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Thinking About Learning

Marino C. Alvarez
Tennessee State University
Nashville, Tennessee

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Marino C. Alvarez
Tennessee State University
Nashville, Tennessee
malvarez@coe.tsuniv.edu

Abstract

This paper focuses on how teachers and students become "communities of thinkers." Communities in the sense that the school classroom becomes a place where ideas are shared through interactive learning environments in an atmosphere of coming to know through understanding and discussion. The Explorers of the Universe Scientific/Literacy Project is presented as a means by which teachers and students are participating in such communities using metacognitive tools and electronic communications.

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Marino C. Alvarez
Tennessee State University
Nashville, Tennessee
malvarez@coe.tnstate.edu

Knowledge that is isolated into compartmentalized units of study does little to advance the interest and curiosity of high school science and mathematics teachers and their students. Instead, students are placed into a position of memorizing information for later retrieval or using formulae for solving mathematical problems with prescribed solutions for checking one's answers. This type of learning reduces knowledge into capsules that are sorted by topic with the ultimate purpose of retrieval by testing. Processes for thinking about how to achieve meaningful understanding and application of new knowledge is secondary and in most cases given minimal consideration. This type of compartmentalized instruction includes over-reliance on single texts and studying information within parameters of a given discipline. Little, if any, attempts are made to incorporate the curriculum with other subjects. Upon completion of such courses, students are hard-pressed to state what they have learned and even more so when asked how to use the information they have "learned" in their daily lives. For these students, school is perceived as a series of courses to be taken and checked off when completed. Relevance of subjects either individually or collectively is not contemplated.

This paper focuses on ways that teachers and students become "communities of thinkers" (Alvarez 1996a, 1996b, 1997). Communities in the sense that the school classroom becomes a place where ideas are shared through interactive learning environments in an atmosphere of coming to know through understanding and discussion. A learning environment where teachers think about their subject in ways to promote and invite students to participate by offering lessons and assignments that require critical thinking (thinking about thinking in ways to bring about change in one's experience) and imaginative thinking (exploring future possibilities with existing ideas) rather than emphasizing rote memorization of facts.

BACKGROUND

Thinking and learning are enabling processes but they are not synonymous. The former is a process that moves from some beginning event to some conclusion or solution. The latter is a process that focuses on increasing or perfecting the execution of the solutions in the form of a product outcome. Thinking takes place during learning but is an intermediate phase rather than a final product (Russell, 1956). It is possible to learn new information through rote memorization or association without understanding what this new knowledge is or how it can be assimilated or applied to other meaningful situations. For example, in a study with middle school students who were asked to read a social studies passage in a textbook entitled "Reformers," the term was never defined but instead was referred to as "muckrakers." When students were asked, "What is a "reformer?" They replied, a "muckraker." At face value they were correct, however, upon further interrogation, none of the students knew or understood the term "muckraker" or "reformer" (Risko & Alvarez, 1986). Texts that lack coherence among the concepts or that are loaded with abstract concepts not related explicitly to supporting details contribute to students' comprehension difficulties (Alvarez, 1993).

Likewise, when college students were given a sentence that read "The Dutch built polders to protect their land" and asked, "What are polders?" Some responded: "land protectors." When asked specifically what they meant by "land protectors" or how the term was defined, an overwhelming majority in the class had limited knowledge. Again, the teacher could take their response as having somewhat of an understanding of the term "polders," but the students did not have a rich context for its meaning. These students had applied a strategy of taking the word "polders" and associating it with a plausible definition contained within the sentence. Many students use this word association and find it to be successful in getting the "right" response to a question, even though they have limited understanding of its meaning, use, or application. This type of "learning" takes place in many classrooms giving the false impression that students are achieving meaningful understanding of facts and ideas. This emphasis on product outcomes that is prevalent in many classrooms, while expedient,

sacrifices thinking process outcomes new to them that involve more thinking and consume more time.

If we expect critical thinking to take place, we need to provide students with problem-solving lessons in meaningful learning contexts in order for them to understand and use new information. These learning contexts become meaningful when new information is linked to existing concepts, and when learned, become incorporated (integrated and related to other knowledge sources in memory) rather than compartmentalized (isolated due to rote memorization). We also need to understand how new knowledge is understood by teachers and students engaged in research in a specific discipline, so that we may better understand the workings of different knowledge paradigms. Since all knowledge is constructed, we need to ascertain how an individual constructs his or her mental models (personal constructs) with this new knowledge. In so doing, it helps us to better understand how to incorporate this knowledge into related subject disciplines rather than allowing it to be kept in isolation and compartmentalized within a given discipline. This notion is consistent with Ausubel's (1968) theory of learning, Gowin's (1981) theory of educating, Novak's (1977) theory of education and knowledge, and Gragg's (1940) warning that "wisdom can't be told."

COMMUNITIES OF THINKERS

A community of thinkers is defined as an active group of students and teachers striving to learn more about a discipline by engaging in critical and imaginative thinking (Alvarez, 1995, 1996a). Developing a community of thinkers focuses on the kinds of thought processes needed by the teacher and students to achieve learning outcomes. Within our community of thinkers, teachers and students ask questions, seek answers, and reflect on their thoughts and feelings as they engage in problem-oriented investigations. *Thinking of ways to achieve learning outcomes is different from focusing on ways that learning outcomes can be achieved* (Alvarez, 1996a). The former is process oriented; the latter product oriented. When lessons are designed to obtain prescribed answers with little contemplation for their resolution, they are product oriented. However, lessons that engage students by immersing them in problem-oriented tasks with

authentic materials, and provide them with multiple venues to reach a resolution or solution using divergent paths are less focusing and allow more thinking. Learning more with less is the cornerstone of this thinking/learning process with the emphasis on "teaching" the facts and concepts of a given discipline instead of "covering" the material.

A way in which students create their own learning contexts when confronted with authentic problem-oriented tasks is addressed in this paper by describing the Explorers of the Universe project and specifically showing examples of how knowledge is constructed by analyzing e-mail communications between teachers, students, and astronomers and by examining concept maps and vee diagrams prepared by high school students that reveal reorganization of concepts.

EXPLORERS OF THE UNIVERSE

The Explorers of the Universe Scientific/Literacy project encourages teachers and their students to think about astrophysics by having them analyze and report data received from variable stars through automatic photoelectric telescopes (Alvarez, 1995; Alvarez & Rodriguez, 1995). These telescopes are housed at the Fairborn Observatory in Washington Camp, Arizona and controlled over the Internet by astronomers at Tennessee State University in Nashville, Tennessee. High school students conduct self-directed case-based investigations with variable stars and utilize concept maps and vee diagrams to plan, carry out, and report their findings. They also collaborate with students at other high schools and electronically communicate with astronomers and university educators. They publish their findings on the World Wide Web and receive feedback from faceless and unknown persons throughout the world.

Concept maps and vee diagrams are two metacognitive tools used to regulate and monitor one's own *thinking*. Concept mapping is intended to assist students to see relationships of central and subordinate ideas (see Novak, 1990; Novak & Gowin, 1984). Vee diagrams are used to aid students to understand the structure of knowledge, and are used in this investigation for teachers and students to plan their research study (see Gowin, 1981). The vee is a heuristic that depicts the important epistemological elements that are involved in the construction of knowledge, or new meaning. These learning tools serve to promote self-analysis and to enhance critical thinking by having one think about the ideas and their relationship to each other. When constructing and sharing these maps with others, an individual is able to rethink and reflect upon the ideas visually portrayed on the map. When redoing the map, an individual is able to capture these reflections and represent these reformulated ideas in ways that are better understood. Likewise, the vee diagram enables the learner to plan how the case will be researched. Both sides of the vee (conceptual and methodological) are interactive in this process. The vee allows the learner to think about how the research will be undertaken as well as provide a basis for doing the necessary data collection, transformations, and knowledge claims that are necessary in actively participating in reaching a resolution. We have developed an ***Interactive Vee Diagram*** on our Explorers of the Universe web site (http://coe2.tsuniv.edu/explorers). The students and teachers in our project communicate their ideas with each other, astronomers, and university educators. This interactive vee enables learners to exchange ideas and share information pertaining to their individual investigations via the Internet.

An example of Katy, John, and Mazi's vee diagram appears in Appendix A. In this vee, they list the events that were undertaken to investigate their study of Cepheid variable stars. Their research questions focus on these events as do the concepts and records for data collection. Ideas help by a world view and philosophy is given. The theory to be tested, results obtained, and the transformed data into phase plots, string plots, and a concept map are given. The knowledge claims answer the research questions, and the value claims tell the worth of the study. This vee can be used as a template to write their research report combining the

conceptual (thinking) with the methodological (doing) side interactively in the process.

These three students were able to reveal their thinking with their teacher and peers. The concept map developed by Katy, John, and Mazi appears in Appendix B. This map accompanies their vee diagram and incorporates literature and science. Algol is also known as Beta Perseus and is an eclipsing binary star in the constellation Perseus. In Greek mythology, Perseus was thought to be a hero. In Arabic mythology, Algol was known as the "demon star." These students through their map tell a story of how an eclipsing binary star and mythology are related over time and distance. Their map clearly portrays their ideas of how this star is related to a series of events of Greek and Arabic mythology. The map also served as a tool to engage in reflective thinking and served as a template from which to write their case report.

PUBLISHING PAPERS ON THE WWW

Once their papers are written, students publish them on the World Wide Web (WWW) for others to read, react, and discuss their thoughts. We find that students become more critical of their written text after it is displayed on the WWW because of feedback from outside readers who are faceless and unknown (Alvarez, 1996b). As a consequence, the students become more conscious of their writing style and presentation format. Preparing papers and visual representations in a familiar setting for one's own peer review in a class or for the teacher is one circumstance; preparing documents for unfamiliar faces is another.

For example, Katy, John, and Mazi have written a paper entitled "Variables in the Universe" that appears on the WWW. Before publishing their paper, they rewrote their paper several times and submitted it for peer review. Among the students reviewing their paper was the school editor who, with other students, made comments. It was important for these three students that their paper would be understood by people who were not familiar with an in depth knowledge of astronomy. Therefore their audience was an important factor in developing and expressing their ideas in

ways that could be understood by readers who didn't have an extensive background of variable stars. The written comments of the peer reviewers aided the authors in reconceptualizing their ideas to better inform an audience with Perseus and its relationship to eclipsing binary stars.

E-MAIL COMMUNICATIONS

Electronic mail communications take place on a regular basis. Teachers and students communicate with others in our project and with our astronomers. Bill Rodriguez, one of our teachers, receives communiques from students at another school concerning aspects of our variable star project. In the following message from students at our affiliated high school, Bill reads that students in this high school are missing files procedures in a program he developed to analyze star data:

Mr. Rodriguez,

> We copied the apt files into the apt-data directory but we still get an error
> while Attempting to run the program through windows. Here is what the
> error basically says:
> File does not exist
> Do main.
> Called from "APT.PRG
> The program does seem to start up (I see the beginning) but then the error
> comes up.
> Once again, thanks for your time.
> The TJ Astronomy Dept. (Aditya)

Bill responds by thanking them for pointing out these ambiguities and provides them with further information that is more detailed and comprehensible.

> Brian,
> The apt.fox is the compiled program which requires foxprun.exe (on your directory

already) to run.
I thought I made an icon for the software in one of the window panes.
Double click on it and see what happens. Let me know if there are any problems.

Bill receives a second message:

Hello Mr. Rodriguez,
We downloaded the apt.fox and apt.prg.files, but we're not sure how to use them.
Do we have to get something else? The prg file is the code but is the fox file an
executable?
Sincerely,
The TJ Astronomy Team

His response to these students:

OK Team,
Here is what should be on your directory (apt.data) - the files apt.fox, apt.dbf, apt-
temp.dbf, string.dbf, and summary. Exit windows and from dos change into this
directory. Then issue the command foxprun apt.fox and see what happens. I
apologize for the problems, there must be a file missing.

These sample dialogues reflect a genuine exchange of meaningful and pertinent information that stimulates the thinking/learning process. In this exchange between students at one high school and a teacher at the other the process of downloading the program is the initial step for data analysis not the culmination. The teacher enters into the dialogue as a partner to clarify the problem. He apologizes to these students for omitting certain files and

accepts this as one does with a peer. The teacher-student relationship evolves into one of "trust" between the students and this teacher. Together they make the learning situation become clearer and more precise.

CONCLUSION

Learning contexts that encourage students to *think about learning* enables them to learn principles instead of learning prescriptions that they may not understand or partially understand. Building communities of thinkers involves social interaction between teachers, students, and members of the community in ways that new information is incorporated (integrated and related to other knowledge sources in memory) rather than compartmentalized (isolated due to rote memorization). Such a community is situated within an emergent curriculum that evolves when ideas are negotiated between teachers and students. In this setting, time is viewed as a movement toward resolution instead of a marker of endurance that signals the end of a prescribed task or period. This kind of community consists of teachers who think and learn more about their subject, and who encourage critical and imaginative thinking by providing their students with problem-solving lessons in meaningful learning contexts.

Critical thinking is in evidence because the research is situated in a context that students conduct naturally as they actively engage in multiple paths of inquiry. These paths include: reading and revising the text and supplementary materials; accessing library resources within the school and community and through the Internet and making discerning judgements as to their content; receiving feedback from their peers and teachers; negotiating the thinking/learning process by exchanging in meaningful dialogues with peers, teachers, scientists, and university educators; publishing papers on the World Wide Web; writing, revising, and rewriting papers; using metacogntive tools to monitor their understanding of new information; incorporating information from other subject disciplines; using their imagination to think about unrealized possibilities; applying logic, mathematics, scientific, and literacy skills in meaningful contexts; and, making new knowledge about the kinds and types of stars.

The traditional emphasis of "covering" the text in sequential stages is being abandoned in favor of "teaching" the facts and related ideas of a given discipline. Thinking is becoming a conversation between an author and a reader. The kind of conversation may vary (e.g., face-to-face, electronic mail, voice communication, etc.), but the transaction that occurs receptively is that of constructing meaning and reflecting on these facts and ideas. Thinking is also a conversation between a student and a teacher and between other students as each constructs meanings, communicates ideas, and pursues unanswered questions. Within these classrooms, communities of thinkers are evolving. Participants are sharing information, discussing unrealized possibilities, and engaging in a forum in which schools were meant to be.

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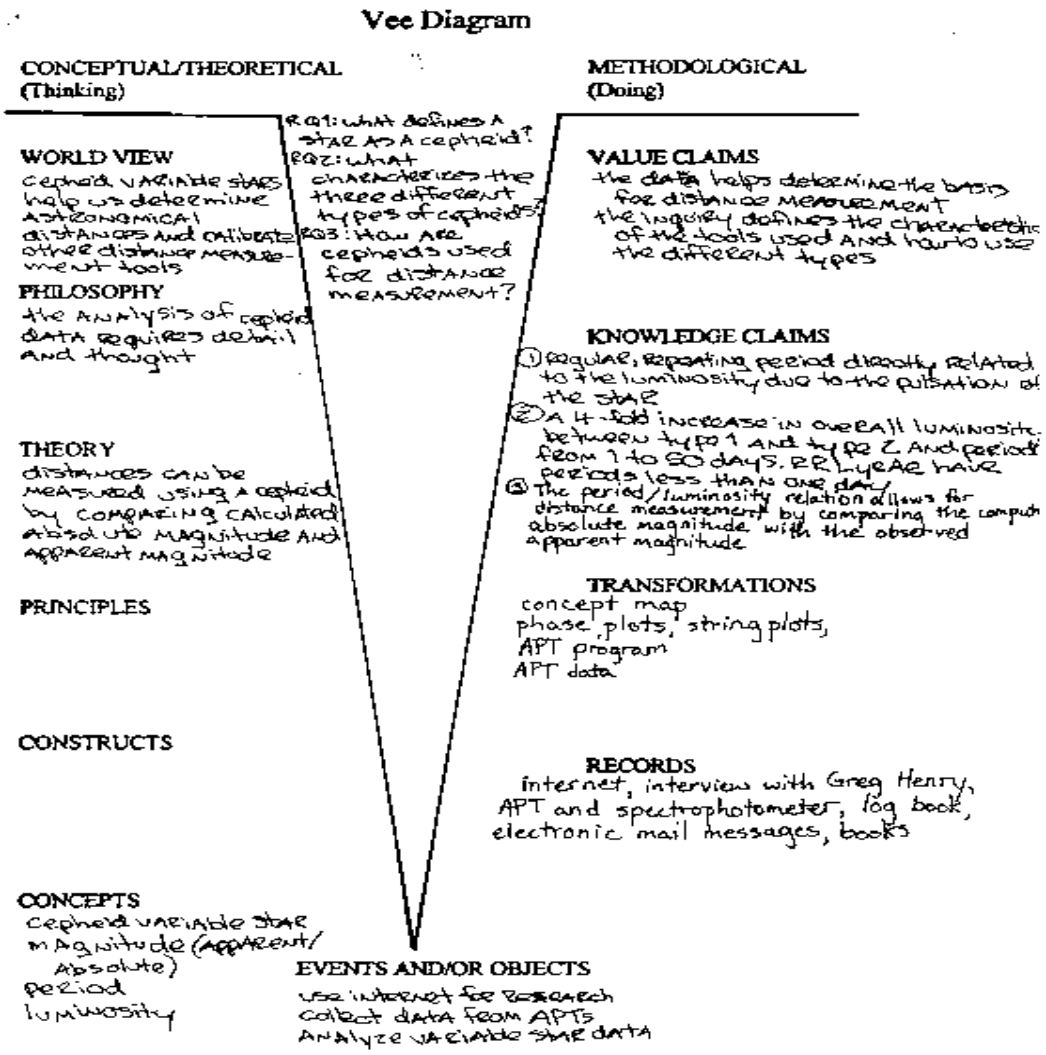
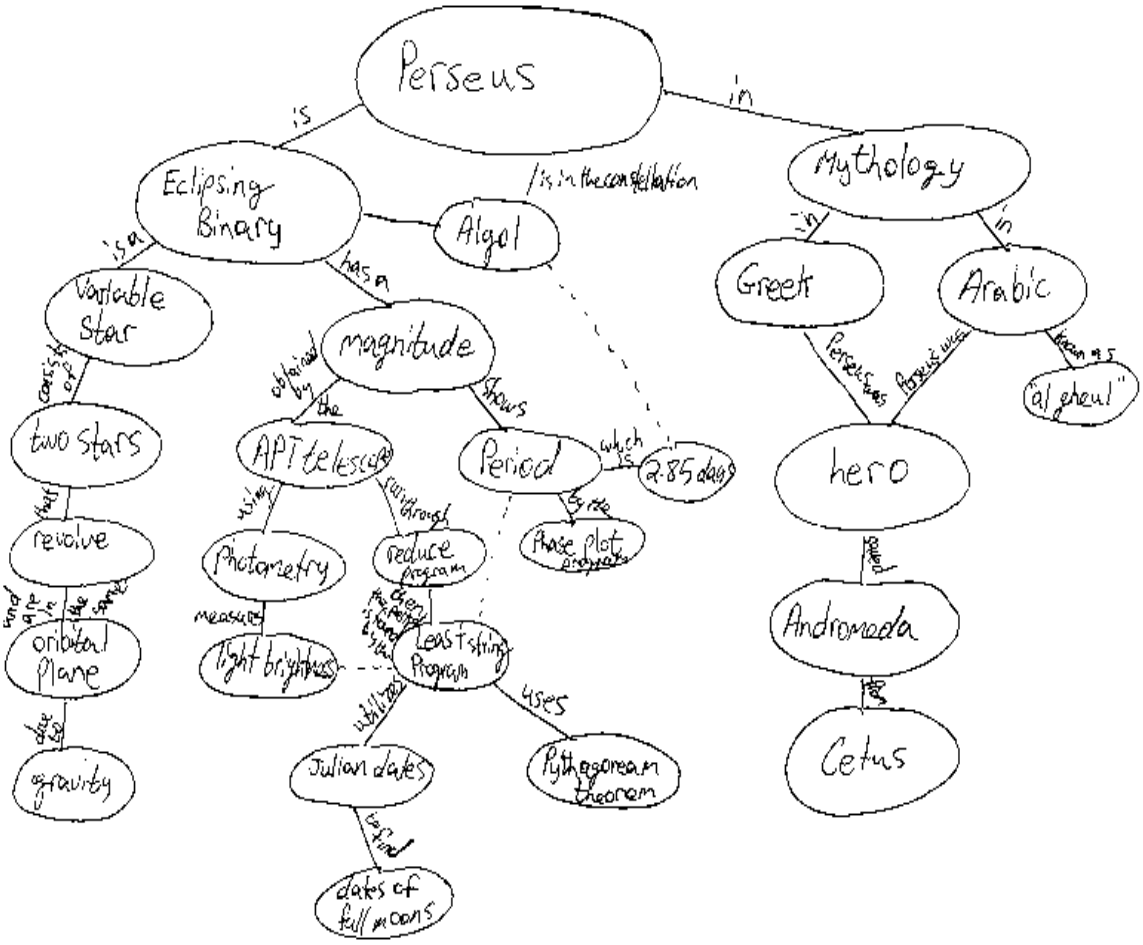
Marino C. Alvarez is Professor of Education in the College of Education, Department of Teaching and Learning. He is the Principal Investigator for the Explorers of the Universe Project, "Center of Excellence in Information Systems." Tennessee State University, Nashville, TN 37209.

Appendix A


Vee Diagram
CONCEPTUAL/THEORETICAL
(Thinking)
METHODOLOGICAL
(Doing)
RQ1: what defines a star as a cepheid?
RQ2: what characterizes the three different types of cepheids?
RQ3: How are cepheids used for distance measurement?
WORLD VIEW
cepheid variable stars help us determine astronomical distances and calibrate other distance measurement tools
PHILOSOPHY
the analysis of cepheid data requires detail and thought
THEORY
distances can be measured using a cepheid by comparing calculated absolute magnitude and apparent magnitude
PRINCIPLES
CONSTRUCTS
CONCEPTS
cepheid variable star
magnitude (apparent/absolute)
period
luminosity
VALUE CLAIMS
the data helps determine the basis for distance measurement
the inquiry defines the characteristic of the tools used and how to use the different types
KNOWLEDGE CLAIMS
1. regular, repeating period directly related to the luminosity due to the pulsation of the star
2. a 4-fold increase in overall luminosity between type 1 and type 2 and period from 1 to 50 days. RR lyrae have periods less than one day
3. The period/luminosity relation allows for distance measurement by comparing the computed absolute magnitude with the observed apparent magnitude
TRANSFORMATIONS
concept map
phase plots, string plots,
APT program
APT data
RECORDS
internet, interview with Greg Henry, APT and spectrophotometer, log book, electronic mail messages, books
EVENTS AND/OR OBJECTS
use internet for research
collect data from APTs
analyze variable star data

Appendix B



Katy John, Mazi