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Informing Practice through Collaborative Partnerships

MARINO C. ALVAREZ* Stephanie A. Stockman† William J. Rodriguez‡
Robert Davidson** Katie Schwartz††

*Tennessee State University, malvarez@coe.tsuniv.edu
†NASA Goddard Space Flight Center
‡University School of Nashville
**University School of Nashville
††Unversity School of Nashville

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Marino C. Alvarez
Tennessee State University

Stephanie A. Stockman
NASA Goddard Space Flight Center

William J. Rodriguez
Robert Davidson
Katie Schwartz
University School of Nashville

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Abstract

This paper focuses on students and their teacher engaging in authentic tasks and materials couched in problem-oriented formats within meaningful learning contexts that foster thinking and learning. Authentic in that students construct meaning from real data and are asked to make sense of the world around them. Students pursue individual paths of inquiry using critical and imaginative thinking, and engage in social and solitary contexts that involve them in writing, intervening, and reflecting on ideas gleaned from conversations and readings (electronic and conventional) with a university educator and NASA science educator. The process engages students in formal skills such as written communication, literacy, logic, and calculation using an innovative electronic interactive network. Evaluations of timed writings, concept maps, and Vee diagrams are presented and discussed.

Informing Practice through Collaborative Partnerships

This paper details how *self-directed* case-based research and instruction together with collaborative interactions with teachers, students, scientists, and university educators using metacognitive tools (e.g., concept maps, interactive Vee diagrams, and thematic organizers), and innovative technology promotes meaningful learning in ways that differ from conventional and atypical educational settings. Teachers and researchers mutually define research problems. Students engage in “real-life” self-directed case research. Together, this collaboration informs practice for students, teachers, and researchers. Within this negotiated learning environment educational processes and outcomes are achieved that meet both local and national contexts for achieving meaningful learner-centered science, mathematics, and literacy goals (e.g., American Association for the

Advancement of Science, 1989; International Reading Association, 1992; National Science and Technology Council, 1995; Science Council of Canada, 1984; Royal Society, 1985; NASA's Education Program, 1999-2003).

Theoretical Framework

Gowin's (1981) theory of educating, Ausubel's (1963, 1968) cognitive theory of meaningful reception learning, an emphasis on teachers and students becoming "communities of thinkers" (Alvarez, 1996, 1997a,b,c), and an action research constructivist epistemology provide the philosophical and theoretical background upon which this investigation was designed and through which the results were interpreted. Gowin's theory of educating focuses on the educative event and its related concepts and facts. This theory is helpful in classifying the relevant aspects of the educative event. In an educative event, teachers and learners share meanings and feelings so as to bring about a change in the human experience. This theory stresses the centrality of the learner's experience in educating. In order for meaningful learningto occur in Ausubel's theory three conditions need to be considered: (1) materials need to be concept rich, with clear relationships; (2) the learner needs to have relevant prior knowledge and experience with the concepts and propositions that are presented in the new materials; and, (3) learners need to have a meaningful learning set - a disposition to link new concepts, propositions, and examples to prior knowledge and experience (see Novak, 1998). A community of thinkers is defined as an active group of students and teachers striving to learn more about a discipline by engaging in the processes of critical thinking (thinking about thinking in ways to bring about change in one’s experience) and imaginative thinking (exploring future possibilities with existing ideas, Alvarez, 1996, 1997b). The notion presented by this theoretical framework enables both students and practitioners to become better informed and knowledgeable about practices that enhance conceptual learning and meaningful understanding.

To better understand how teachers, researchers, and students activate and build upon existing knowledge it is necessary to study the ways schema is activated and new knowledge is constructed. Schema (plural schemata) is a mental construction of an event, object, or an individual characteristic that can be fragmentary, inaccurate, or inconsistent. It is based upon a belief that can be applied to either physical systems or semantic meanings depicted in a text. When reading a text, the text can be seen as a series of acquisition statements within a given topic or subtopic. The notion of schema theory is that a person can comprehend a text when it is congruent with his or her belief system. Educators and researchers have suggested numerous instructional strategies to help students activate and use prior knowledge to aid comprehension. Yet, schema theory does not explain how readers modify and create new schema when presented with novel information in texts. Because texts are never completely explicit, the reader must rely on preexisting schemata to provide plausible interpretations. Yet, there is much evidence that good and poor readers do not always use schemata appropriately or are unaware of whether the information they are reading is consistent with their existing knowledge (e.g., Bartlett, 1932; Bransford, 1985). Also, there is evidence that students who do not spontaneously use schemata as they read will engage them if given explicit instructions prior to reading (e.g., Ausubel, 1960; Bransford, 1985).

Action research is a paradigm that is grounded in the reality of classroom culture and under the control of teachers. Findings' emanating from this type of research investigation informs teachers and guides their practice when formulating lessons and conducting future classroom research projects. Action research is defined as the acting on an event, object, problem, or an idea, by an individual or group directly involved in gathering and studying the information for themselves, and using the results for the purpose of addressing specific problems within a classroom, school, program, organization, or community (Alvarez, 1995). Action research is deliberate and results in ownership by the participants. The consequences affect participants personally. The *action* is the acting on an event, object, problem, or an idea for the purpose of monitoring and evaluating its course and outcomes. *Research* is a systematic deliberate critical inquiry of an event in order to enlighten one's thinking, learning, and practice. This setting in motion of a strategy for the systematic study of an event that evolves from an idea or problem is the basis on which these investigations are predicated. In this project, the events that are studied take place in an educational setting and the study is conducted by student and teacher researchers in collaboration with university educators and scientists in the areas of earth and space science. This action research strategy is accomplished through a recursive cycle of (1) identifying an idea problem area, (2) studying it by gathering data, and (3) reflecting on the data in order to make teaching and learning decisions grounded in evidence (see Appendix A - Action Research Strategy, Alvarez, 1995).

The focus of this action research inquiry centers on the research question: RQ1 "How do metacogntive tools and electronic communications influence practice when studying cases using authentic data in collaborative formats?" Within this realm of inquiry are included the effects of thematic organizers and timed writings and their influence on schema activation and knowledge construction.

Method

This study was conducted over a three-month period in a private high school located in urban Nashville, Tennessee. Two students, Katie Swartz a tenth grader and Bobby Davidson an eleventh grader, and their teacher, Bill Rodriguez, together with Stephanie Stockman, a NASA educational scientist, and Marino Alvarez, a university educator, participated in this study. These students and their teacher at this high school are part of a consortium of middle and secondary schools affiliated with the Tennesssee State University's Explorers of the Universe Project, at the Center of Excellence in Information Systems. In this action research scientific/literacy project teachers, students, scientists, university educators, and community persons are involved in collaborative research studies using self-directed cases, metacogntive tools, and interactive electronic learning environments (Alvarez, 1995, 1996,1997, 1998a; Alvarez & Rodriguez, 1995; Stockman, Alvarez, & Albert, Jr., 1998). Students and teachers research cases using authentic data received from: TSU's variable star project; and, NASA Goddard Space Flight Centers' Mars Orbiter Laser Altimeter (MOLA) and the Vegetation Canopy Lidar (VCL) missions.

Bill Rodriguez had several students in his class doing case projects in astronomy. He and his students have been working with Marino on the Explorers of the Universe Scientific/Literacy project for four years. Bobby and Katie indicated they were interested in doing the case dealing with the Mars Orbital Laser Altimeter (MOLA) mission. Stephanie and Marino visited Bill’s class and met with the students. Katie and Bobby discussed their ideas with Stephanie. It was agreed that they would pursue their ideas with the case: Water on Mars.

All of the students and the teacher in this astronomy class were taught how to construct and use Vee diagrams and concept mappings by the university educator. The procedures followed those advocated by Novak and Gowin (1984), and used scoring protocols developed by Alvarez. The Vee heuristic was developed by Gowin (1981) to enable students to understand the structure of knowledge (e.g., relational networks, hierarchies, and combinations) and to understand the process of knowledge construction. Hierarchical concept maps and Vee diagrams are two methods that students can initiate on their own for schema construction and application. Hierarchical concept maps (Novak & Gowin, 1984) are designed to help the reader clarify ambiguities of a text while simultaneously revealing any misconceptions that result from a reading. More importantly they provide the learner with a tool from which to initiate ideas that can be shared by visual inspection with someone else. The Vee diagram (Gowin, 1981/1987) is a method by which a learner can learn about the structure of knowledge and knowledge-making within a given discipline and use this knowledge in novel contexts.

Information is entered electronically by students and collected for analyses in a database at our TSU web server via the Explorers of the Universe web site (http://explorers.tsuniv.edu). Within this site is a linkage to Gateway, a password protected site, that provides entry into a Student Console, Teacher Console, and Researcher Console. Teachers manage their student electronic accounts by assigning passwords, determining the degree of portfolio sharing among students, and responding to student inquires. Students post their thoughts, progress, inquires, and data on their individualized electronic notebook. Likewise, they plan, carry out, and finalize their case-based research using electronic transmissions via e-mail and the Internet of their concept maps and interactive Vee diagrams. Students follow sequential stages of the Action Research Strategy: (1) problem/situation, (2) plan/strategy, (3) course of action, (4) resolution, and (6) action. Each stage corresponds to the epistemic elements arrayed on the Vee Diagram. Their concept maps, Vee diagrams, and other pertinent items (e.g., video clips, models, simulations, journal articles, etc.) related to their case report are stored in individual electronic portfolios. Student peer-edited papers are posted on the WWW for others to read and react. Students present their research reports with their teachers, scientists, and university educators at international, national, and state science, mathematics, technology, and literacy conferences. The final process involves students developing CDs of their case research report, which serves as a longitudinal case for others to pursue.

For this study, two students and their teacher used a newly designed *Interactive Vee Diagram* electronically on the Internet (Alvarez, 1998b). This Vee is menu driven and asks students for their name, school address, and e-mail address. Also included are instructions for entering information on the Vee. A *Case Guide CD-ROM* (Alvarez, 1998) was developed as part of the Explorers of the Universe and given to the students and teacher that contains visual, animations, and audio descriptions of Vee and concept mapping procedures, and an Action Research Strategy with learner-centered questions in each stage. The teacher acted as a facilitator in this study and became the researcher of his students by testing the effectiveness of the metacognitive strategies and monitoring the progress of their cases using essay tests, timed writings, journal entries, and portfolio assessments. The teacher and researchers scored their concept maps and Vee diagrams. The NASA scientist educator and the university educator received incoming information from the Vee and concept mappings of the students and responded accordingly to their representations and questions.

Thematic Organizer

A thematic organizer, developed by Alvarez (1983), is an adjunct aid designed to: (1) highlight systematically and explicitly the central theme of a text; (2) relate the theme to experiences and/or knowledge that the students already possess; (3) provide cohesion among the ideas to accommodate text structure; and, (4) aid schema construction by elaborating upon new and extended meanings of a thematic concept (Alvarez, 1983a; Alvarez & Risko, 1989; Risko & Alvarez, 1986). A thematic organizer is a preview strategy intended to activate students' prior knowledge, relate this knowledge to the central theme of a passage, define the theme by explaining its attributes, and ask students to predict what will occur in reading and viewing passages.

The thematic organizer was presented electronically on the Explorers of the Universe web site (http://explorers.tsuniv.edu) and was constructed by modifying a procedure developed by Alvarez (1980, 1983) and following the format of Risko and Alvarez (1986). For this study, it was believed that the thematic organizer could provide cohesion by illustrating the common elements of the case using multiple contexts rather than to rely on students' spontaneous association which may or may not happen. Hyperlinks to related information about the target concept were included.

Following Ausubel's (1968) differentiation between types of advance organizers, it was decided that a comparative organizer would be used. It was planned that the thematic organizer would explain explicitly the theme (e.g., Water on Mars). As in Ausubel's (1960, 1968), it was written in prose and intended to activate the reader's prior knowledge and enable the reader to assimilate ideas that had previously been unrelated. The thematic organizer differed from Ausubel's organizer in that it was written on a level believed to be commensurate with the students' reading ability and included information that dealt specifically with the topic of the reading. It was further designed to provide referents that were believed to be within the reader's experiential background. In addition, the thematic organizer was written to adhere to specified guidelines for organization and structure (see Alvarez & Risko, 1989; Risko & Alvarez, 1986).

Specifically, the thematic organizer for the case “Water on Mars” was developed by Marino and Stephanie and written as follows. The first section contained three paragraphs, which compared the similarities of scientists and detectives according to the thematic concept (Water on Mars). Students are presented with a Situation/Problem that is intended to arouse curiosity with the target concept. The first paragraph "set the scene" by introducing the thematic concept in a setting believed to be relevant to the students' experience. A hyperlink was included to provide background knowledge to the reader/viewer about Martians on Mars and the radio broadcast “The War of the Worlds.” The second paragraph presented several examples which further explained the fascination with the planet Mars, and its comparison with Earth. The third paragraph discussed the need for a careful study of the geological features on Mars. Students were asked to write any impressions they had about these features in their Electronic Notebook.

The next two paragraphs were developed as follows. The fourth paragraph contrasted the relationship between Earth and Mars and ended with a question “Did Mars have a warm past." The fifth paragraph gave the reader/viewer a precise and clear direction of what he or she was expected to know when the reading was completed. The reader/viewer was also asked to record their initial thoughts in their Electronic Notebook.

The second part of the thematic organizer was a set of six interpretive statements that presented attributes and non-attributes of the concept. Written directions were given asking the students to read these statements and select the ones that they thought were correct either during or after reading the Background information provided. The statements corresponded to the target concept. There was reason to believe that statements such as these would facilitate student ability to interpret information implied by the author of this passage (Alvarez, 1980, 1983; Risko & Alvarez, 1986). Responses to these statements by the students were analyzed by the teacher; and, subsequently, by the NASA scientist. This analysis was done in response to students' questions submitted in their electronic notebook and E-mail entries.

Notebook Entries

Bobby and Katie are initially introduced to the Case: Water On Mars with a

Situation/Problem:

> **Did Mars have a warm wet past? What can the history of Mars tell us about our own planet? Are we seeing a picture of Earth's past, two billion years ago, or is it Earth's future? New information is being currently received from Mars probes that give more insight into the unraveling of this mysterious planet. NASA also has two spacecraft on the way to Mars (arriving in the Fall of 1999) and plan a number of additional missions during the next decade (http://cmex.arc.nasa.gov/MarsNews/Missions/Missions.html). The hyperlink further explains the mission.**

As Katie and Bobby read the thematic organizer they responded to the interpretive statements therein via the electronic notebook. The statements and their responses are given below. Stephanie's replies are written in italics beneath each statement.

1. Water on Mars is a relevant topic for investigation.

   Water is a relevant topic for the mars study because if there was water on mars what happened to it and where did it go. What was the effect did the disappearance of the atmosphere. The water has moved to the poles and when the atmosphere disappeared. The study of water on mars can tell us how the land was shaped and how the deep craters were formed. The canyons and other land forms were formed by the movement of water.

   You have identified some of the questions about water on Mars that scientists hope to answer during the Mars Global Surveyor mission and future Mars missions. There are features on Mars that appear to be formed by water.
   We don't know the relationship between the polar icecaps and the Martian atmosphere, but we do know that for liquid water to exist the Martian atmosphere had to be different than it is today. Remember, that to better understand what landforms on Mars were possibly shaped water, we need to look at water-shaped features on earth. You may want to think about how craters form (or do some research), they are not really water-related features.

   Something for you to think about: Biologists tell us that a planet must have water for life to have existed on that planet.

2. Martian days differ in length from Earth days.

   The martian days are much shorter then those on the earth. The days on mars go by faster because the satellite orbits about every seven martian days and that only takes about two hours on earth.

   Think about this one. How long is an earth day? Why do we have day and night on earth? Remember, Earth and Mars revolve around the sun and rotate on their axis ....the revolution around the sun gives us the length of the year and the rotation gives us the length of the day for each planet

3. MOLA measurements give accurate information about Mars's topography.
http://mars.jpl.nasa.gov/mgs/sci/mola/data1/mola_first.html

   The MOLA does create good topography because the error that the laser gets is very small. The laser is more accurate then there has ever been.

Be careful how you phrase this. MOLA allows us to measure the elevation of the Martian surface (the topography). MOLA does not create topography, it measures it.

4. There is agreement among scientists about liquid water on Mars.
http://cmex.arc.nasa.gov/SiteCat/sitecat2/water.htm
http://cmex.arc.nasa.gov/VOViews/CHANNELS.HTM

There seems to be an agreement about the water on mars. They believe that there was water on mars but there are two suggestions as to where it is now and how it existed. Some say that there was an atmosphere that was warmed by CO2 emissions by volcanoes on the surface. This results in rainfall which caused many surface canals. The other idea is that there was little atmosphere similar to the way it is now and the water flowed under ice. We think that there probably was an atmosphere (or at least Bobby does-Katie has no idea whatsoever) and perhaps it deteriorated once the volcanic activity stopped. Perhaps this period of volcanic activity occurred during the early stages of the planet, while it was still determining its surface structure, resulting in lots of plate movement (which caused the volcanic disturbance and random mountains and stuff). Or, another random possibility: perhaps there wasn't an atmosphere and the water flowed to the poles, were it it presently located in the form of ice caps. Or maybe, like the scientist think, the water did flow under ice, but the ice was in the form of glaciers, like earth, a loooong time ago. Or something like that.

There is still not agreement about LIQUID water on Mars. Some scientist suggest that some of the surface features we see are actually carved by flowing ice and not flowing water. Again, by looking at these processes on
earth have a better chance of understanding what may have happened on Mars. MOLA and the Mars Orbiter Camera will provide a more detailed look at surface features on Mars. Check out the MGS website to see the latest data. Be careful with how you describe features, while we see channels on mars we don't see any canals. What's the difference between a canal and a channel?

5. It is not important to estimate the volume of the water ice cap.

We disagree that it is not important to measure the volume of water in the polar ice caps. In, fact we believe it is very important to measure them for the following reasons: We could find out how much water Mars contains, estimate what happened to the rest of it when whatever happened (and perhaps estimate how much dissipated into space) Perhaps the volume of water on Mars could help to determine the mineral composition of the surface of Mars in the past. That’s about it...

Sounds good to me. But tell me more about mineral composition. During SPO 1 and SPO 2 MOLA made measurements over the northern ice cap, which allowed the science team to estimate the volume of ice in the North. Now that MGS is in its *circular mapping orbit, MOLA will soon have enough measurements to estimate the volume of ice at the south pole.*

6. Determining if there was water on Mars, while interesting, is not very helpful in determining the Earth's past or future?

It could be important to determine what happened to the water on mars because it could tell us what might happen to our planet. Since earth and mars have similar features. Perhaps the cause of disappearance of the Martian atmosphere will allow us to find out what might happen to the earth's atmosphere.

Well said!!

The dialogue between Katie, Bobby, and Stephanie pertains to preliminary thoughts about their case research. Stephanie's comments are intended to facilitate their understanding about the MOLA project by spurring them to access other Internet sites and resources. She also asks them to think about their response to statement 2, and cautions them in using "measurement" in a context relevant to MOLA's mission on Mars in statement 3. These comments are shared with Bill who is able to monitor the degree of understanding between Katie and Bobby and message conveyed by Stephanie.

The process involves not only active dialogues between students, teacher, and the NASA scientist, but more importantly begins to establish "trusting relationships" between the collaborators. Ideas begin to be shared and negotiated in "real" ways through pertinent questions, reflective responses, and mutual understanding.

E-Mail Communications

The first E-mail message that follows outline a series of difficulties encountered by Katie and Bobby as they attempt to access the data on the Internet. The second message contains several inquires into craters and the term "off-nadir position." The message also asks a question posed by their teacher Bill about IDL software.

From Katie Swartz

Hello Dr. Stockman,

Its Katie, I have yet to set up an e-mail address and Bobby is Missing In Action, so I have to use Mr. Rod's account. We're having some problems with the data translator programs. We downloaded both the Windows software and the IDL software off the internet, but the IDL is stubborn and refuses to work, and the Windows software merely converts data files into some other equally unreadable form. Mr. Rod suggests that his brain is malfunctioning, but perhaps there is hope for him and there is actually some software glitch or other software required to work in conjunction with the software that we currently have?

Thanks for your time,
Katie Swartz

From Katie and Bobby

Dr. Stockman

We had a couple of questions that we were not able to ask you when you here. One was what are the reasons that some of the craters have plateaus in the middle? We were also wondering what it meant when it talks about the MOLA being observed in an off-nadir position? In the site that talks about the channels that were created it talks about mass wasting. What is that? Mr. Rod also wants to know where the software that lets us view data using IDL?

Bobby and Katie

Stephanie states her reaction to this E-mail: Bobby and Katie took some time to look at the websites in the case guide, and they looked at images of craters on the planet's surface. The off-nadir question pleased me. It seemed to demonstrate some understanding of the importance of knowing how measurements were made (understanding the instrument).

From Stephanie Stockman

Hi Bobby and Katie,

Greetings from Tucson! I think you need to do a little research on cratering and mass wasting...but here are a few hints: The plateau in the middle of some craters is

called a central peak and has to do with crater formation (imagine a raindrop or rock falling into a pond). Mass wasting is related to erosion and landslides.

Off nadir means that MOLA was not pointing straight down to the planet's surface, instead the beam struck the planet at an angle.

The IDL software should be on the MOLA website (I think under SPO 1 data). Let me know if you have trouble finding it and I'll get Mr. Rod in touch with Greg Neumann, the person who wrote the programs.

Glad to hear from you!

Steph

Stephanie discusses her reasoning when responding to Katie and Bobby:

Cratering and mass wasting are both processes that significantly shaped the surface of Mars. I hoped to encourage Bobby and Katie to do additional research in these areas. There are a number of good references on Cratering that are targeted for middle/high school students. Mass wasting is covered in High School earth science classes and texts. She encourages them to use their imagination when conceptualizing "a raindrop or rock falling into a pond."

Regarding the IDL message: I'm not a software expert, so I sent Katie and Bobby to our expert on the MOLA team. I was surprised to find that Rod's class had and was using IDL. It's a key tool for us in data processing, analysis and visualization.

From Stephanie Stockman

Hi Katie,

I'm sending this message to Greg Neumann, the scientist who has developed some of the software and knows about all (most) of it. Hopefully Greg can save Mr. Rod's brain.

steph

Gregg Neumann receives Stephanie's message and E-mails Katie and Bobby.

From Gregg Neumann *(scientist who took part in developing the software)*

I believe the PC version of the IDL software "mprofpc.pro" is now fixed. It may be downloaded from

ftp://ltpftp.gsfc.nasa.gov/pub/projects/tharsis/MOLA/SOFTWARE/SMALLENDIAN

Please see the files in the SOFTWARE directory mprof.txt and pedr2tab.fmt

During these exchanges, Stephanie and Bill kept Marino informed of the E-mail transmittals. Bill followed up the software problem first contacting Greg, and then continuing with questions to persons referred by Greg. Stephanie responded to inquiries by Katie and Bobby by acting as a resource and facilitating their progress. Not by giving answers, but by asking them to reflect on their questions, their writings, and by guiding them to relevant sources.

Evaluation

This project is being monitored by using Gowin's (1981) four commonplaces of educating: teaching, learning, curriculum, and governance. We are also using triangulation (informants, records, and observations) as a method to cross-check our findings (see Denzin, 1978). Gowin's theory of educating is a conceptual approach to problem solving that focuses on teacher/student social interactions and the ways in which students and the teacher negotiate meaning between and among themselves.

In many classroom situations teaching is telling students what they need to know about a given set of facts for a particular subject area and assigning lessons. Our assessment of the project indicated that ***teaching*** is achieving shared meaning between the teacher and students, and among students themselves. This was accomplished through shared meanings that resulted from negotiating facts and ideas. It also included altering lesson plans to meet individual needs. For example, Bill involved Bobby and Katie with the Mars Orbital Laser Altimeter (MOLA) case "Water on Mars." This type of case deviated from his normal plan that focused more on astronomy. Within this teaching context, Bill describes a change from "disseminating information" to the "role of learning from my students as well as sharing what I learn with my students."

> **In the past the focus on traditional astronomy projects yielded good results with students tackling and understanding the tools that professional astronomers use as well as being able to make excellent decisions about what their data tells them about a celestial phenomena. Katie and Bobby's project is more in the realm of geology looking for water on the planet Mars and determining the amount of water that exists on the planet. Since my background on this topic was minimal only what I had read in *Astronomy and Sky and Telescope* magazines we were all in this project together. This forced me to work alongside them reading about the MOLA project in general, the method the satellite uses to gather data, as well as how we would use this data to answer the question about water on Mars. My role differed from the traditional in the sense that I do not research various aspects then lecture to the students we work on them side-by-side. We learn and teach each other as the case develops. Each of us uses our expertise to help the group progress.**
>
> One of my main contributions is to deal with software problems how to get the actual software used by the NASA scientists working in our room on our computers. This is requiring a fair amount of time using email, downloading software routines, and testing them to understand what exactly each routine (or tool) is looking for in the data. From my point of view this is very exciting.
>
> **I am not cast in the role of disseminating information, but in the role of learning from my students as well as sharing what I learn with my students. Working as a team we tackle larger problems and answer more difficult questions. I cannot plan each class with the precision one might normally plan a class, i.e., which page I will discuss during which class period. The learning flows from class to class based on the complexity of each day's information or, in some cases, each day's frustration. Frustration at not finding a source of information or not understanding why the software is not working, to just a feeling of being overwhelmed by the topic. However frustrated Bobby and Katie get, they still enjoy what they are doing and plugging along at the topic. It is more exciting than a regular class and more difficult at the same time.**

Learning in the traditional sense is under the control of the teacher. In essence, the teacher tells students what they need to know. We were interested to see if learning could be placed in a context under the control of the students. Given the opportunity, could these students take charge and be responsible for their own learning? This question was answered in the affirmative when we read the concept maps, Vee diagrams, and electronic journal entries that these students had written in their self-directed case based research. The concept maps showed how reconceptualization of ideas influenced their views on their target concept. The case provided a forum by which the students could take an active role in structuring and creating their own meaning. Not only did students engage in teacher-assisted instructional strategies such as the use of thematic organizers, but they also learned how to use interactive hierarchical concept maps to organize their thoughts, and Vee diagrams to plan and carry-out their investigation. Bill describes his thoughts about Katie and Bobby before and after they became involved in the project.

Student learning before and during the project

> **My students typically do very well on traditional research projects and when faced with the MOLA project they embarked on a similar strategy to review information in astronomy books, read web pages, and discuss ideas with a NASA scientist involved in the MOLA project.**
>
> During the course of these actions they also began constructing their Vee diagram and building a concept map. What these two tools showed was that the students had a good deal of information, but no framework in which to "hang" the information. They could write a decent paper about the Mars project, but as far as real understanding about the underlying questions and how scientists (and they themselves) would use actual data collected by the orbiting satellite to decide about water on Mars, they were very unclear and frustrated. Talking with them and reviewing their early concept map yielded positive results as they began to rewrite their map they started to understand in more detail the concepts involved in their study. They also realized that when working on a problem, to which the answer is not yet known, not even by leading researchers one's approach must be very thorough and detailed. Not just in acquiring note cards and sources, but in evaluating the

information and carefully constructing a knowledge base upon which one can build a very solid case to answer their research question.

You can see the development of Bobby and Katie's thought processes by comparing their early concept map with their most recent. Early on they mapped out their strategies for the project rather than the concepts involved in the project. In other words, they spent time analyzing what they were going to do, not how the information they were acquiring fit together. In a way this fits into a student's traditional mode of learning justifying one's work by showing everything one has done to answer a question. It fits the mold of "I'm working hard see my note, so I should receive a good grade".

Bobby and Katie now realize that many people work hard at acquiring knowledge, but the use of the knowledge is far more important than the amount one acquires. Also, they are starting to struggle with the question "how will we support our own ideas about the amount of water on Mars?"

Bobby and Katie are realizing that they need to spend more time understanding the tools and methods scientists use to search for water on Mars as well as determine the amount they find. Their project has taken a geological turn they need to look at how water shapes the surface of a planet by looking at the earth and then comparing these shapes and structures to the surface of Mars to see if they exist there. Katie and Bobby are also realizing that they are working in an area in which they may have to make a "best answer" rather than the correct answer because we may never know definitively how much water is on Mars.

The ***curriculum*** that evolves from this project is emergent rather than fixed. The basic materials go beyond the traditional use of teacher-centered lectures and hand-out materials devised and published by others. Instead, students are presented with a problem/situation, a thematic organizer, background material, and are asked to formulate questions of interest to pursue. Both the thematic organizer and background material provides hyperlink connections within the Internet. Students are also presented with an animated CD that describes the uses and functions of concept maps, interactive Vee diagrams, and an Action Research Strategy that enables them to think about their research.

The events in these sources provide the learner with a record of events as they exist in the past and the present, and serve as a venue for students to make new events happen in the future. These sources guide students to other resources and materials in their quest to seek resolutions to their self-directed cases.

The ***governance*** exercised in this project differs from policies and formats that are typical in curriculum guides, teacher's manuals, or module-based lessons. This project allows teachers and students to express their thoughts freely and make critical decisions. Other teachers, scientists, university educators, and community members are involved in the learning of the students. The learning atmosphere is nonthreatening and promotes a social context where ideas are openly shared and discussed. The teacher, in conjunction with scientists, and university educators, guide students by specifying criteria in executing and completing their cases. However, students are also encouraged to make decisions in governing and conducting their research.

Both Bobby and Katie are exercising their own form of governance that differs from past school experiences. More time is devoted to carry-out their case research investigation. The research questions that they ask differ from those that are imposed by a teacher or by outsiders who develop questions with packaged answers. Since they are in charge of their case, they are responsible for analyzing data, making decisions about their worth, using statistical methods, sorting through relevant and irrelevant data sources, and accessing the Internet and to determine whether or not the information is pertinent and authentic. By incorporating other subject-areas into the teaching of his course, students become aware of how these disciplines are interrelated. Traditional compartmentalized curricula are replaced by one that is interdisciplinary (see Alvarez, 1993).

Evaluation of students' portfolios on the Explorers restricted web site are assessed by the teacher. Statistical analysis of student concept maps, and interactive Vee diagrams, were conducted by the teacher and by researchers at TSU's Center of Excellence in Information Systems.

Timed Writing

Timed writings (see Alvarez, 1983b, 1993) were used to assess students' prior knowledge, world experience, and degree of spontaneous relationships between course content and the specific topic of study in the self-directed cases. Qualitative evaluations were analyzed by coding the data and then using NU*DIST 4 software to organize the data sets.

Bobby and Katie were asked by their teacher to write about their case "Water on Mars." They wrote for six minutes without stopping their pens in the process. They were told beforehand that if they stopped writing during the time they were to write their first and last names over and over until another thought came to mind. Their writings were reviewed by Bill and given to Marino. Marino made copies of each student's timed writing and gave one to Goli Sotoohi, a TSU researcher with the Explorers of the Universe project. Each read the two timed writings and made initial codings for comparison. Marino then typed these writings for incorporation into the NUD*IST 4 software program. In addition, Marino reviewed each of the students' writings and made a concept map of each showing their representations. These maps gave a visual representation of each student's thought processes as they engaged in this spontaneous writing activity. The maps helped to clarify the coding procedures for qualitative analysis of the timed writings.

Marino predicated on Stephanie's view of the Mars Orbital Laser Altimeter (MOLA) project had constructed an overall concept map showing the major and minor categories. Coding of the timed writings were categorized according to these relationships. For example, under Comparative Planetology were four major feature categories: Geological, Water, Cratering, and Atmospheric. Subcategories under Geological were: channels, faults, canyons, landslides, and volcanoes. Water features included erosion, ice caps, glaciers, oceans, and rivers. Listed under Cratering were size, multiring, and distribution. Atmospheric features were clouds under which were subsumed low, high, and composition (i.e., dust, CO_2, and water vapor); dust storms, structure, and density.

The Table represents the time writings by Katie and Bobby, and lists the grade, time, topic, and number of words written.

Table 1. Katie and Bobby's Time Writing.

Katie's Timed Writing
Grade 10
Six Minutes
Number of words = 195
Case Topic: Water on Mars

Transcribed verbatim from written entry. *Crossed-out words were not recorded.*

There are many people who believe there was a tone [sic] time, millions (possibly billions) of years ago, water on Mars. The fact that there is no water on Mars (other than in the icecaps) now does not take away from the evidence that shows that there was. What people seem to believe is that the atmosphere on Mars, which is primarily made up of CO_2 and currently is very thin, was at one time much thicker. It was supposedly thick enough to raise the extremely cold temperature on Mars to level at which water can run in a liquid form. What people think happened was that in the beginning of Mars "life" there were a lot of volcanos that spewed tons of CO_2 into the atmosphere, causing it to be thicker much like earth's global warming. Mars crust now is very thick and does not really have plates so there is now no volcanos and also no place for magna to get through. This means two things – the CO_2 amounts in the atmosphere went down causing Mars to cool, and there is also relatively little renewal of Mar's crust so there is good evidence [time expired]

Bobby's Timed Writing
Grade 11
Six Minutes
Number of words = 188
Case Topic: Water on Mars

Transcribed verbatim from written entry.

Water on Mars is an interesting topic. There was once water on mars. The scientist believe that it either existed in one of two forms. The first idea is that the water was trapped under a glacier and flowed freely beneath it. The other is that there was once a denser atmosphere than there is today and that the water flowed like rivers on Earth. The atmosphere was supported by volcanic activity. This volcanic activity allowed for a warmer climate and the water to flow freely. There are landforms on Mars that closely resemble some of the landforms on Earth. The landforms are such like channels and canyons that are shaped like one's on Earth. The channels are cut roughly which might show that water flowed thru them at one time. The water makes the sides of canyons and channels rough instead of the wind which makes them smooth. The features on Earth that have been formed by water are almost identical to some of the landforms that are on Mars. The water has been lost whether it is in the atmosphere or in the polar ice caps [time expired]

A review of the table indicates that Bobby and Katie each focus on different, but related aspects of their case. When comparing their spontaneous writings to a draft concept map of MOLA several relations are incorporated. For example, under the category Geological Features, Bobby mentions "channels" three times, while Katie does the same with "volcanoes." Neither mentions Cratering in their writing, but Bobby discusses the role of Water once in each of its subcategories: "ice cap," "glaciers," and "rivers." Katie, on the other hand, mentions CO_2 six times under the Atmospheric category while Bobby refers to its "density" once.

Stephanie reviewed both Bobby and Katie's timed writings and checked them for accuracy, misconceptions, or faulty reasoning. She then provided feedback to these two students via their teacher:

Katie's writing:

She has a basic grasp of the idea that a more dense atmosphere would have allowed for liquid water on the surface of Mars. That is one of the prevailing theories on how liquid water could have existed on the planet. It is not clear if Katie understands the link between increased CO2 in the atmosphere and temperature.

>causing it to be thicker much like earth's global warming<

Yes, increased >CO2 in the atmosphere does contribute to global warming. Katie also seems>to understand the relationship between volcanism and crustal thickness.

She infers that there is a misconception in Katie’s reasoning concerning CO_2 raising the temperature of the atmosphere.

Bobby's writing

Bobby seems to have synthesized a great deal of information. His statements are accurate as they pertain to the competing theories for how liquid water could have existed on Mars. He makes the comparison between features on earth and similar features on Mars. It is not clear what Bobby means by>channels are cut roughly<. He may have some misconceptions about the difference between water and wind eroded features.

In this message she asks Bobby to clarify his meaning of “channels are cut roughly” and also his understanding of the effect of water and wind with erosion.

Timed writings are valuable for all parties involved in this collaborative research project. These spontaneous writings provide the teacher with knowledge that students possess as they progress with their inquiry. The university and science educators are able to evaluate student progress and conceptual understanding with a target concept. These writings provide a basis for the teacher, university, and science educator to provide feedback to the students, and compare these entries with the ideas portrayed on their concept maps. Students are able to reflect on these comments, reconceptualize, and self-monitor their learning.

Interactive Vee Diagrams

Scoring procedures of student Interactive Vee Diagrams and concept maps followed a modified protocol suggested by Novak and Gowin (1984, pp.70-72) developed by Alvarez. Vee diagrams were scored on a quality point scale (0-4) with a maximum score being 30 in two stages using the following criteria (point values in parentheses for each of the categories): research question(s) (0-3), objects/events (0-3), concepts (0-4), records (0-3), theory (0-2), world view (1), philosophy (1), principles (0-4), transformations (0-4), knowledge claims (0-4), and value claims (0-1). Stage 1: Research Question(s), Events/Objects, Concepts, Records, Theory, World View, Philosophy, Principles, and Transformations (preliminary plans to analyze and represent the data). Stage 2: All components of the Vee are evaluated.

The university educator and Goli,Sotoohi, a TSU researcher, evaluated the Vee by Katie and Bobby. Stage 1 scores by the two raters are given in parentheses: Research Question(s) (3,3), Events/Objects (2,2), Concepts (3,3), Records (2,3), Theory (2,2), World View (1,1), Philosophy (1,1), Principles 2,2), and Transformations (0,0). Their scores agreed except for Records.

Concept Maps

The university educator and Goli, a TSU researcher, used a scoring protocol developed by Alvarez to independently score the concept maps (see scoring system in Appendix B). Stephanie reviewed the concept maps for accuracy, misconceptions, or faulty linkages associated with the target concept “Water on Mars” and provided feedback to the students. Bobby and Katie first constructed a concept map using the format given in the CD for using a concept map to plan their case report. Then they constructed concept maps on their case topic “Water on Mars.” The first, second, and third concept maps developed by Bobby and Katie’s were scored after each was received electronically. Both raters had identical scores for each map. The total score of the first concept map was 70, the second map was 77, and the third map was 106. The first concept map was constructed more like a summary resulting from a brain-storming session. The map represented ideas that emerged in the form of questions to be pursued for their case. The map depicted questions about their case "Water On Mars," such as "Where did it exist?” "Where did it go?" and "What happened to Atmosphere?” In essence the map portrayed an array of alternatives and possibilities to their questions. Also represented were categorizations of the information and facts to which they had prior knowledge.

In reviewing the second revised map there were marked differences from the first. Instead of questions, the map depicted three major concepts: landforms, atmosphere, and polar ice caps. Ideas were displayed under the first category landforms. These subordinate concepts showed hierarchical relationships with the major idea. Their third revised map included expanded ideas and relationships beyond their second. The other two major categories (atmosphere and polar ice caps) each had subordinate hierarchical representations that included chemical symbols and relevant related ideas. This map when compared to the first and second was more detailed with the items specifically itemized. Comparing the three maps, one can visually discern how the students formulated and organized their thoughts in the first concept map, and how they actually researched the topic and methodically organized their thoughts in the second concept map. Their third map incorporates the ideas from the first map combined with a more focused map in the second. Their maps reveal their thought processes as they progress from each respective map.

These concept maps revealed any misconceptions or faulty linkages. The maps also aided Bobby and Katie to self-monitor their progress and achieve a better understanding of their cases by clarifying conceptual relationships as evidenced by the rethinking of their ideas revealed in the second revised map. Bill and his students viewed these metacognitive tools as enabling conceptual understanding with new information. The NASA science educator and university educator became better informed regarding student and teacher learning contexts as they studied and analyzed authentic data. The NASA scientist and university educator gave feedback to the students.

Discussion

Informing practice through collaborative partnerships leads to a conceptual change approach to teaching and learning. This kind of approach should include explicit ways for teachers, students, and affiliated persons to become aware of their own beliefs and to come to understand the nature and construction of knowledge. Interactive Vee Diagrams and concept maps that are shared on the Internet provide collaborations that inform practice and, in the process, provides an electronic forum for facts and ideas to be learned and communicated meaningfully. Timed writings enable the teacher to follow the understanding and progress of his students with their case research. These interactive communications and rethinking of ideas resulting from collaborative meaning-making aid students, teachers, scientists, and university educators alike to better understand the learning process and search ways to make learning meaningful.

The thematic organizer presents information that is relevant to students' prior knowledge and revisits this information in a sequence of statements and restatements. This text adjunct seems to activate student ability to recognize and relate ideas that are common within both familiar and novel contexts (see Morris, Bransford, & Franks, 1977). In order to recognize the applicability of an idea to a new situation the student needs to know that the idea can be applied in different forms to various situations (Bruner, 1966). Extending students' prior knowledge of various attributes of thematic concepts before they read varied contexts is at least one way to facilitate ability to generate explanations for "new" information. This process of alerting students to common elements between their prior knowledge and concepts presented in varied contexts can reduce confusion and encourage the generalizability of knowledge.

Students can be taught to incorporate new information into their existing world knowledge. This can be accomplished through teacher guided instruction and self-initiated strategies that includes methods and meaningful materials that induce critical thinking with conceptual problems. In order for schema construction to occur, a framework needs to be provided that helps readers to elaborate upon new facts and ideas and to clarify their significance or relevance. Students need to learn more about themselves as learners. Notable in this learning context is the relationship between facts and ideas learned in formal school settings and those encountered in everyday learning environments. Perhaps within this type of action research inquiry we will be led to discover the ways individuals choose to relate new information to existing schemata and how this new information influences their future knowledge and decision-making.

In order for research findings to have relevance to a given school setting, it needs to be initiated by its constituents (teachers and administrators) to meet the needs of their students and community (Alvarez, 1993). The findings from this study lend credence to the premise espoused by Britton (1987, p. 15) that "what the teacher does not achieve in the classroom cannot be achieved by anybody else." Research conducted by others for someone else is less effective than when participants are equal partners in the planning and conducting of research to meet a particular need. This same premise also holds for students. Providing opportunities for students to "show" what they can do promote multifaceted interactive engagements that enhances process and leads to meaningful learning outcomes.

In this project, students become active participants in action research. They learn to use metacognitive tools from which to self-monitor and assess their own learning, and become researchers during the process using phases of the Action Research Strategy to guide their inquiry. Their case-based research enhances their knowledge of the target concept and aids them in becoming more independent learners. How students think about learning provides them with principles instead of learning prescriptions that they may not understand or partially understand. Prescriptive formats may lead to learning experiences that are artificial, because the information presented lacks a situational context for students to link new ideas to existing knowledge (Alvarez, 1993). Within the context of this project both thinking processes and products are examined to determine the extent that principles are related to the target concept, and how meaningful these principles are incorporated (integrated and related to other knowledge sources in memory) rather than compartmentalized (isolated due to rote memorization) by the students.

This project continues as it began, with change coming from within the walls of the school by concerned administrators and faculty. Students who engage in self-directed case research assume more responsibility for their own learning; furthering this transformation from conventional classroom settings. The role of the university educator changes from that of an external facilitator (an outsider) to one of a co-facilitator (an insider), as does the NASA science educator who becomes part of the learning consortium. Although collaborative contexts are reported in this paper, we do not dismiss the importance of solitary contexts as essential for exercising critical and imaginative thinking. For it is the combination of critical and imaginative thinking combined with reflection that contributes to viable ideas that serve as the core for action research to occur.

Acknowledgements

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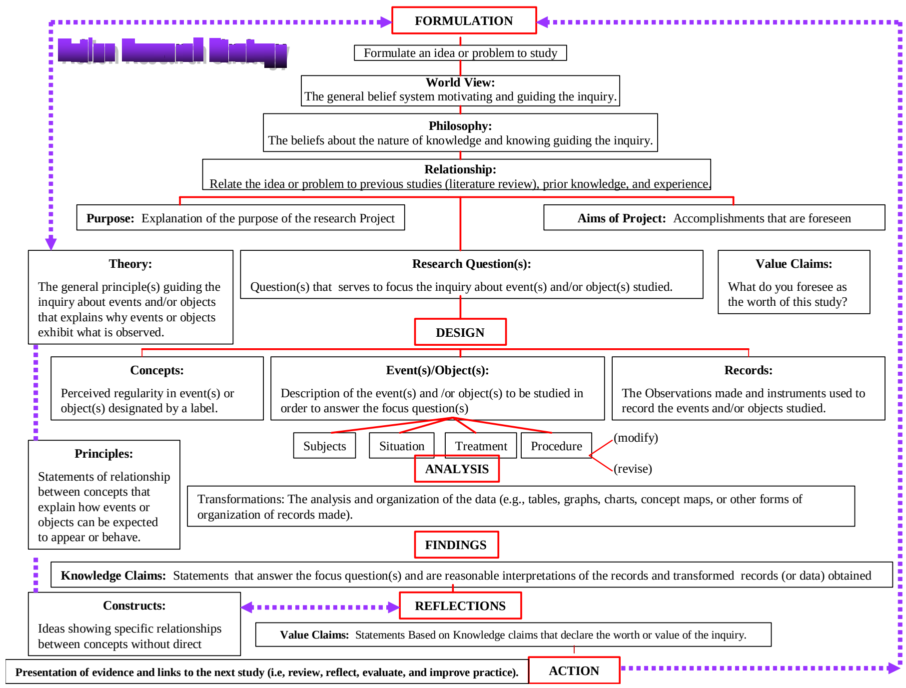
Appendix A
Action Research Strategy



Appendix B

Scoring Criteria for Concept Maps*

Marino C. Alvarez
Tennessee State University

Hierarchy. The map shows hierarchy by displaying different levels of space. It moves from most inclusive concept, to less inclusive concepts, to least inclusive concepts: superordinate, coordinate, subordinate. Five (5) points are awarded for each level of space (see Scoring Model). Examples and non-examples do *not* constitute a level.

Relationships. Each concept is linked by a line which signifies a *proposition* (a meaning relationship) between two concepts. In order to receive points the concept should be connected to the other and be meaningful. If the relationship is valid and the word or a word phrase is labeled on the proposition (line) one three (3) points are awarded. If the relationship is valid, but is not labeled one (1) point is awarded. Cross-links, examples and non-examples are *not* counted as relationships.

Branching. This occurs when a coordinate or subordinate concept has links to several specific concepts. *Within* each hierarchical level, points are awarded for each coordinate, subordinate, and specific concept listed within a grouping: Level 1 = 5 points; Level 2 = 4 points; Level 3 = 3 points; Level 4 = 2 points; Level 5 and beyond = 1 point. Examples and non-examples are *not* counted as branches.

Cross Links. Ten (10) points are awarded when one meaningful segment of the map is connected to another segment of the map (shown by a broken line in the Scoring Model). This cross-link connection needs to be both valid and significant. Cross-links indicate thought, creative ability, and unique awareness.

Examples. Specific events or objects that are valid instances of a designated concept are awarded one (1) point *within* the listing regardless of the number. These examples are *listed*, not circled, since they represent *specific items* of the labeled concept. For example, under the subordinate concept "reptiles" a listing appears such as: 1. Snake 2. Lizard 3. Alligator. Even though three examples are *listed*, the total is one (1) point.

Non-Examples. Specific events or objects that are *invalid* instances of a designated concept are ***stated** as non-examples*. One (1) point is awarded *within* the listing regardless of the number.

Deductions

Faulty Links. Linkages to concepts that are *invalid* or are *misconceived* are deducted from the total number of points for each category. These faulty linkages are very important in the learning process. They serve as points to discuss with the learner for clarification and further understanding of the target concept.

***Note:** Total points may exceed one hundred (100) depending upon the number of valid and significant entries portrayed on the concept map. A word of caution concerning scoring of hierarchical maps. Scoring is secondary to the purpose of constructing concept maps. The rater uses scoring as an ancillary record. The primary use of scoring is to aid the developer by clarifying conceptual ambiguities, faulty linkages, and extending their knowledge with the target concept. Scoring criteria is not shared with the learner. Instead, the scoring by the rater allows more in-depth review of the map and provides points of discussion with the learner. The difficulty establishing a static scoring system lies with the organic nature of the map itself. The map is a visual representation of an individual's thought processes and therefore, by its nature, evolves into various states. The stage at which the map is scored and analyzed represents a slice of the condition with the target concept as it exists at the time it was developed. The teacher may wish, in some instances, to construct an exemplar concept map and use it as a basis for comparison scoring. However, caution is advised due to students being able to construct a map that may differ from that developed by the teacher, but includes pertinent and relevant information associated with the Key Target Concept.