions presented in figure 1-2. The prior knowledge questions were intended to give a rough measure of students’ degree of familiarity with the science and computer-related concepts being assessed. Although the Search interface was designed to be as close to a standard web search browser as possible, some features—such as buttons for reading directions and accessing the box to enter answers—are particular to the TRE software.

**Figure 1-2.** Computer screen with directions for TRE Search scenario, grade 8: 2003



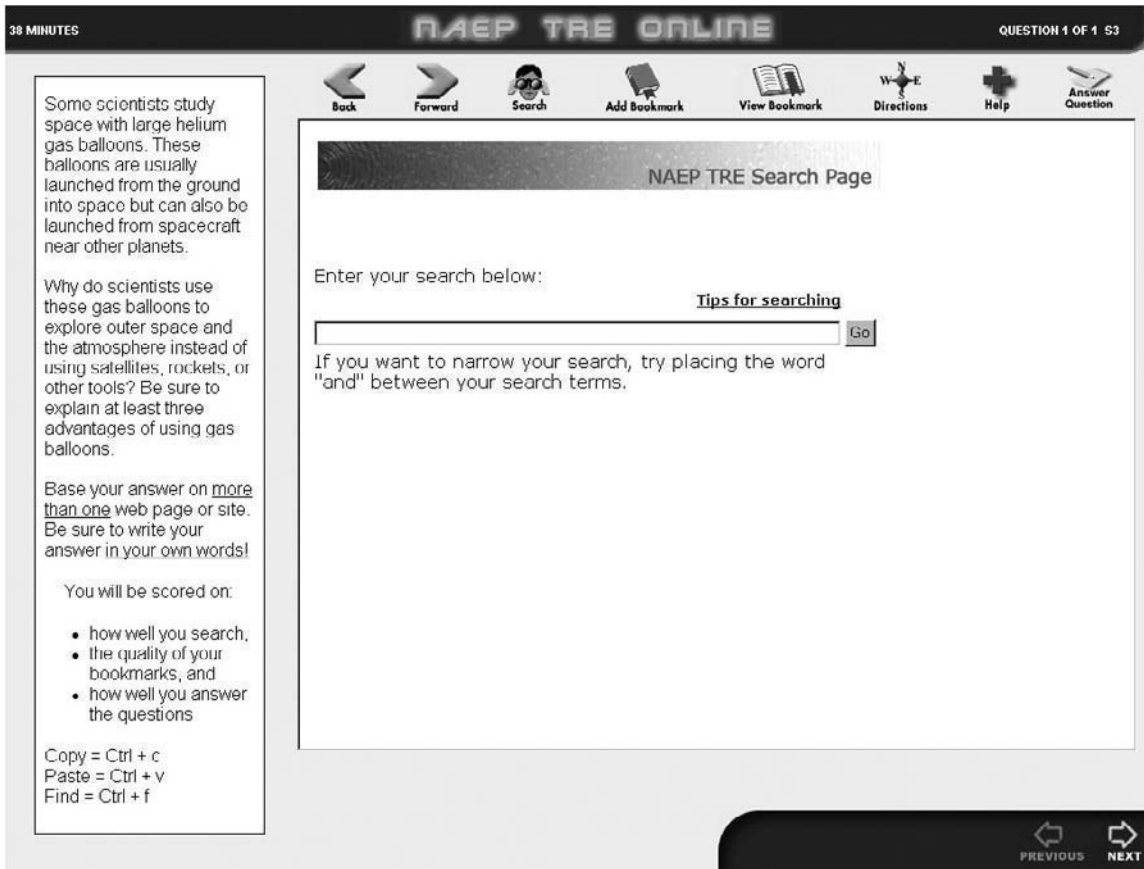
NOTE: TRE = Technology-Rich Environments.

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2003 Problem Solving in Technology-Rich Environments Study.

The directions, shown in figure 1-2, were designed to introduce students to the tasks they would be performing and to let them know the basis on which their responses would be evaluated: their searching adequacy, the quality of the information they located, and the quality of their answers to the question (referred to in this report as the “problem”) posed to motivate their searching.

After the directions screen, students moved to the Search interface (see figure 1-3) to which they had been introduced in the tutorial. The problem intended to motivate students’ searching was located, and always visible, on the left-hand side of the screen. Also always visible was a summary of scoring criteria for students’ work. On the right side was a web browser created for the purposes of this TRE scenario. At the top of the browser was a toolbar that included buttons for moving back and forth among pages,

**Figure 1-3.** Computer screen with TRE Search motivating problem in left pane and web browser in right pane, grade 8: 2003



NOTE: TRE = Technology-Rich Environments.

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2003 Problem Solving in Technology-Rich Environments Study.

returning to the search page, bookmarking, viewing bookmarks, getting more extensive directions, receiving science help, and going to a page to take notes or answer the motivating problem. In the center of the browser page were a space for entering queries and a link to tips for searching.

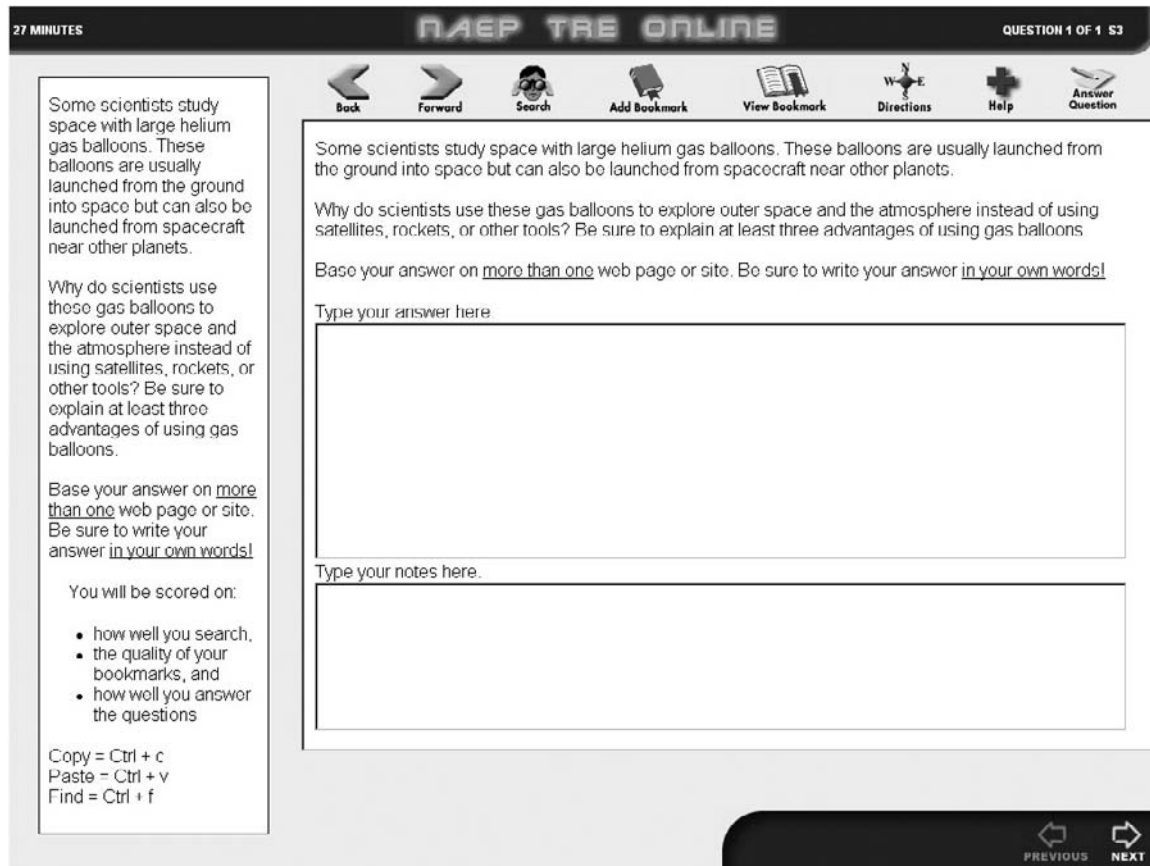
The motivating problem in the left-hand column of the screen, shown again in figure 1-4, was developed over many iterations and pilots of the scenario with students. The problem was designed to be open enough to encourage searching, and yet specific enough so that reasonably skilled searching would supply substantive information to answer it within the 40-minute time allotted for the Search scenario.<sup>3</sup>

Skilled searching using relevant terms from the motivating problem and methods for focusing searches (e.g., quotations, use of “near” and “or”) yielded a list of pages, including some suitable for answering the question. Unskilled searching that employed only generic terms from the motivating problem (e.g., “balloon”), on the other hand, yielded less relevant or irrelevant hits.

To ensure that the TRE universe was as authentic as possible and would yield results ranging from the very irrelevant to the highly relevant, with many gradations in between, skilled and unskilled searches were run to identify the kinds of pages students would find by searching the real World Wide Web (WWW). Web pages ranged from those pertaining to party bal-

<sup>3</sup> The motivating problem refers to balloons being launched “into space” because that is how scientists often speak of the upper parts of the atmosphere where the balloons operate. To date, only one balloon has been launched in the atmosphere of another planet (Venus), but several countries have considered using balloons to explore the atmosphere of other planets.

Figure 1-4. Computer screen with spaces for note-taking and for answering TRE Search motivating problem, grade 8: 2003



NOTE: TRE = Technology-Rich Environments.

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2003 Problem Solving in Technology-Rich Environments Study.

loons, which would be returned to students who used undirected search queries such as “balloons,” to pages from NASA describing uses of gas balloons in space research. Once many thousands of pages had been collected, a NAEP staff member assigned scores to each page based on the relevance of the page to the Search scenario motivating problem. The scores ranged from a low of 1 to a high of 4. Two additional NAEP staff members also rated all the pages considered by the first rater to have at least some relevance, i.e., all pages scored at least a “2.” Any differences in scores assigned

were resolved among the raters to ensure that pages were properly scored for relevance.<sup>4</sup> Ultimately, a sample of some 5,000 pages from the World Wide Web was selected and used as the TRE web universe.

To maximize authenticity, students could use the tool bar to cycle among searching, bookmarking, and other activities, including responding to the motivating problem. Figure 1-4 shows the box for entering both the response and any notes made while searching. Students were permitted to take notes but were told in the initial directions that their notes would not be scored.<sup>5</sup>

<sup>4</sup> Ratings were done by NAEP assessment development staff members and associates with graduate degrees according to criteria defined by the rating group. Because group discussions of exemplars indicated that irrelevant pages were easily agreed upon, only pages receiving a score of at least “2” were independently rescored.

<sup>5</sup> As in any real-world, information-search task, students in the TRE study could have used non-technological alternatives like paper-and-pencil or memory in place of electronic note-taking. The extent to which such alternatives were used could not be determined.

To ensure that a response was collected from each student, students could not leave the Search task without entering some text into the answer space. Once students had made some attempt to answer the question, they were given (assuming time had not run out) the option of reviewing their work. They were

then moved to a set of four multiple-choice questions designed to test how well they had synthesized the information they had found about the use of helium gas balloons in space exploration. As with the motivating question, students could search while answering. Figure 1-5 displays the synthesizing questions.

**Figure 1-5.** TRE Search synthesizing questions and answer options, grade 8: 2003

What is one important, current problem with using scientific gas balloons for space research?

- Many balloons cannot carry the necessary heavy equipment.
- Balloons cannot easily transmit their data back to earth.
- Balloons are very expensive to build, launch, and recover.
- Many balloons cannot stay aloft for lengthy periods of time.
- Hydrogen gas cannot safely be used to lift scientific balloons.

Why might scientists choose to use helium balloons instead of rockets and satellites to research space?

- Balloons can withstand the effects of space travel better than many satellites and rockets.
- Balloons can be launched from a wider variety of locations than satellites and rockets.
- Balloons are not affected by high winds as much as satellites and rockets.
- Balloons are more reliable for conducting experiments where there is no gravity.
- Balloons can be placed into higher orbits than satellites and rockets.

Why is the zero-pressure scientific balloon designed to drop ballast during flight?

- To maintain a certain altitude when temperatures grow cool at night.
- To maintain the necessary amount of helium inside the balloon.
- To ensure that the balloon reaches its goal altitude after launch.
- To ensure that the balloon can return to earth after flight is completed.
- To ensure that the balloon maintains a constant internal pressure.

Why are scientific gas balloons only partially filled with helium before launch?

- To prevent them from going too high.
- To allow room for the gas to expand.
- To keep the balloons from rising too slowly.
- To keep the balloons from becoming too heavy.
- To allow the balloons to be filled (launched) more quickly.
- To save money on an expensive gas.

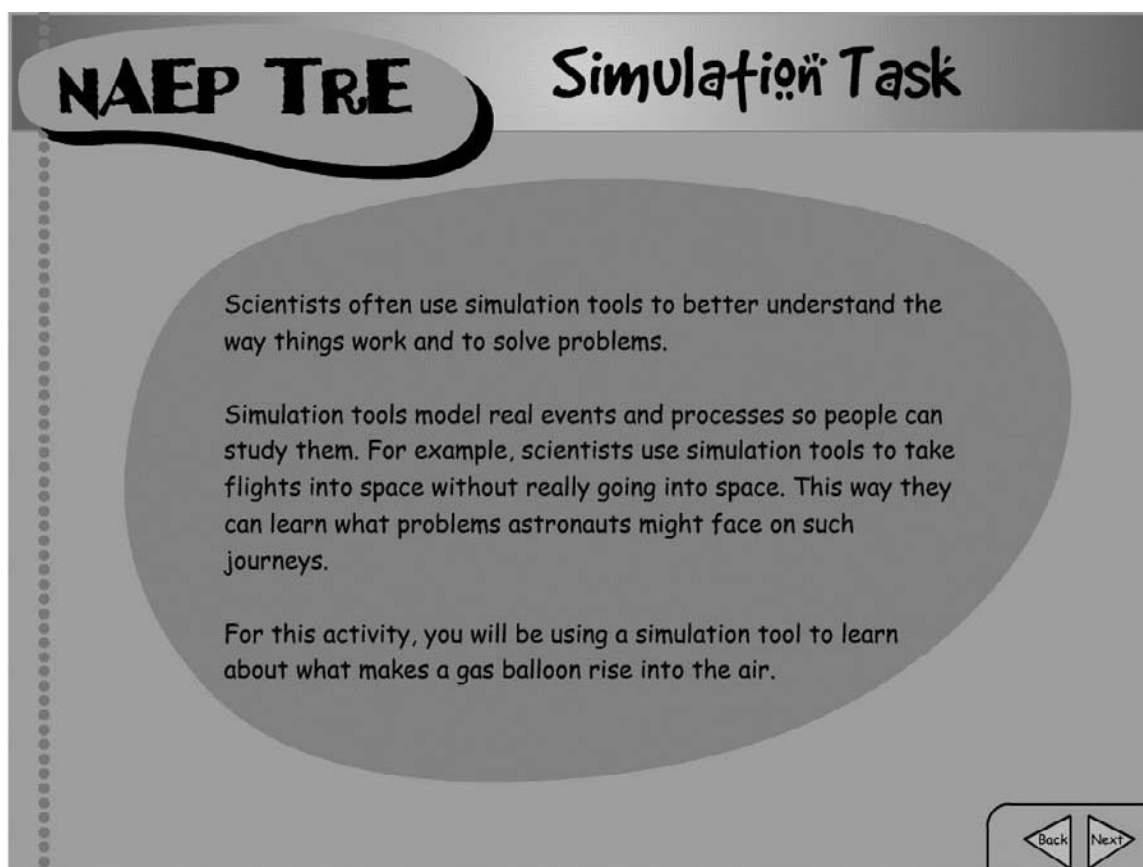
NOTE: TRE = Technology-Rich Environments. Questions were presented individually, one per screen, and not as shown here.  
SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2003 Problem Solving in Technology-Rich Environments Study.

Students had to answer all four multiple-choice synthesizing questions before they could leave the Search scenario. After completing the scenario, students responded to background questions intended to gather information about their demographic characteristics, school science classes and activities, and computer familiarity. (The full text of the background questions is available in appendix D.) A detailed discussion of the percentages of students in various background-question response categories appears in chapter 3 of this report.

### **The TRE Simulation Problem-Solving Scenario**

Figures 1-6 through 1-22 illustrate the progression students followed through the Simulation scenario. Figures 1-6 and 1-7 display the introduction that students received after they responded to a set of prior science and computer knowledge questions, as they did for the Search scenario. The introductory pages told students the purpose of simulation tools generally and what kind of simulation tool they would be working with during the course of the scenario, and then explained how they would be applying the simulation tool. “Back” and “Next” buttons on the lower right-hand side of the screen allowed students to navigate among the Simulation scenario pages, so they could review the introductory pages.

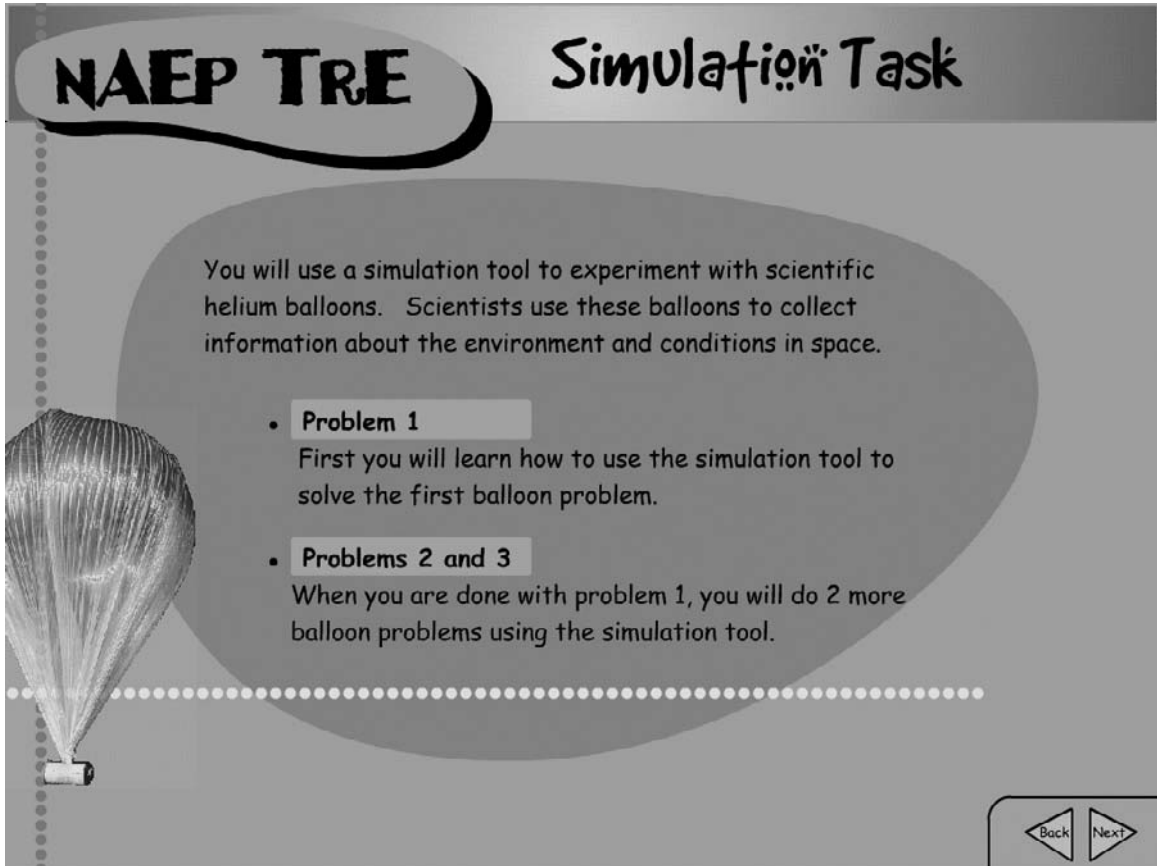
**Figure 1-6.** Computer screen introducing use of simulation tools in science for the TRE Simulation scenario, grade 8: 2003



NOTE: TRE = Technology-Rich Environments..

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2003 Problem Solving in Technology-Rich Environments Study.

Figure 1-7. Computer screen introducing content of the TRE Simulation scenario, grade 8: 2003



NOTE: TRE = Technology-Rich Environments.

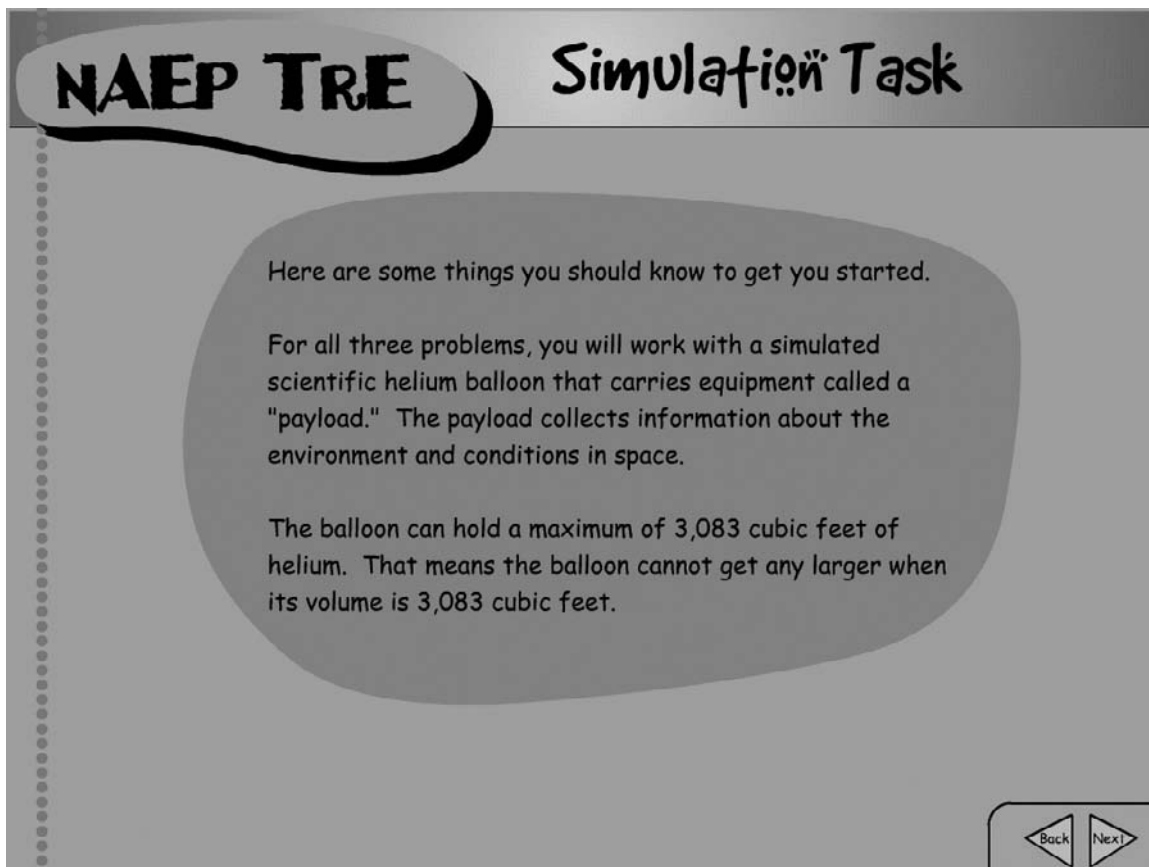
SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2003 Problem Solving in Technology-Rich Environments Study.



Moving at their own pace (with the understanding that they had 60 minutes to complete the scenario), students were given some conditions and definitions, as shown in figure 1-8, to keep in mind as they

proceeded. These included definitions of “scientific balloon” and “payload,” and the maximum volume of the scientific balloon with which students experimented.

**Figure 1-8.** Computer screen with conditions and definitions for the TRE Simulation scenario, grade 8: 2003



NOTE: TRE = Technology-Rich Environments.

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2003 Problem Solving in Technology-Rich Environments Study.

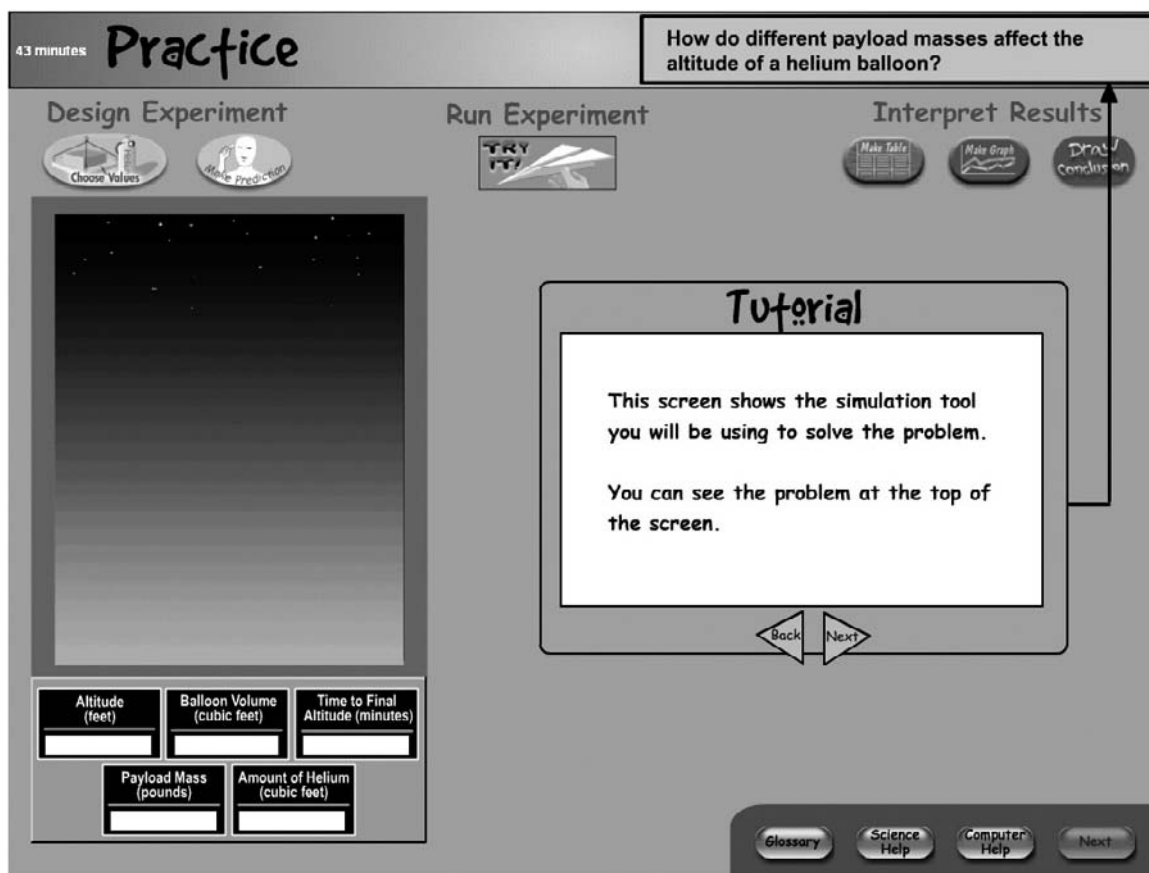
Figure 1-9 displays the first page of the tutorial for the Simulation tool interface. (See appendix E for screens in the Simulation tutorial.) During the tutorial, students were introduced to each component of the Simulation tool and were directed to run an experiment and make a prediction about the results, with the option of repeating the various steps of the tutorial. (Note that the screen clearly indicated “Practice” in the upper left-hand side, so students knew they were not yet being scored for their performances.)

The Simulation tool interface in many aspects resembled instructional software and simulation games students might already have encountered. For example, the top of the interface featured a task bar for designing, running, and interpreting experiments, and the “Back” and “Next” buttons enabled students to navigate among screens.

The problem to solve was displayed in the upper right-hand corner. It asked students to determine the relationship between payload mass and balloon altitude. To design an experiment to explore this relationship, students clicked on the Choose Values button in the Design Experiment area. A prediction could then be made about the results of the experiment. Although making predictions was optional, the interface alerted students that they could not make predictions without having first chosen values for experiments. When students were ready to run an experiment, clicking Try It caused the instrument display to activate and caused the balloon in the flight box to rise or remain stationary, depending on the value of the payload mass chosen.

Students could construct tables or graphs if they wished to keep track of experimental results by

Figure 1-9. Computer screen with the TRE Simulation scenario tutorial, grade 8: 2003



NOTE: TRE = Technology-Rich Environments.

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2003 Problem Solving in Technology-Rich Environments Study.

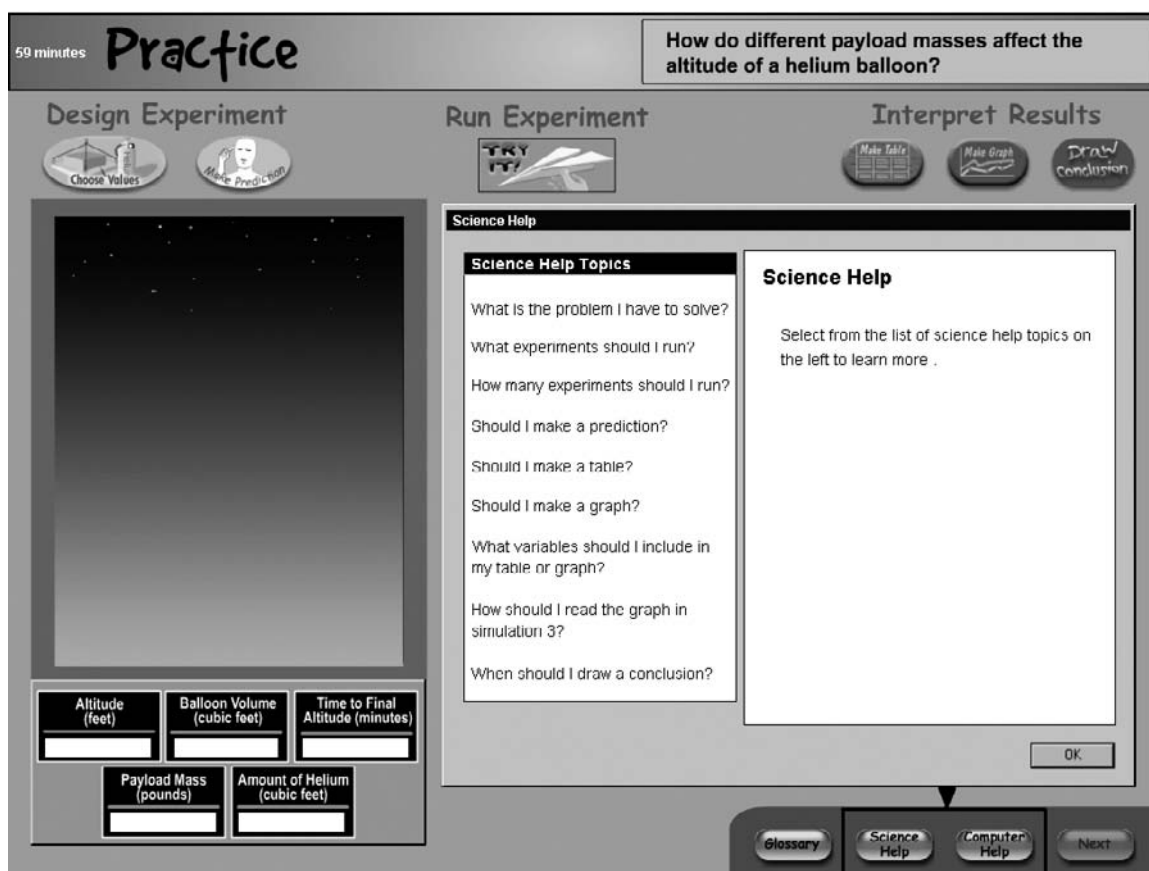
clicking on the appropriate buttons under Interpret Results. The interface then presented results for all experiments run to that point. (Although it can be argued that students should not have been able to access data they did not explicitly record, the automatic recording of data is typical in scientific simulation environments.)

Students were able to watch the balloon rise in the flight box, and could observe changes in the values of dependent variables (altitude, balloon volume, and time to final altitude) in the instrument panel below that box. Values for the independent variables (payload mass and amount of helium) were also displayed in the instrument panel. When students were ready to draw conclusions, they clicked on the

Draw Conclusions button under Interpret Results to bring up a box where they could enter a response to the problem featured on the upper right-hand part of the screen. Students could continue to experiment and use tables and graphs while they responded to the question.

Three forms of help were offered, as indicated by the buttons in the lower right-hand corner. These buttons brought up a glossary of science terms, science help, and computer help. Science Help gave hints about the substance of the problem. The menus for Science Help are shown in figure 1-10. Computer Help described the buttons and functions of the Simulation tool interface. (See appendix E for Science and Computer Help screens.)

**Figure 1-10.** Computer screen with Science Help for the TRE Simulation scenario, grade 8: 2003



NOTE: TRE = Technology-Rich Environments.

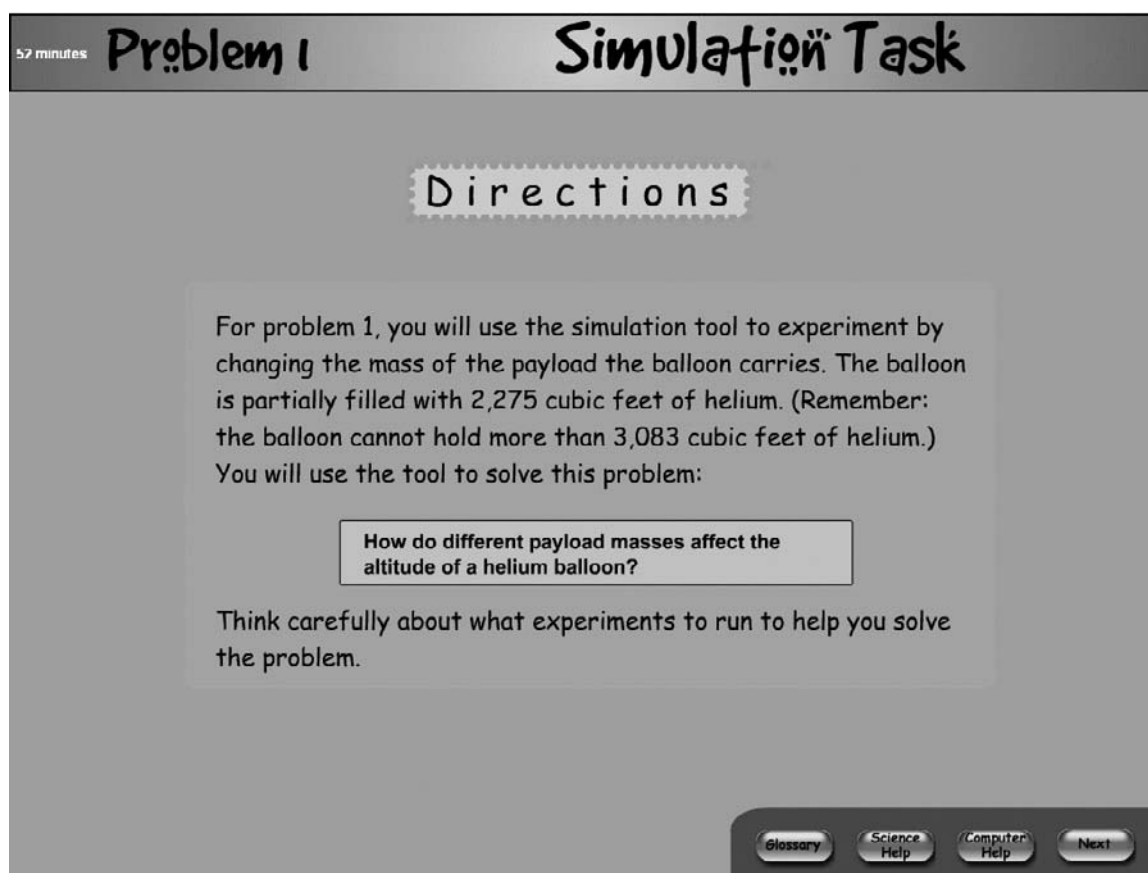
SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2003 Problem Solving in Technology-Rich Environments Study.

After students completed the tutorial, they were presented with directions for the first problem in the simulation, shown in figure 1-11. The problem asked the student to determine the relationship between the amount of mass that a balloon can carry and the height to which the balloon can rise in the atmosphere. The only available independent variable was mass, and the values of mass that the student could select were restricted. (The balloon held a constant amount of 2,275 cubic feet of helium.)

These constraints were imposed because of assessment time limitations and concern that the problem might otherwise be too difficult for significant numbers of eighth-graders. Note that the directions reminded the students that the balloon could hold only 3,083 cubic feet of helium.

Figure 1-12 displays the menu of possible masses from which students could choose for experimentation in problem 1.

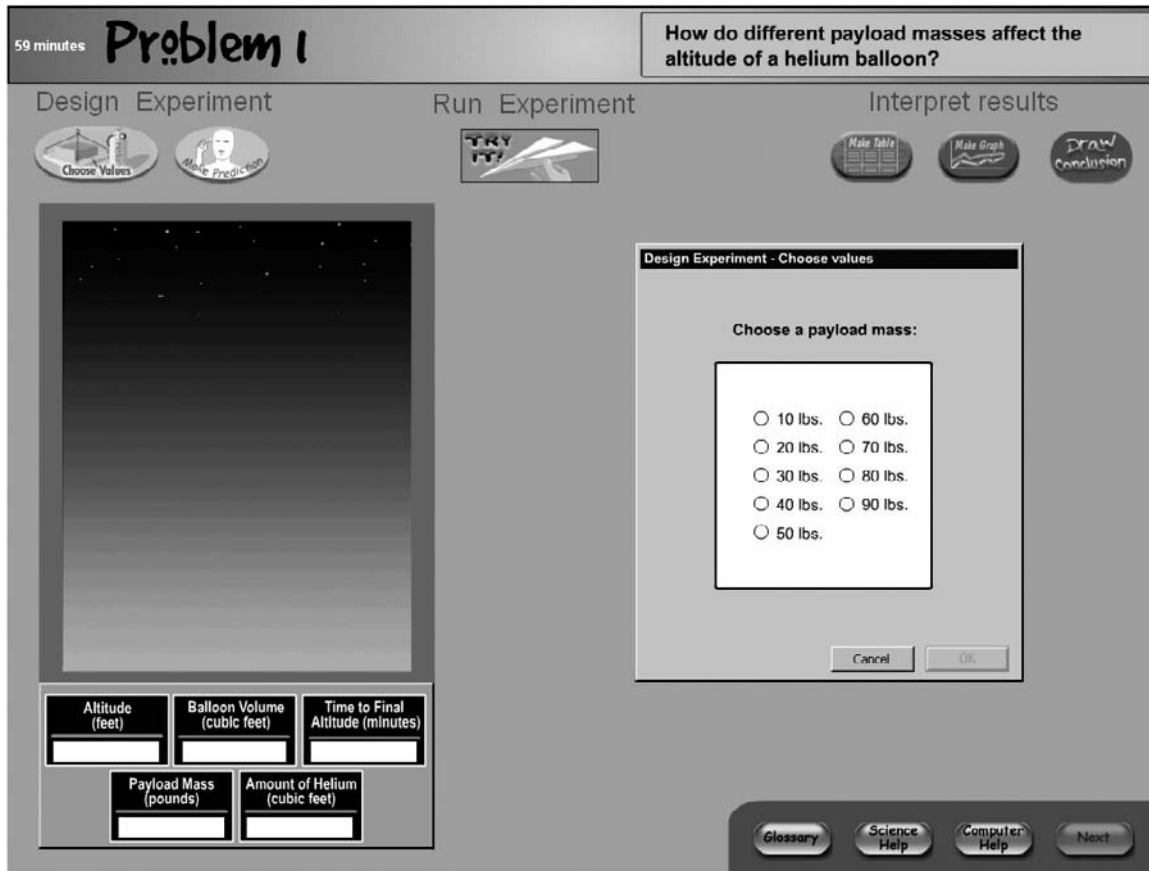
**Figure 1-11.** Computer screen with directions for TRE Simulation scenario problem 1, grade 8: 2003



NOTE: TRE = Technology-Rich Environments.

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2003 Problem Solving in Technology-Rich Environments Study.

**Figure 1-12.** Computer screen with the menu of values for the independent variable, payload mass, in TRE Simulation scenario problem 1, grade 8: 2003



NOTE: TRE = Technology-Rich Environments.

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2003 Problem Solving in Technology-Rich Environments Study.