"Where are We?"

An interactive multimedia tool for helping students "translate" from maps to reality and vice versa

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Abstract

We have developed a computer-aided learning tool to help students develop their ability to translate mentally between their visually-perceived, three-dimensional physical surroundings and a planview schematic representation of that reality: in other words, a map. An ability to visualize reality from maps and vice versa is a valuable life skill, a prerequisite for success in many jobs including virtually all geoscience careers, and, we believe, a prerequisite for using the powerful map metaphor as an organizing principle for complex bodies of knowledge. Our application, called "Where are We?", simultaneously displays a visual-representation of an interesting, real, environment, and a map view of that same terrain. The student/user is challenged to (a) figure out his/her location on the map based on clues in the visually-perceived environment, (b) plan a route to a destination on the map and follow that route based on clues in the visually-perceived environment, (c) locate specific unmapped features in the visually-perceived environment and add appropriate symbols to the map to indicate these new features. The program is targeted at middle school Social Studies classes and eighth or ninth grade Earth Science classes.

Keywords: map

Description of the application

"Where are We?" simultaneously displays a map view and a visual display of an interesting, real environment (figure 1 [150K inline .gif]). In the existing prototype, we use Central Park in New York City as our locale, but our interface could also be applied to a variety of geologically- and environmentally-significant terrains. Working on the left side of the screen, the student can "move" through the visually-displayed environment at will. Each time the student clicks "turn left," "turn right" or "go forward" buttons, the application displays a snippet of digital video corresponding to the requested motion. Meanwhile, the right-hand side of the screen displays a map view of the same territory. The student is challenged to figure out, keep track of, anticipate and/or annotate his or her location on the map view, based on clues from the visual display. "Where are We?" poses several sorts of challenges and opportunity for the student:

"Out for a Walk " mode: Students can "move" through the map world at will, exploring the application and the park in a unstressful, non-competitive manner. As the student clicks "left," "right" or "forward" buttons to move through the visually-perceived environment, a marker on the map echoes the student's moves and turns. The contrast between the slow motion of the marker across the map, and the rapid motion of the ground in the video, gives the user a strong visceral sense of the map as a scale model of reality.

"Lost! " mode: The student is "dropped" into the map world at a randomly-chosen unknown locality. By observing visual clues in the surroundings, the student tries to figure out his or her location on the map. The student then clicks on the map at the inferred position, and the program provides instant feedback about whether this effort has been successful.

"Are We There Yet?" mode: Students are assigned to find their way to a specific feature shown on the map, such as the entrance to the Nature Sanctuary (figure 1 [150K inline .gif]). In this mode, the student are responsible for tracking their own position on the map; however, if they get lost, a click of the "hint" button temporarily indicates the current position and view direction on the map.

"Basemap" mode: The program provides a basemap which has paths and roads and bodies of water marked, but which lacks certain important details about the terrain portrayed. The assignment is to travel through the map-world, placing icons on the map to indicate the presence of specific observable features (lampposts, flowering shrubs) in the environment.

"Make your own Map-world" mode: Instead of merely exploring the map-world that we have prepared, students and teachers can use our template to construct their own interactive map-world of their neighborhood or school. We provide detailed instructions, plus a template in which all of the navigation functionality is already scripted. School groups take photographs of their intended area, scan and import the photographs carefully into the template, scan and input a basemap, fill in a few fields, and click systematically on a copy of their basemap to indicate the position of their photography nodes. No scripting or programming is required.

Why is this application necessary?

The motivation for developing this computer-aided learning tool was the observation that many students enrolled in a Columbia University undergraduate Earth Science course for non-science majors do not use maps as part of their repertoire for organizing information: they are not very effective at extracting information from published maps, and they find it difficult to express information by creating a map of their own. This is obviously a serious handicap in studying Earth Science, a field in which observations, interpretations and hypotheses are all frequently expressed by geographic or spatial relationships. Even for students with no professional aspirations in science, ability to work with maps and find oneÕs way in the world is an important life skill in a mobile society.

Maps are included in the pre-college curriculum of most schools, typically in fourth, fifth and/or sixth grade Social Studies. High school Earth Science and History classes present additional exposures to maps. So how is it that so many academically-accomplished students reach college with such weak map literacy skills?

An examination of the hands-on exercises used in teaching pre-college map literacy reveals a common thread and a common missing element. Most of the skills practiced could be described as "map analysis." After looking at a simple sketch map, a middle school student is asked questions like: "What road leads from Bloomington to Lake Aponda?" (Carratello and Carratello, 1990, p.65); or "The entrance to the zoo is on the [north/south/east/west] side" (Rushdoony, 1988, p.73); or "Who lives at the corner of Turtle Street and Lion Street?" (Klawitter, 1985, p. 11). After looking at a topographic map, an Earth Science student is asked questions like: "What is the elevation of the highest contour line shown on the map below?" (McGuire, 1991, p. 24), or "What is the slope in feet per mile of the eastern side of Mount Price from the summit to the shore of Garibaldi Lake?" (Tarbuck and Lutgens, 1994, p. 46).

Certainly such "map analysis" skills are indispensable for a skilled map user. Unfortunately, the questions above can be answered entirely within the schematic framework of the map; there is no incentive, and indeed no mechanism, for students to consider the physical reality of which the map is a representation as they prepare their answers. Such "map analysis" exercises neglect an important aspect of map using: a skill that could be described as "map visualization," or as the ability to "translate" fluently between one's visually-perceived, three-dimensional physical surroundings and a planview schematic representation of that reality. An effective "map visualizer" can look at a map and create an accurate mental picture of what the terrain would look like if s/he were standing in it. We suspect that failure to make this mental link between a map and the physical reality that it represents underlies the problems that many undergraduates and adults have with maps.

Until now, this "map visualization" or "translation" skill has not been readily teachable within the four walls of a classroom. Instead, map reading has traditionally been taught by a parent, a scout leader, a military superior, or those few pre-college teachers involved in field-based education. Individuals who lacked such a mentor either discovered map visualization strategies by trial and error on their own, or they grew to adulthood lacking this skill. The goal of our project is to use instructional technology to expand the bounds of what can be learned in a classroom setting, to include map visualization skills in addition to the traditional map analysis skills. In no sense do we envision our application as a complete substitute for field-based map exercises; we think all students should use and make real maps in the real world as part of their pre-college education. But we recognize that the opportunities for field-based education are limited in most schools, and we think that visually-informative, computer-aided learning tools can accelerate the acquisition of map skills. Our application is targeted at middle school Social Studies classes and eighth or ninth grade Earth Science classes, but could be productively used by anyone who wishes they had a better "sense of direction."

Specific skills objectives

"Where are We?" is a skills-oriented rather than content-oriented application. We have classified the skills objectives into slightly-overlapping categories of Maps & Wayfinding skills, Spatial Intelligence, Visual Literacy, Organizational Skills, Interpersonal Skills, and Computer Skills.

Map-reading, Way-finding, and "Sense of Direction":

We postulate that "sense of direction" comprises a skill set that can be strengthened through practice. "Where are We?" permits dozens of way-finding mistakes to be compressed into a very short amount of time, without the dire consequences that can accompany way-finding mistakes in the real world. Feedback on the success or failure of each way-finding step is immediate, and the feedback is discovered by the student (when the next step either does or does not work) rather than imposed by the teacher. After working with "Where are We?", we hope that:

- Students will be able to figure out where they are located on a map by recognizing landmarks and the spatial relationships among landmarks.
- Students will be able to plan a route to reach a destination on a map, and then successfully follow that route.
- Students will be able to give oral or written directions to another person about how to find a given destination, and the directions will be of sufficient quality that the second person will succeed in reaching the goal.
- Students will be able to use compass directions to orient themselves, and this skill will be internalized so that it feels intuitive rather than intellectual. In other words, if a student is facing west, s/he will know right away, without painful mental effort, that by turning left s/he will end up facing southwest or south.
- Students will be able to recognize and identify the conventional symbols used to identify common features on maps.
- Students will make immediate and facile correlations between map symbols and the real-world features or objects they represent. Note that making such correlations involves multiple simultaneous mental transformations: two rotations

and a simplification (see below under "spatial intelligence" and "visual literacy" respectively.)

- Students will be able to visualize the shape of simple landforms by looking at topographic contours.
- Students will be able to analyze and interpret a data set in which a parameter varies spatially over the map area. They will be able to contour such a data set , and to discuss possible causes of the observed spatial variability. They will be able to apply these techniques regardless of whether the mapped parameter is perceivable to the human senses.
- Students will realize that maps are made by human beings, and can be erroneous or obsolete.

Spatial Intelligence:

We think that the mental skills exercised by "Where are We?" are applicable to a broad range of challenges outside the realm of map-reading and way-finding. Many of these skills call on the students' spatial intelligence, their ability to mentally manipulate and process information about shapes and the relationships among shapes. After working with "Where are We?", we anticipate that:

- Students will be more adept at mentally rotating an object and visualizing what it would look like from another point of view. Success with "Where are We?" requires that the user execute dozens of mental rotations from the sideways, human's-eye perspective of the video, to the planview, bird's eye perspective of the map. In the real world, this would be a rotation about a horizontal axis oriented left-to-right across the user's body; in the computer application, it is a mental rotation about a horizontal axis in the plane of the screen. In addition, the user must mentally rotate either the map or the video-view so that the view is perceived as towards the appropriate direction on the map. In the real world, this would be a rotation about a vertical axis; in the computer application, this is a rotation about an axis perpendicular to the screen.
- Students will be comfortable switching back and forth between relative and absolute directions. The azimuth arrow on the left side of the screen (figure 1) always shows the view direction as straight-ahead relative to the user's position. In contrast, the azimuth arrow on the right side of the screen (throughout "Out-for-a-Walk" mode, or in response to the button in "Are we there yet?" or "Basemap" mode) shows the view direction as an absolute direction measured relative to geographic north.
- Students will be better at recognizing and remembering distinctive shapes and geometries. For example, the successful user of "Lost!" mode will learn to recognize the shapes of intersections.
- Students will begin to realize that there are spatial relationships among intangible, non-visible properties, as well as among physical objects. For example, the ambient noise measurements in the "Environmental Mapper" mode illustrate a characteristic spatial pattern, with generally decreasing noise level as one moves

away from the bounding streets.

Visual Literacy:

We use the term "visual literacy" to mean the ability to extract information from pictures, images, drawings, graphs, and maps, and, conversely, the ability to express information in these forms. After working with "Where are We?" we hope that:

- Students will be able to analyze a complex visual environment and parse it into ephemeral elements (such as people) and relatively-permanent elements (such as paths). They need not articulate the results of this effort, but they should use the results in working with the map. There's no use looking for the ephemeral elements on the map; the mapmaker typically has chosen only permanent elements to include on the map.
- Students will be able to correlate between different images or visual representations of the same object or feature, even if one representation is schematic and the other is pictorial. In order to correlate between a map symbol and the corresponding real-world feature or object, students must mentally simplify from the intricately-detailed feature in the seen-world, to the schematic and spare representation of the map-world.
- Students will understand that there is a symbolic language of maps, which can be used to convey information. They may begin to recognize that this symbolic language can carry certain kinds of information that is difficult to convey in words or mathematics (i.e. the directions-writing exercise in "Out-for-a-Walk" mode). The most perceptive students may begin to identify what types of information are best conveyed through this symbolic language, and may elect to draw a map when they find themselves needing to convey information of these types.
- Students will begin to convey meaning in the symbolic language of maps. In "Basemap" mode, they add meaning to an existing map by adding symbols for features that the original mapmaker chose not to include.

Organizational Skills:

Although organizational skills were not the main target of our development effort, we anticipate that use of "Where are We?" could strengthen students ability to organize knowledge, to organize data, and to organize complex tasks. After working with "Where are We?":

- Students may be better able to combine several lines of evidence to reach a conclusion. For example, in "Lost!" mode, the user might need to find the place that is (a) on the east side of the lake, (b) on the path closer to the lake, and (c) a little ways north of a staircase. No single line of evidence alone would suffice to pinpoint the mystery location.
- Students may be better able to plan and execute a thorough, methodical investigation. For example, in "Basemap" mode, or "Environmental Mapper" mode, students need to formulate and implement a strategy to make sure that they

cover all parts of the mapworld.

- Students may be better able to keep track of multiple events in an event-chain. For example, the successful user of "Are we there yet?" mode will continuously keep track of his or her position, move after move, building the interpretation of the current move onto the carried-forward interpretation of the outcome of the previous move.
- Students may be better able to plan and carry out a complicated project. This is particularly true for users of "Make your own Map" mode, who must gather materials and supplies, plan where to make their map, locate and scan a basemap, take photographs, accurately record numerous details about their photo sessions, manipulate photographs in a graphics application, and work with a multimedia authoring application.

Interpersonal Skills:

"Make your own Mapworld" mode and "Environmental Mapper" both place a premium on ability to work collaboratively. In "Environmental Mapper" groups of students must combine their data sets into a master map, which they must then interpret together. "Make your own Mapworld" involves far too many tasks for a single individual to complete in a realistic timeframe; students must divide up the work and combine their efforts.

Computer Skills:

Users of "Make your own Map" mode will become multimedia application developers. The "Make your own Map" template is designed so that student groups can create a genuine interactive multimedia application, their own map-world, without requiring that they write or modify any scripts. With this first, sheltered, step, students begin to develop fluency in a new language, the language of multimedia communications.

Assessment Strategies

"Where are We?" has several built in devices to help classroom teachers assess whether students are learning. The assessment strategy varies from mode to mode:

"Lost!" Mode: The program reports how many right and wrong position guesses the student has made, which is a useful indication of mastery of this task. The program needs to be run for long enough that each student encounters more or less the same number of hard and easy drop locations (the program generates drop locations randomly.)

"Are we there yet?" Mode: The program reports which targets the student has reached, and how many times s/he used the button. Successful reaching of targets, with little or no recourse to the button, is a good indication of mastery of this task.

"Basemap" Mode: Students print out their map and hand it in to the teacher for evaluation. The teacher's guide will include a comparison copy of the completed map.

"Out for a Walk" mode: "Out for a Walk" mode is primarily intended for uncompetitive, unevaluated exploration of the application. However, "Out for a Walk" mode can be incorporated into a writing exercise as follows. The class is divided into teams of two to six students, such that there is one computer per team. Each team is then further subdivided into the "writers" and the "finders." The teacher gives a paper copy of the "Where are We?" map to the "writers" in each team; on this map, a secret destination is marked with an "X". The "writers" have to find their way to the destination, and then produce a written set of directions (words only, no sketches) from the starting point to the destination. Then the "finders" take over the computer, and based on the written directions only, they have to find their way to the destination. The first group to reach the destination wins.

"Make your own Map" Mode: The completed stack of the student-created mapworld is submitted for evaluation.

In addition to assessing the student's facility with the computer map, we encourage teachers to take their students into a real world setting and have them try their skills at map reading and map making.

Treasure hunt: Before the students arrive, hide a "treasure" in the area that the students will visit. Give pairs or trios of students a paper map on which the location of the "treasure" has been marked. Students who have mastered map-reading skills will use their map to home in directly on the "treasure", whereas students who have not mastered these skills hunt around in random Easter-egg-hunt style.

Complete the map: Give pairs of students a paper map of the area they are visiting, on which roads and pathways and bodies of water have been marked. Students are asked to complete the map by filling in the buildings and statues and other specified features. Students who have mastered map reading skills will produce more detailed maps with a higher percentage of the hand-drawn features in the correct location. Directions for future development

The current version of "Where are We?" is a prototype. A limited number of copies of the prototype are available for distribution to educators who are willing to provide a written review of the application. Among the directions we are considering for future development are:

- Choice of Maps: The map in the prototype is a schematic map showing paths and roads, rocky outcrops, water, stairs, a bridge, and a fence. We would like to offer the user a choice of maps: a topographic map, an aerial photograph, a geological map, and an ecological (vegetation-type) map. The message for students would be that the same reality can be meaningfully and truthfully represented on a map in different ways, and the choice of appropriate map depends on what aspects of reality interest the map-user at the moment.
- Changes through Time in the Visual Representation: At a few locations in the map world, the user will be able to "travel through time" by clicking a special icon on

the visual side of the screen. Students will note that even though the changes in the visual environment on the hours- and months- time scales are dramatic to the eye, all those different views are accurately represented by the same map. In fact, a central goal of most physical maps is to codify permanent features while ignoring ephemeral features; this is a powerful strategy for reducing the intricate detail of the seen-world to the schematic representation of a map.

- Environmental Mapper Mode: Our existing prototype helps students learn to work with maps of visible features in physical space. We think that working with such maps is a necessary but not sufficient condition for facility with more abstract types of maps. We will add one new mode, tentatively called "Environmental Mapper," to help students transfer their newly-learned map skills from highly-realistic to more abstract map types. In the new mode, students will be able to "measure" environmental parameters such as ambient noise or carbon monoxide level, as they "walk" through the mapworld. Students will read an instrument, enter the data point into a field, and indicate the location of that data point on the map. When all areas of the mapworld have been explored and monitored, students will print out their maps with superimposed environmental data. The data can then be contoured, and used as the focus of a discussion of the spatial variability in these non-visible, intangible parameters.

The value of instructional technology for Earth Science education The process of creating "Where are We?" has lead us to reflect on the general utility of interactive, multimedia tools for Earth Science education. We think that the potential is excellent, higher than in almost any other discipline, for the following reasons:

1. Relative to other fields, Earth Science carries an unusually large fraction of its information in shapes and in spatial relationships. Law, for example, carries most of its information in words; physics, in equations. But we Earth Scientists care inordinately about shapes: the shapes of fossils, the shapes of continents, the shapes of deformed rock bodies, the shapes of crystals, the shapes of minerals, the shapes of plate boundaries, the shapes of magnetic anomalies, the shapes of sedimentary units, the shapes of ore bodies. And we care about spatial relationships: the spatial distribution of earthquakes, of fossil groups, of water masses. Three-dimensional shapes and spatial relationships are difficult to convey in black and white on paper, but feasible to convey through modern computer-aided visualization techniques. Because our science relies so heavily on shapes, images, maps, and spatial relationships, Earth Science educators have more to gain from visually-rich computer-aided learning tools than do educators in text- or equation- or number-dominated fields.

2. Changes through time are at the heart of earth science. In earth science education, a moving image--a video or an animation--is not merely a cute device for catching the student's attention; a moving image can convey fundamental information about how the Earth has changed through time.

3. Many important earth processes occur on temporal or spatial scales that cannot be reproduced in the laboratory. A Chemistry or Physics instructor can easily set up

hands-on lab experiments in which students observe, measure and manipulate significant chemical or physical processes. Earth Science instructors have generally not had that luxury, and our traditional labs have consequently tended to focus on products (rocks, minerals, landforms) rather than on processes. Computer simulations of natural processes offer students a chance to "experiment" with what-if scenarios on systems (a watershed, a volcano, a deforming mountain range) that are too large and too slow to observe in a hands-on "wet" lab or field trip.

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References Cited

Carratello, J. and Carratello, P., 1990. Beginning Map Skills. Teacher Created Materials, Inc., Huntington Beach, CA, 80 pp. Klawitter, P., 1985. Learning about Maps. Milliken Publishing Co., 28 pp.

McGuire, T., 1991. Reviewing Earth Science. Amsco School Publications, Inc., New York, 184 pp.

Rushdoony, H. A., 1988. Exploring our world with maps: Map skills for grades K-6. Fearon Teacher Aids, Carthage, Illinois, 138 pp.

Tarbuck, E. J., Lutgens, F. K. and Pinzke, K. G., 1994. Applications and Investigations in Earth Science. Macmillan College Publishing Company, New York, 321 pp.

Figure Caption

Figure 1 [150K inline .gif] :

The right-hand side of the "Where are We?" screen displays a map of a portion of an urban park. The left-hand side of the screen shows a video representation of a scene from within the area of the map. By clicking on the forward, left or right buttons, the user can "move" throughout the park by viewing appropriate video segments. The user is challenged to keep track of, figure out, or annotate his position on the map, based on visual clues in the video. The pedagogical goal is to be able to "translate" mentally back and forth between a visually-perceived, intricate, profile view of reality (the video) and a schematic, sparse, planview representation of that reality (the map).