Generalizing Activity Structures from High School to Middle School Science

Steven McGee & Bruce Howard
NASA Classroom of the Future
Wheeling Jesuit University, Wheeling, WV
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It is often said that students who perform well in school are those that understand the rules of the game. In other words, students need to understand not only the content related to an activity, but also the teacher expectations for how to participate in that activity and how the activity is typically structured (Doyle, 1979; Mehan, 1980). Lemke (1990) provides an example of a predominant activity structure, which can be characterized as following the sequence "Teacher Question-Student Answer-Teacher Evaluation" or as Mehan's (1979) more general sequence of "Initiation by teacher-Reply by student-Evaluation by teacher" (I-R-E). Recently, an investigation of United States mathematics and science classrooms by the Third International Mathematics and Science Study (TIMSS) has confirmed this earlier research indicating that there are clear patterns of classroom activity structures. TIMSS found that most science instruction involves activities that are short in duration and that focus on transmission of information (Schmidt et. al., 1997).

Currently, however, the rules of the game in science education are changing. There are several reasons for this. One reason is the the national science standards being produced by various groups, such as the National Science Education Standards, suggest that students ask and investigate their own questions. In order to meet these standards, it is necessary for teachers to use alternatives to the I-R-E activity structure. Another reason for a change in the game plan has to do with the increased use of constructivist learning approaches (Yager, 1995). Such approaches represent a radical change both in activity structure and teacher expectations.

Given an environment where traditional activity structures and teacher expectations are evolving, it is likely that students will have difficulty adapting. This hypothesis is based on recent reports that students have a tendency to interpret new activity structures in light of familiar activity structures (McGee, 1998). These interpretations can create difficulties for students trying to adapt to the new rules of the game. By creating activity structures that can generalize across grade levels and across disciplines, it will be possible for students to become familiar with the new rules of the game and then transfer that familiarity to a new class.

This paper will discuss attempts to generalize the activity structures of the *Astronomy Village®: Investigating the Universe*™, which is geared at high school students, for use at the middle school in a related program called *Astronomy Village®: Investigating the Solar System*™. Designers at the Center for Educational Technologies (CET) at Wheeling Jesuit University, which houses the NASA Classroom of the Future, attempted to use the basic architecture of the high school version to develop a middle school version focused on solar system content. There were a number of changes made to the activity structures for the middle-school version. Many of these changes were improvements to the program based on research with the high-school *Astronomy Village*. These changes have been discussed elsewhere (McGee & howard, 1999). This paper will focus on two significant changes that were made to the interface of *Astronomy Village* that were a function of migrating from high school to middle school. A discussion of these changes will provide insight into the possibility of developing generic activity structures.

This paper is available online at: http://www.cet.edu/research/papers.html [1999, April 17].

ADAPTATIONS TO THE UNIT STRUCTURE

Unlike traditional science content, which is delivered as “chunks” of information, scientific inquiry involves active, sustained investigation by students. To support sustained student investigations, teachers must link activity structures over several class periods. We have developed the term *Unit Structure* to refer to the underlying structure that results from grouping activities. Instructional designers at the CET use four common elements to represent components of a Unit Structure for scientific inquiry: (1) identifying questions to investigate, (2) designing investigations, (3) conducting investigations, and (4) formulating and communicating conclusions. This Unit Structure is based on the representation of scientific inquiry that can be found in the TIMSS curriculum framework (Robitalle et. al., 1993). In addition, we have linked those four components of scientific inquiry with relevant theories of learning that might inform the design of multimedia materials to support inquiry. We call the resulting framework Testing Educational Theory through Educational Practice (TETEP) (see Table 1). Using the TETEP framework it is possible to identify how specific elements of both the high school and middle school version of *Astronomy Village* interface support scientific inquiry.

Astronomy Village: Investigating the Universe

This discussion will begin with a description of the high school version. In March 1996, the CET produced a CD-ROM called *Astronomy Village: Investigating the Universe* for use as a curriculum supplement in high school science classrooms. It was distributed to over 11,000 teachers, educators, and resource centers, and it won *Technology and Learning* magazine’s Science Software of the Year Award for 1996. *Astronomy Village* uses the metaphor of living and working at a mountain-top observatory (the village) as the primary interface from which students investigate contemporary problems in astronomy (see Pompea and Blurton, 1995). Academic activities are designed to promote learning of astronomical concepts and processes related to scientific inquiry. Students join a research team and choose one of ten investigations to complete. In the Wobbler investigation, for example, students search for planets orbiting other stars. For each investigation, students progress through five phases: background research, data collection, data analysis, data interpretation, and presentation of results. See Table 1 for a description of how these phases relate to the Unit Structure for scientific inquiry. For any given phase, there are from

Scientific Inquiry	**Theories of Learning**	***Astronomy Village (High School)***	***Astronomy Village (Middle School)***
Identifying questions to investigate	• Motivation theory • Memory organization	• Select investigation	• Core Research Question • Exploration phase
Designing investigations	• Problem solving	• Background Research	• Background Research
Conducting investigations	• Science process skills • Self-regulate learning	• Data Collection • Data Analysis • Data Interpretation	• Data Collection • Data Analysis
Formulating and communicating conclusions	• Communication theory • Memory organization	• Virtual Press Conference • Class Presentation	• Virtual Press Conference • Class Presentation

Table 1: Testing Educational Theory through Educational Practice framework

three to seven content-related activities to be completed before proceeding to another phase. The primary means of tracking progress through an investigation is the *Research Path Diagram*—a chart that displays icons representing activities within each phase (see Figure 1). Each time a student clicks on one of the icons in the Research Path Diagram, a virtual mentor appears and describes activities relevant to that particular investigation. This version of Astronomy Village was designed for high school students to work independently for four weeks to complete the investigation.

Figure 1: Research Path Diagram

Astronomy Village: Investigating the Solar System

In June 1997 CET received funding from the National Science Foundation to use the architecture of the high school version to create a middle-school version. At the beginning of the project, we assembled a group of exemplary middle-school astronomy teachers. They reviewed the high school version and provided feedback on issues that would need to be considered for the middle school level. Two major issues raised were time and complexity. They felt that most middle-school teachers would not be able to take four weeks to study one topic in astronomy. In addition, they felt that students would not be able to handle the level of complexity contained in the high school version. Activities would need to be simplified. A third issue that was raised from previous research on the high school version (McGee & Howard, 1998) was the difficulty that students had in integrating the activities in each investigation with the overall research question for that investigation.

It was decided that the Unit Structure for the high school version would need to be modified. In order to address the issue of integration across activities, previous research recommended that students should be given multiple opportunities to practice a complete cycle of research centered on the same research question. As indicated above, the high school version contained 10 independent investigations. However, in the middle school version the investigations were organized around three core research topics: Search for Life in the Solar System, Mission to Pluto, and Effects of the Sun. After selecting a core research topic, students complete an entire investigation cycle related to the core question. The purpose of this first investigation is to generate understanding of a question and promote interest in investigating that question.

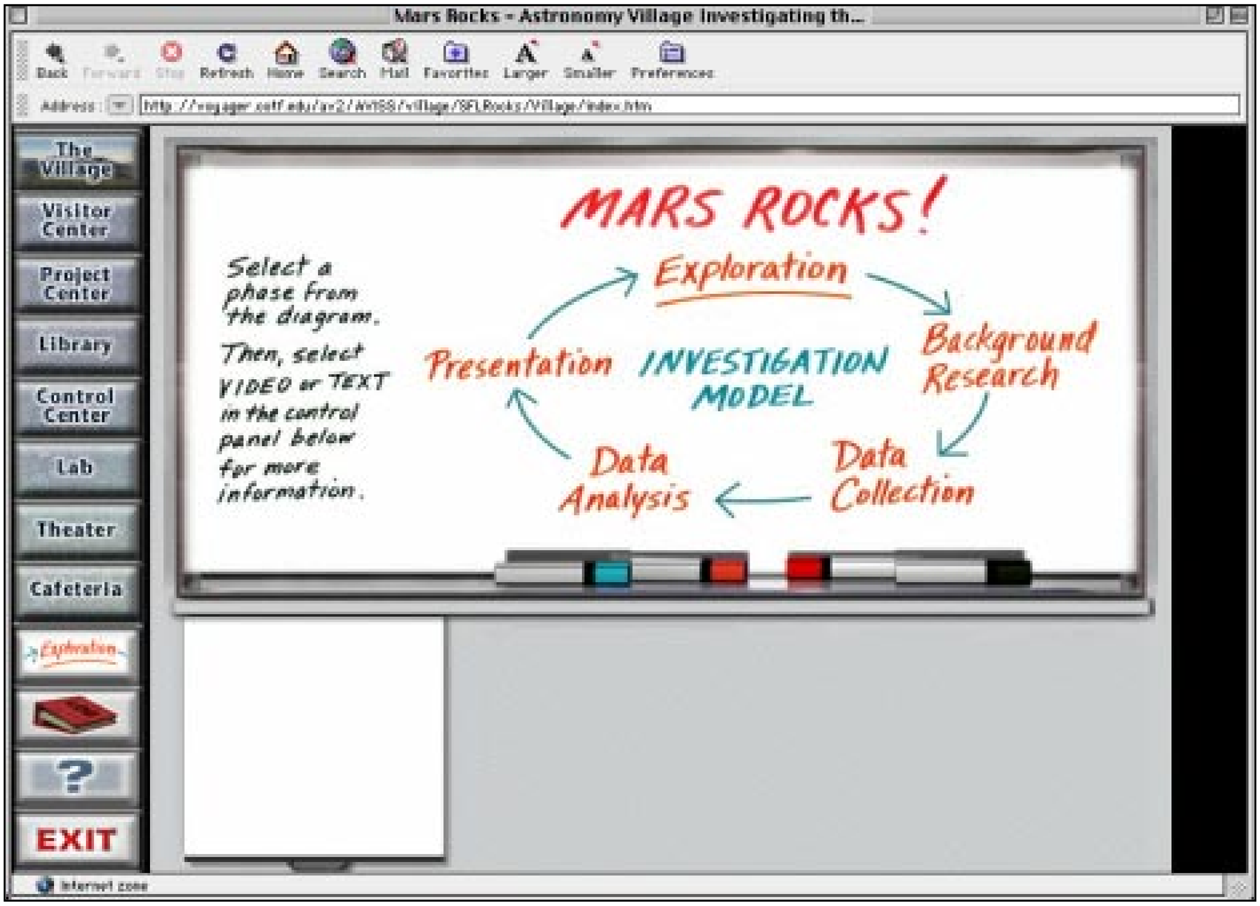

Figure 2: Mars Rocks Investigation Cycle Diagram

After completing a core research investigation, students select from a list of 3-4 project investigations that center on answering the core research question. Table 1 indicates the manner in which project investigations in *Astronomy Village: Investigating the Solar System* relate to the Unit Structure for scientific inquiry. The major modification to the high school Unit Structure is the addition of a phase for exploring the project questions. This serves to further generate understanding and interest in the core research question. Also, the representation of the investigation has been modified from the high school version. In this case, the investigation is represented as a cycle, which implies that when one investigation is completed it leads in to another investigation (see Figure 2). This representation was a better match for the purpose of having students complete multiple investigations on the same question. In order to address the issue of reducing the time spent on one topic, each investigation is designed to be completed within on week of class time. Therefore the minimum time spent on one topic would be two weeks—one for the core and one for a project. However, there is flexibility that teachers can have students complete more than one project investigation if their course supports a depth approach.

ADAPTATIONS TO AN ACTIVITY STRUCTURE

Common notions of activity structure or academic task (Doyle, 1983; Stein, Grover, & Henningsen, 1996) usually refer to activities that take less than one class period to complete. It is these activities that are grouped to form Unit Structures. Both versions of *Astronomy Village* use a wide variety of activity structures. There include lectures, article readings, hands-on activities, simulations, animations, image processing, and thought questions. Each of these activity structures has undergone refinement to adapt them to the middle school.

This section will discuss changes to one of the activity structures, namely, the image processing activity structure. The discussion focuses on image processing for two reasons. First, image processing is the core data analysis activity for all of the high school investigations and most of the middle school investigations. Second, students get relatively few opportunities in school to learn how to interpret images, which means they may not be as efficient at processing visual information as they are at processing textual information (McGee & Sturm, 1999).

Image Processing in Astronomy Village

Image processing is a method of extracting relevant information from images. Typically, it requires students to attend to shape, color, and placement of objects in the image. Through animation, each of these attributes can be studied over time, as well. All of the investigations in the high school version require the use of NIH Image for image processing during the data analysis phase of the investigation. Both NIH Image and stellar astronomy are unfamiliar to most high school students, therefore it was difficult for them to bring their prior knowledge to bear on the image processing activities in *Astronomy Village.* To help students complete the activities, *Astronomy Village* provides tutorials on how to use the specific tools that are needed for each investigation. After completing the tutorial, which takes about one class period, students are then given a set of instructions for processing the images to extract information relevant to their investigation. As an example, in two investigations students observe the motions of stellar objects in space. By recording the x and y coordinates of a moving star from one frame of an animation to the next, students can determine the angle of displacement for the star. For nearby stars, this information can be used to calculate the distance from the Sun to the star. For other stars, this information can be used to compute whether there are any planets orbiting the star.

The computational nature of these image processing activities is well-suited for high school students. However, the designers of the middle-school version did not believe that computationally-based image processing activity structures would be well-suited for middle school students for two main reasons. First, the pilot test teachers expressed concern over the mathematical abilities of middle school students. They felt activities that were computationally intensive might prevent many students from understanding the underlying science. Second, given the abbreviated structure of *Astronomy Village* projects at the middle school, teachers could not afford to take up an entire class period for learning software tools.

The *Astronomy Village* team settled on a pattern recognition activity structure for image analysis. Identification and classification is a common activity structure found at the elementary grades. *Astronomy Village* builds upon the classification activity structure by having students compare images of familiar objects to images of unfamiliar objects in order to classify and draw conclusions about those unfamiliar objects. The comparison is based upon similarities in shape and color between the familiar and unfamiliar objects. Figure 3 provides an example of one such activity. In this case, students are shown an image from the surface of Mars. They are asked to identify what features they see in the image. On the right-hand portion of the screen, students have seven different satellite images from Earth that they have identified in a previous activity. By comparing the Mars image to the satellite images from Earth, students can use pattern recognition to identify the Earth feature that most closely resembles the Martian features, which will allow the student to classify the Martian feature. In this example, the student will classify two objects in the Martian image as volcanoes.

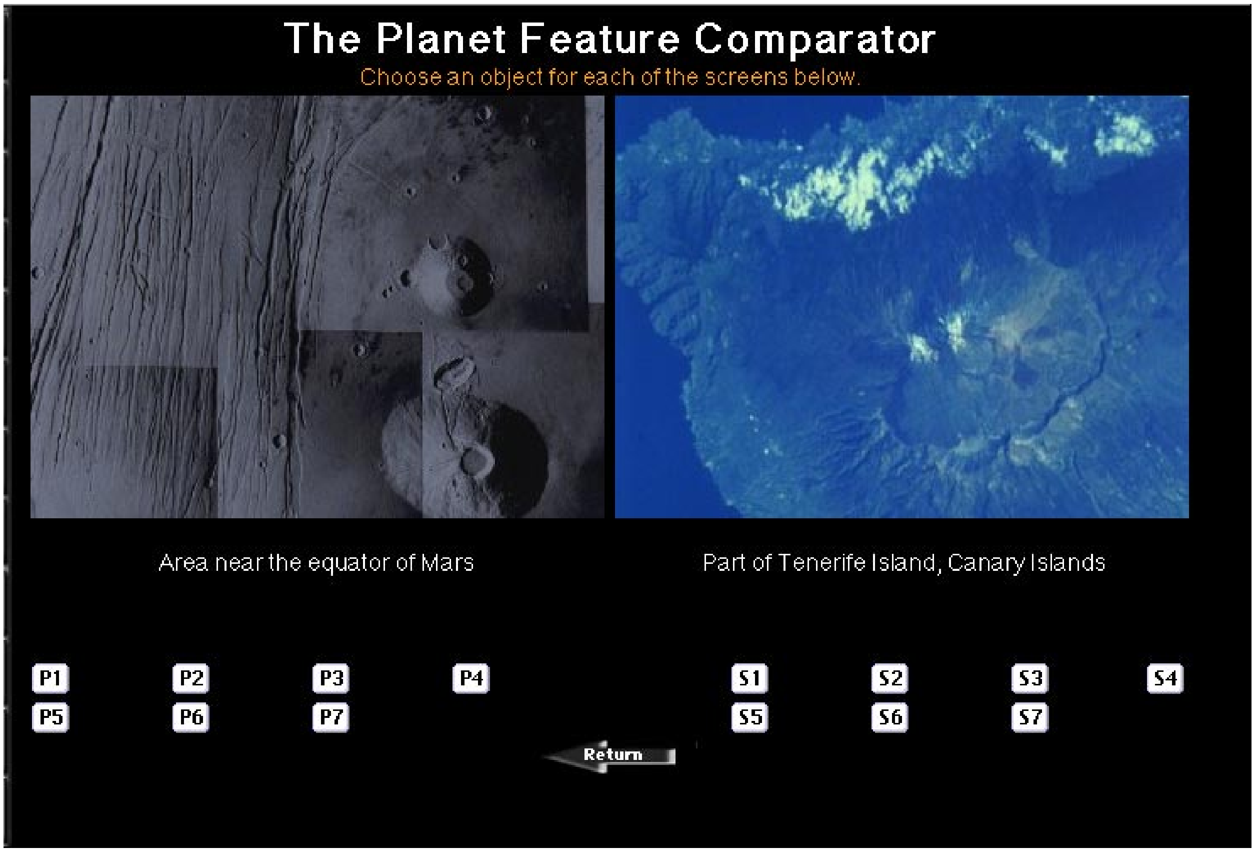

Figure 3: Planet Feature Comparator

CONCLUSION

The process of migrating the architecture of *Astronomy Village* from high school to middle school created a unique opportunity to investigate the viability of generalizing activity structures. This paper discussed activity structures at two levels. At one level, there are activities that take place in less than one class period. At the next level, activities are grouped into a Unit Structure. At both the activity and the unit level, *Astronomy Village* was successful and creating structures that can generalize from high school to middle school science. At the activity level, designers focused on three attributes of image processing: shape, color, and placement. The emphasis on these attributes was consistent at the high school as well as the middle school level. This activity structure also provided flexibility for the designers to adapt activities to meet the needs of the topic and the needs of students' prior knowledge. At the unit level, the TETEP framework remained consistent at both middle school and high school. In each case, designers identified important science questions for students to investigate and supplied a variety of activities that students could do to investigate the question. The students conducted the investigation, formulated conclusions and communicated their results. As in the case of the activity structure, the unit structure was also flexible enough to accommodate the demands of topics and students. As students progress from the high school to the middle school version, they should become familiar with the general structure of scientific inquiry and the general structure for image processing. The would then be prepared to apply that general understanding to other disciplines in science.

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