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High School Students Using Electronic Environments for Informing Learning and Practice

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Abstract

This action research case study focuses on three high school students using case-based learning, a timed writing and a concept map as part of their research investigation during a two month summer action research program. The astronomy/educator monitored the choice of topic and progress. The students pursued individual paths of inquiry that involved writing, intervening, and reflecting on ideas gleaned from conversations and readings (electronic and conventional) during this self-directed case-based research. The process engaged the 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 open-ended survey are presented and discussed.

Few studies are published yearly that report uses of content literacy and their effects on instruction and practice with high school students. How students create their own thinking-learning contexts when confronted with authentic problem-oriented tasks is an important issue influencing instruction and learning. Thinking-learning contexts are those mental models (conceptual frameworks) that students invoke when confronted with problem-oriented tasks that go beyond memorizing and compartmentalizing information (Alvarez, 1993). 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, 1997), 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 concept and facts. This theory is helpful in classifying the relevant aspects of the educative event using the four commonplaces of educating: teaching, learning, curriculum, and governance. A fifth component, the societal environment is also part of this evaluation process (Gowin & Alvarez, in press). In an educative event, teachers and learners share meanings and feelings so as to bring about a change in human experience. This theory stresses the centrality of the learner's experience in educating. 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. 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.

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 and imaginative thinking (Alvarez, 1996, 1995). During this inquiry, the teacher thinks about the facts and concepts that need to be understood by students, the supplementary reading materials and artifacts that need to be provided, ways in which to incorporate other subject disciplines into the inquiry, and selects from an array of teacher-directed/teacher-assisted strategies and meaningful materials that can be used to facilitate student thought. Likewise, the student becomes an active thinker in the learning process by engaging with the lesson by relating prior knowledge and world experience both informal and formal, selecting from an array of student learning strategies that are part of an individual's arsenal, and with the teacher works toward extending meaning and understanding with the subject matter.

Developing a community of thinkers focuses on the kinds of thought processes needed by the teacher and students to achieve learning outcomes. *Thinking of ways to achieve learning outcomes are not the same as focusing on ways that learning outcomes can be achieved* (Alvarez, 1996). The former is process oriented; the latter product oriented. Thinking for processes to achieve a learning outcome is different from thinking for a learning outcome. The former is a process of thinking moving from some initiation to a conclusion or solution. A learning outcome focuses on increasing a skill or perfecting solutions (see Russell, 1956). In an effort to increase learning efficiency, we focus on the processes of thinking, selecting, eliminating, searching, manipulating, and organizing information. Emphasis is placed on thinking as a process involving a sequence of ideas moving from some beginning thought, through a series of a pattern of relationships, to some goal or resolution.

Within our community of thinkers, teachers and students ask questions, seek answers, and reflect on their thoughts and feelings as they engage in action research case-based investigations.

Action research is a paradigm 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. It also enables students to become actively engaged in the research process. 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). This action research strategy is accomplished through a recursive cycle of (1) identifying an idea or 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.

The purpose of this study was to determine how hierarchical concept maps and time writing influence learning contexts of both students and educators when learning astrophysics. Three high school students learned concepts dealing with "astronomy" following an action research protocol using self-directed case-based research in a collaborative electronic format using the Exploring Minds Network developed by the university educator. The research question was: RQ1 "How do metacognitive tools in an electronic format influence thinking and learning contexts?" Related research questions dealt with student, professor, and university educators' perceptions in determining if these metacogntive tools influenced learning and practice when studying a multifaceted case using authentic data in collaborative formats. The purpose of this study was to determine how thinking-learning contexts are altered once metacogntive tools and responsibility for self-determination of unknown outcomes are approached, mediated, and finalized with high school students engaged in astronomy research.

Method

This study was conducted over a two-month summer session at the Tennessee State University, Center of Excellence in Information Systems in Nashville, Tennessee, with three high school students who had just completed the eleventh grade. One female student (AB) was from Puerto Rico, another female student (JQ) was a Mexican-American from San Antonio, Texas, and the other was a white male (TM) from Orlando, Florida.

The two females worked as a team and the male studied individually. They selected the topic "planetary transit HD209458b" to study. This case was written on a CD developed by the researchers containing a thematic organizer (Alvarez, 1983; Alvarez & Risko, 2002, Alvarez & Risko, 1989; Risko & Alvarez, 1986) with the target concept "planetary transits." It contained video clips of President Clinton taking about the Tennessee State University discovery, Dr. Geoff Burks showing simulations of the planetary transit and a section on "Math Talk" concerning the geometry of the planet, and Gregg Henry the astronomer who discovered the planet discussing automatic photoelectric telescopes located in Washington Camp, Arizona and controlled via the Internet from TSU in Nashville, Tennessee and presents the data of HD209458b represented on a light curve. There were possible general questions to pursue at differing levels of difficulty and interest with an opportunity for students to select others of their own choosing, phases of action research, links to related Internet sites, student expectations and teacher expectations of the project, an artists painting of this extrasolar planet, and other pertinent information related to this topic. Greg Henry, a TSU astronomer, has discovered a planetary transit the first extra solar planet ever detected HD209458 and served as an advisor. The students came on a daily basis from 10:00 am to 4:00 p.m., five days a week. The students shared their thoughts both verbally and electronically with the astronomer/educator and university educator. The students were part of a consortium of secondary and postsecondary students affiliated with the Tennessee State University's Exploring Minds Project. 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, 1993, 1996, 1997, 1998, 2001).

The three high school students were taught how to construct and use concept mappings. The procedures followed those advocated by Novak and Gowin (1984), and used scoring protocols developed by Alvarez. Information was entered electronically through the Exploring Minds Network by the students and collected for analysis. The students followed stages of the Action Research Strategy and posted their thoughts and feelings in written narratives. CMap was used for the construction of concept maps.

The astronomer educator, Geoff Burks, facilitated this study by monitoring and meeting with the students as they conducted their science research. Both the university and astronomy educators tested the effectiveness of the metacognitive strategies and monitored the progress of the case using time writings, journal entries, and development of hierarchical concept maps. The astronomer educator reviewed student progress. The university educator, astronomer educator, and one researcher, Goli Sotoohi, scored the concept maps and time writings. The astronomer educator and the university educator received incoming information from the concept mappings of the students and responded accordingly to their representations and questions. The time writings were categorized and scored based on the key concepts appearing on each students' time writing.

For this study, the students were given a *Researcher's Notebook: A Resource of Faculty, Staff, and Students* (Alvarez, 2002) that included an Introductory chapter of the Exploring Minds Project and chapters describing and illustrating the Exploring Minds Interactive Network, Concept Mapping, **V** Diagrams, Electronic Journaling, Action Research Strategy (problem/situation, course of action, resolution, and action), Student Checklist.

Our Exploring Minds Network was developed at the Center of Excellence for Information Systems, Tennessee State University, from a teacher's perspective with classroom experience at the middle, secondary, and postsecondary levels that includes management, interactive communications, monitoring, and metacognitive tools (Alvarez, 1998). Exploring Minds is a metaphor for a conceptual system and an electronic network that enables individuals to think about thinking in ways that differ from conventional forms. This thinking accounts for solitary, collaborative, and mindful learning that contributes to personal meaning that results in either intrinsic or instrumental applications. Ideas are revealed in narrative and visual formats through electronic journals, conceptual arrangement of ideas, and **V** diagrams so that metacognitive tasks such as self-monitoring, reflective and imaginative thinking, and critical analyses are a crucial part of the learning process. The basic premise that underpins Exploring Minds is that the mind deals with meaning and meaning is the basis for conceptual understanding of facts and ideas.

The astronomy/educator facilitated this study and monitored the progress of the case by reviewing and responding to questions. He also directed the students to pertinent resources. Because the students were at the Center of Excellence doing their case research, both the astronomer/educator and university educator were available for any questions or clarifications that needed to be addressed.

Evaluation

This study was monitored and evaluated by using Gowin's (1981) and Gowin & Alvarez (in press) four commonplaces of educating: teaching, learning, curriculum, and governance. 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.

Our assessment of this study indicated that ***teaching*** is achieving shared meaning between the teacher and the student. The students and the astronomer/educator accomplished this condition through shared meanings that resulted from negotiating facts and ideas. The students were at first overwhelmed with the responsibility of forming their own research questions and path of inquiry. This format was different from those they had encountered during their formal schooling. The astronomer/educator educator facilitated and mediated their thoughts and feelings as they strived to take charge of their own learning.

Learning in the traditional sense is under the control of the teacher. In essence, the teacher tells students what they need to know. Our philosophy is consistent. We want learning to be placed in a context under the control of the students. In past studies (e.g., Alvarez, Burks, & Sotoohi, 2002; Alvarez & Rodriguez, 1995; Alvarez, Stockman, Rodriguez, Davidson, & Swartz, 1999; Alvarez, et. al. 2000) we have found that students take responsibility when confronted with meaningful projects and materials. We wanted to discern if given the opportunity, these students would take charge and be responsible for their own learning during a summer session? This question was answered in the affirmative when we provided a forum by which the students could take an active role in structuring and creating their own meaning. The students learned how to use interactive hierarchical concept maps to organize their thoughts, and wrote formal case reports.

The ***curriculum*** that evolved from this study of Planetary Transits was emergent rather than fixed. The basic materials went beyond the traditional use of teacher-centered lectures and hand-out materials devised and published by others. Instead, they were presented with a problem/situation and asked to formulate questions of interest to pursue. They were also presented with an animated CD that described the uses and functions of concept maps, interactive V diagrams, and an Action Research Strategy that enabled them to think about their research agenda. The contents of this CD activated students schema with planetary transits and provided them with records of planetary transits and related conceptual categories that served as a venue for students to make new events happen resulting from their own questions. The information provided in the case CD guided the students to other relevant resources and materials in their quest to seek resolutions to their self-directed cases.

The school climate differed in that these students did not have other classes during this summer session; had the advantage of being at the Center and consulting with the astronomer/educator as the need arose; and, were able to work together over a sustained period of time during the day unlike a typical classroom time period. Although we do not expect the same kind of learning environment in the summer that occurs in a formal classroom setting during the school, the findings were consistent with our studies that occurred during the school-year (e.g., Alvarez & Rodriguez, 1995, Alvarez, et al., 1999).

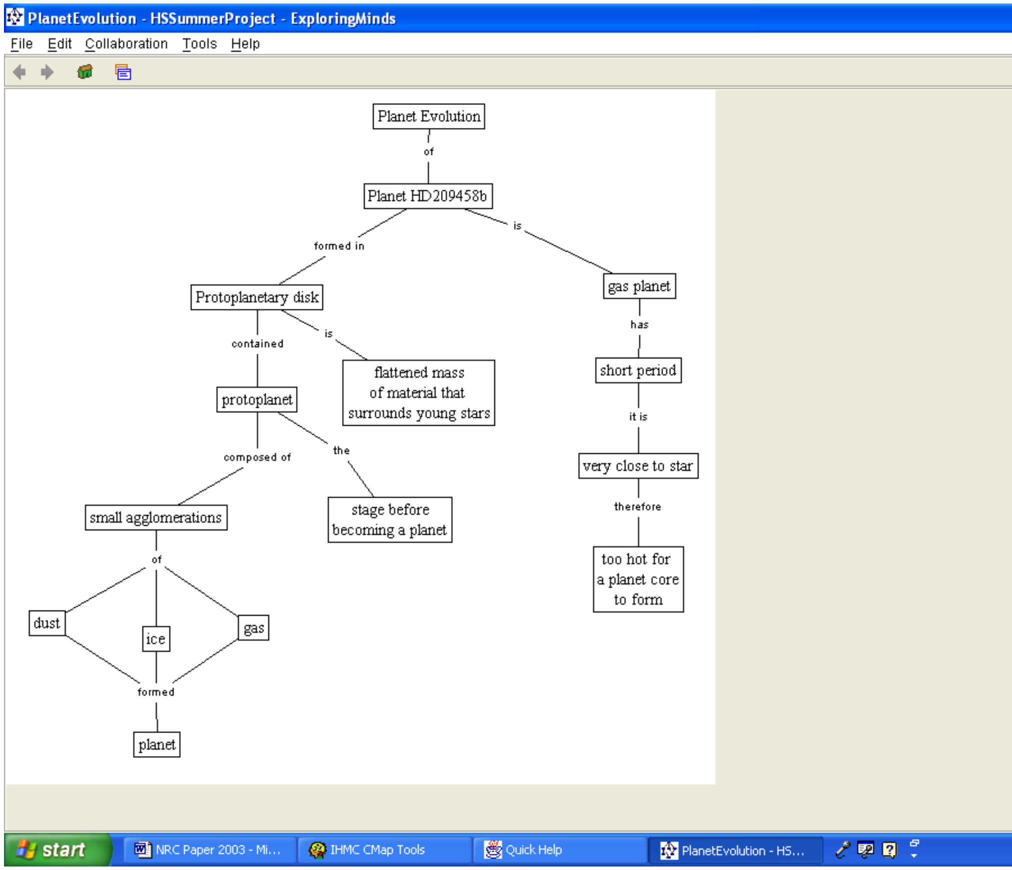
The ***governance*** exercised in this type of study differs from policies and formats that are typical in curriculum guides, teacher's manuals, or module-based lessons. These students expressed their thoughts and feelings freely and made critical decisions. The learning atmosphere was nonthreatening and promoted a social context where ideas were openly shared and discussed. The astronomer/educator guided the students by specifying criteria for executing and completing the case. The students were encouraged to make decisions in governing and conducting their research. This research experience differed from their previous encounters in formal school settings where questions and procedures are predetermined with expected outcomes.

The students exercised their own governance during his research investigation. They would sometimes leave the environment of the Center and go to another location within the building or to the library. This type of governance differed from their regular school experiences where a more structured learning environment is in place. Since they were in charge of their case, they became 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 was pertinent and authentic.

Concept Maps

The university educator, astronomer educator, and a researcher with the Center of Excellence used a scoring protocol developed by Alvarez (2002) to independently score the concept maps (see Appendix A). This paper focuses on the two concept maps developed by the two students in a team (AB and JQ). The astronomer/educator reviewed the concept maps for accuracy, misconceptions, and/or faulty linkages associated with the target concepts studied by AB "Planet Evolution" and that studied by JQ, "Theories of Migration." CMap, developed at the University of West Florida, was used to construct the concept map. AB's concept map is represented in figure 1.

Figure 1. AB's Hierarchical Concept Map.



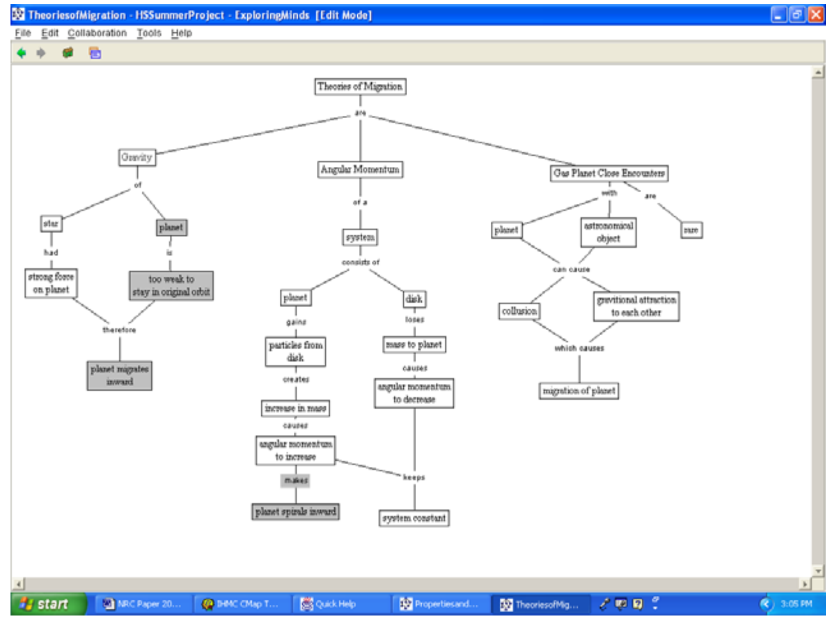
The three raters had identical scores for both concept maps. The scoring for AB's concept maps appears in table 1.

Table 1. Scoring Protocol for AB's Hierarchical Concept Map.

Categories	Total	Not Valid	Total Valid Score
Relationships Each level **1** = not labeled **1 x** = **3** = labeled 3 x 14 = 42	42		42
Hierarchy 5 Points Each Level **5 x** 6 = 30	30		30
Branching **Level 1 = 5 Points** **5 x** 1 = 5 **Level 2 = 4 Points** **4 x** 2 = 8 **Level 3 = 3 Points** **3 x** 3 = 9 **Level 4 = 2 Points** 2x3=6 **Level 5** **& beyond = 1 Point** 1 x 4 = 4 1x1=1	33		33
Cross Links 10 Points Each **10 x** 0= 0	0		0
Examples 1 Points Each 1 **x** 0= 0 **Non-Example** 1 x 0= 0	0		0
Grand Total			105

The second concept map developed by JQ appears in figure 2.

Figure 2. JQ's Hierarchical Concept Map



The shaded area indicates that JQ had misconceptions with the target concept she was studying. The misconceived concepts were "How gravity and angular momentum lead to changes in the planet's orbit." This is consistent with what she writes in her spontaneous time writing. Table 2 shows the scoring by the three raters of this map.

Table 2. Scoring Protocol for JQ's Hierarchical Concept Map.

Categories	**Total**	**Not Valid**	**Total Valid Score**
Relationships Each level **1** = not labeled **1 x** = **3** = labeled **3 x 24 = 72**	72	3x4=12	60
Hierarchy 5 Points Each Level **5 x** 7 = 35	35		35
Branching **Level 1 = 5 Points** **5 x 3** = 15 **Level 2 = 4 Points** **4 x** 6 = 24 **Level 3 = 3 Points** **3 x** 6 = 18 **Level 4 = 2 Points** **2x4=8** **Level 5** **& beyond = 1 Point** **1 x** 2 = 2 1x2=2 1x1=1	70	4x1=4 3x1=3 2x1=2 1x1=1	70 -10 60
Cross Links 10 Points Each **10 x** 0= 0	0		0
Examples 1 Points Each 1 **x** 0= 0 **Non-Example** 1 x 0= 0	0		0
Grand Total			155

The maps enabled the astronomy/educator to see the area of most concern to the student. After completion of the students' timed writings this concern was verified.

Time Writing

Time writings (see Alvarez, 1983) were used to assess all three students' knowledge, degree of spontaneous relationships, and understanding of the specific topic of study in the self-directed case on Planetary Transits. These timed writings occurred after the completion of their concept maps.

The students wrote for six minutes without stopping their pencil in the process. They were told beforehand that if they couldn't think of anything to write they were to write their first and last name over and over until another thought came to mind. The astronomy/educator reviewed their timed writings and checked for accuracy, misconceptions, or faulty reasoning (see Appendix B for printed transcriptions of their original hand written entries). The three students were asked to write about the Planetary Transit HD209458b. JQ's time writing was entitled, "Extrasolar Planet HD209458b," AB's title was "Properties and Evolution of the Planet HD209458b," and TM's time writing was entitled "A Study of the Physical Properties of HD209458b."

The astronomer/educator and university/educator each read the timed writings and selected words and word phrases for purposes of coding and comparison. Word and word phrases were selected according to relevant specialized vocabulary associated with the key target concept "Planetary Transit HD209458b" and the concepts stated in their respective self-selected titles. Agreements were decided on the word and word phrases selected based on the astronomy/educator's expertise with this topic.

AB's time writing yielded a total of twenty words that were chosen for coding and comparison.

The key words and number of times written were:

Planets form = 3	Volume = 1
Density = 1	Disk = 2
Gas giant = 1	Star's formation = 1
Planet = 10	Star = 5

Transiting = 1	Angular Momentum = 1
Discovery = 2	Energy = 1
Telescopes = 2	Migrated = 1
Diminishing of light = 1	Mass = 1
Orbiting = 1	Jupiters = 2
Universe = 1	Solar system = 1

A total of nineteen words were chosen for coding and comparison of the time writing by JQ.

Period = 2	Spiraled = 2
Planet = 8	Angular momentum = 3
Gas giant = 2	Born = 1
Mass = 3	Outer protoplanetary disk = 4
Jupiter = 2	Increased = 1
Saturn = 1	Decreased = 2
Density = 3	Concept maps = 1
Discovered = 2	Migration theories = 1
Migrated inward = 2	Transit = 1
Star = 1	

TM's time writing revealed a total of twenty words that were used for coding and comparison.

Transit = 1	Period = 1
Data = 3	Keplers law = 1
Planet = 6	Planets mass = 1
HD209458 = 2	Planets radius = 1
Star = 3	Basic physics relationships = 1
Orbits = 1	Mean density = 1
Spectral type = 1	Solar system = 1
Temperature = 1	Least dense = 1
Sun = 1	Saturn = 1
Orbital radius = 2	HD209458b = 2

Upon completion of this analysis, the university educator constructed a concept map of each student's time writing (see Appendix C). These were given to the astronomer/educator who examined and compared these concept maps for degree of their concept map display that were constructed one-week prior.

General observations comparing the three students' time writings indicate that AB and JQ, while working together, their time writings structure their knowledge differently. JQ's writing is along the line of a "stream of consciousness" in that she writes what she remembers but does not show coherence. She seems to have a lot of information memorized but it is not organized or assimilated in her cognitive structure in a short spontaneous setting. For example, she uses the term "Angular Momentum" in a way that shows an incomplete understanding of how the term is appropriately applied. Her linkage is incomplete and needs more elaboration. Again her writing and a concept map developed by the university/educator of her writing shows that a logical linkage is missing when she again uses "Angular Momentum" without completely explaining the relationships. However, this revelation is an important factor in that it enables the astronomer/educator to better read and "see" this faulty or missing linkage and helps to inform his teaching practice as a follow-up when meeting with this student. Application of this concept seems to be difficult for high school students since the variables within it --- Angular Momentum equals mass x velocity x radial distance (L=mvr) --- can interact in complicated ways under different circumstances. This misconception also appears on her concept map (see Theories of Migration, figure 2). These two measurements (her concept map and time writing) tends to confirm that she is having difficulty understanding the interrelationship between gravity, angular momentum, and the change in the planet's orbit. This is not surprising since this is a difficult relationship for novices to apply to a planet's movement since it requires advanced math study. JQ appears to be numerically oriented in that she includes them in her writing and they are correctly stated.

AB's time writing is more of a mini-essay in that her thoughts are more coherent and include concluding paragraph summarizing her main points. She seems to have a more unified picture of the interrelationships between the concepts. However, she either has a misconception that planets exist outside our "Universe" or she simply inserted the incorrect word instead "Solar System."

The time writing of TM indicates that he is more data oriented than the other two students. Specifically, he mentions the mathematical principle (Kepler's Law) to take the data in order to form a conclusion. His ideas are accurate, but not necessarily coherent, his repeated use of his name shows that the linkages are not automatic, but instead uses his repeated name to think about the next link in his chain of reasoning. This is not unusual since this is a difficult concept to apply.

Both AB and JQ's map of their time writing indicate that they are focusing more on theory than TM who appears to be focusing more on observations. A review of a concept map made of his time writing shows that his time writing is based on data and drives his thoughts.

The concept map in Figure 2 was constructed using CMap and depicts the area in question and how it could be represented. Notice that the student spends time listing the four main hypotheses for the circumstances that precipitate the collapse of molecular clouds. It seems that the student focused or possibly fixated on the uncertain part of the story rather that the generally agreed upon part. This may be an acknowledgement of discomfort with working on a problem without the right answer. Much of high school education seems to be centered with getting the right answer. It is possible that if the timed writing had a longer time-span that he might have written about more of his concept map. But he focused first on the uncertain aspect of his research.

This spontaneous writing provided the astronomer/educator with knowledge to evaluate student progress and conceptual understanding with the target concept.

Survey

Evaluation of the student's responses to the open-ended survey we gave on the last day of participation revealed their thoughts and feelings of what had been accomplished during the two month session. The directions stated: Please answer the following questions/statements on a separate sheet of paper according to number. The following questions/statements relate to your experience with your selected project in the Exploring Minds Project.

Question 1: What I enjoy most about this research project…

JQ: I enjoyed working with real astronomers/educators from a university. I enjoyed the field trips Dr. Burks took us on so we could become historically as well as scientifically educated.

AB: The hands on researching. The actual figuring out of the question (was hard though).

TM: Hands on research. Vast amounts of sources online. Real data to deal with, not just theoretical.

Question 2: What I dislike most about doing the research project…

JQ: I wish I could have seen the telescopes in person. More time would have been better.

AB: No time.

TM: Not enough time!

Question 3: Compared to other school-related projects that I have been involved with this one…

JQ: I enjoyed this project because I got to decide what my problem was going to be. Also, I enjoy astronomy so it made it easier.

AB: This was more independent and at my own liking and choice. Plus I had more resources.

TM: Rocked!

Question 4: The V Diagram…

JQ: I did one V diagram. I had some questions so I couldn't exactly finish it. It did help to organize the ideas I had.

AB: N/A

TM: Too confusing to me.

Question 5: The Concept Maps…

JQ: I am including two concept maps in my appendix of my final research paper. They really helped to visually-aid and organize all my information.

AB: Helped me organize articles and papers.

TM: Very good. A more structured web than I am used to.

Question 6: The feedback on the V Diagrams…

JQ: I think the V diagram wasn't essential, but it helps you organize data.

AB: N/A

TM: ?

Question 7: The feedback on the Concept Maps…

JQ: The concept maps were nice visual aids for my paper. I like the concept maps. They helped me understand the information I read.

AB: It was fast and easy – really helpful.

TM: I like the structure and the joining words and phrases allows you to practically finish your paper.

Question 8: Having to formulate my own research questions…

JQ: I liked being able to ask my own questions because it was interesting to me.

AB: Made me learn more about astronomy. Could understand my question to the fullest.

TM: Time consuming but in the long run was better. It allows someone to know exactly what they should answer if they create the question.

Question 9: Did using concept maps and V diagrams change your way of thinking about learning? If so how? If not, how did they interfere?

JQ: It was the first time I had heard of a V diagram so I thought it was just an extra. But, doing the diagram did help me think about my paper as a whole. I had used concept maps before for brainstorming.

AB: No, because in school I was used to doing outlines and that is an organization tool although the concept map helped me visualize better.

TM: Concept maps allowed a great visual structure to understanding complex ideas. I used them for several articles and found it very useful.

Question 10: Using the techniques and procedures that you were asked to complete during this project, what would be your candid appraisal of learning in this format as compared to other courses or learning experiences you have been involved? Less than, About the same, More than. ***Explain*** *your thoughts and feelings.*

JQ: I have liked this project more than other projects I have completed. I got to ask my own question and I got to work at my own pace. I enjoyed working on a project that interested me.

AB: I would love to work like this again, but with a little more time. It was very organized and simple.

TM: I think a mix is always best. From this program I liked the C-maps a lot. From previous programs I would use note cards and spread them all over the floor to make an "at home" c-map. Either way works well.

Student Reflections Based on Survey

Reponses to the Survey indicate that these students were most captivated by being able to formulate their own questions, work with authentic data, and select their own paths of inquiry for achieving case resolution. Concept mapping enabled them to better understand the target concept under study.

Although **V** Diagrams are not analyzed as part of this study it is significant to mention that this metacognitive tool enables researchers to plan, carry out, and finalize a research investigation (see Gowin, 1981; Gowin & Alvarez, in press). The **V** requires conceptual and methodological elements bridged by research questions and the events under study. The researcher needs to write research questions that correspond to the events that are being investigated. It is vital that these two components are unified. These students had difficulty with this tool and the epistemic elements that comprise the **V**. This was a telling revelation since the V engages mental processes that require formulating, manipulating, revisiting, and decision-making. This finding is consistent with other students who have participated in this project who likewise have difficulty formulating their own research questions and using the elements on the V diagram. This is not a surprising revelation since seldom are students permitted to ask their own questions in school settings. However, it does point out the need to spend more time in teaching the V diagram to students so that they will be familiar with its components and use in the learning and research process.

Four primary findings from this survey suggest:

1. The research project provided an opportunity to select a topic of interest and carry it out.

2. Concept mapping aided with the organization of ideas.

3. Formulating research questions are difficult, but they enjoy the opportunity to pose their own questions for study.

4. V diagramming can be confusing and requires much effort.

Findings of this study better informed the astronomer educator and university educator regarding student and teacher learning contexts as these students studied and analyzed authentic data. Students became knowledgeable about the action research process and were more thoughtful in the study of their cases.

Discussion

Throughout this action research investigation the students were encouraged to seek answers to their own questions, sort through electronic and print mediums, make judgments, and synthesize facts and ideas as they progressed in their case research. Evidence was provided of the learning and understanding with the topic "Planetary Transits" through the visual displays of the concept maps, time writings, and written case reports.

At first they encountered uneasiness when asked to formulate their own research questions. This was brought about due to the requirement of the case to have the student think about possible resolutions. Reconciling the process of formulating research questions that directly related to the events of the case "Planetary Transits" was a difficult undertaking. This required more than casual knowledge with the topic. It required building one's prior knowledge with new information by reading print, nonprint, and electronic texts. Making judgments and then consulting with the astronomer/educator in negotiating and discriminating pertinent from nonessential information of the student's inquiry. This negotiation required considerable effort by the students to relate the disciplines of mathematics, physics, and astronomy in order to delve into an inquiry by posing questions that was new ground having no definite answers. In formal school settings, students typically engage in predetermined questions given by the teacher with expected answers. Seldom are students asked to engage in research tasks that require thoughtful and meaningful analysis, especially when the answers to their questions are not yet known.

Thinking/learning contexts were better understood as a result of this investigation. Ideas revealed in the timed writings and electronic concept maps together with information gathered from the survey and student case reports better informed us of the conceptual change approach to teaching and learning. Likewise, the process raised the level of consciousness of the student researchers concerning the thought processes and requisite knowledge needed to undertake a complex investigation.

Adolescents deserve the right to have learning environments that provide thinking/learning contexts that challenge their cognitive and affective abilities, interests, and curiosity. As a member of the Commission on Adolescent Literacy of the International Reading Association we have published a position statement that emphasizes the need for adolescents to receive and "show" what they can do in meaningful learning environments (see Moore, Bean, Birdyshaw, & Rycik, 1999). Some of these principles are evident in this study: Adolescents deserve access to a wide variety of reading material that they can and want to read; adolescents deserve instruction that builds both the skill and desire to read increasingly complex materials; adolescents deserve assessment that shows them their strengths as well as their needs and that guides their teachers to design instruction that will best help them grow as readers; adolescents deserve expert teachers who model and provide explicit instruction in reading comprehension and study strategies across the curriculum.

Some essentials for adolescent learning are emerging from this study that are compatible with a series of studies that we have conducted (e.g., Alvarez, 1993; Alvarez, Burks, & Sotoohi, 2002; Alvarez & Alvarez, 1999; Alvarez & Rodriguez, 1995; Alvarez, Stockman, Rodriguez, Davidson, & Swartz, 1999; Alvarez, et. al.

2000) and that have been analyzed using the four commonplaces of educating: teaching, learning, curriculum, and governance (see Gowin, 1981; Gowin & Alvarez, in press).

One essential is that Educating is a process of deliberate intervention in the lives of students in order to *change* the meaning of experience. The change educating makes happen empowers students to become self-educating; they learn to take charge of their own experience. This change of the meaning of experience requires teachers and students achieving shared meaning. The deliberate intervention in the lives of students is aimed at negotiating meaning between teacher, curriculum, and student to the point of mutual understanding. In this process, the teacher brings something, the curriculum presents something, and the student brings something. All three are involved in contributing something toward the empowerment of students such that they become self-educating.

Another is that just as teachers cause teaching, students cause learning. The student is therefore responsible for learning. Learning is defined as an active, nonarbitrary, voluntary, reorganization by the learner of patterns of meaning. The student learns the new with the power of the old; the new unfamiliar materials must become integrated with the old, familiar ideas and meanings the student already knows. Learning is the way the student grows from the familiar to the unfamiliar such that these two are progressively integrated and differences reconciled. Adolescents find working with authentic data and primary sources couched in meaningful learning contexts stimulates their curiosity and enables them to incorporate a given subject discipline with other related content areas.

Further, in this study, as with our others, the curriculum is emergent rather than fixed. The curriculum is an analyzed record of prior events that we use to make new events happen; the curriculum is related to teaching and to learning, but *not* reduced to either. The curriculum refers to a material thing that exists not the experiences that can be undergone as a consequence of interacting with those materials. The whole of the educative process is not reduced to one part.

Governance is an essential in the school climate. *Governance controls the meaning that controls the effort*. This formula states that governing events control the meaning that controls the effort put into teaching, into curriculum and into learning. Students in this study, as in our others, are encouraged to exercise their own governance by making decisions and choices in their research and case investigations. They impose control over their work and negotiate the paths of inquiry with peers and teachers that will be taken in reaching resolutions.

Finally, adolescents' societal learning environments directly impact their formal school learning. *Educating is a social practice that takes into consideration both formal and out-of-school experiences*. As learners we need to make connections between our societal learning environments and the formal school type environments while simultaneously enabling us to discover learning contexts to deal with problem-oriented tasks. These societal and school factors are complex, interrelated, and interactive entities that influence our education. Being aware of the sociocultural context in which students live helps the teacher to make learning a meaningful connection between the classroom and the students' world environment (Alvarez, 1993; Dewey, 1902; Donham, 1949; Erickson, 1984; Sarason, 1991).

The three students in this study were thoughtful and diligent who were evaluated using the four commonplaces of educating: teaching, learning, curriculum, and governance. This theory of educating makes sense of educative events. The key event is *a teacher teaching meaningful materials to a student who grasps the* *meaning of the materials under humane conditions of social control*. The teacher initiates the event, the materials (curriculum) are guides to the event, the students take part in the event, and the event as a social event has distinctive qualities governing it.

Electronic contexts provided students with ways to monitor and negotiate meaning with each other and their teachers. In this study, the electronic concept maps were tools used by the students to organize and reveal their thought processes with the target concept under study. This required time, effort, and conceptual understanding with complex ideas.

Simplistic solutions to complex problems do little to enhance the learning process of coming to know and understand. If we want to be knowledgeable in dealing with educational problems and situations we need a theory that is designed to guide us in the process of learning and evaluating what is and has occurred. Such a theory of educating espoused in this study deals with the commonplaces of educating and the ability to become self-empowered. When confronted with novel problems or situations we need to be mindful of the various landscapes that the problem or situation offers us. Our goal is to view its complexities without denying them, and to simplify them so that they can be better known and understood.

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Appendix A

Scoring Criteria for Concept Maps*

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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.

Appendix B

Students' Time Writings

Extrasolar Planet HD209458b

The period of this planet is 3.52 days. It is a gas giant. It is 0.63 of the mass of Jupiter. The density of this planet is 0.23g/cm^3 which is less dense than the densities of Jupiter and Saturn. *Jennifer Quintero* [my italics] This planet was discovered on November 14, 1999. It was discovered simultaneously by Dr. Greg Henry (TSU) and Dr. Geoff Marcy (UC Berkeley). *Jennifer Quintero* [my italics]. Since this planet is a gas giant and it has such a small period, it most likely migrated inward toward its star. I believe it spiraled in due to angular momentum. The planet was born in the outer protoplanetary disk. It would continually plow into the remnants of the disk. By doing this, the mass of the increased, and the mass of the disk decreased. This caused the angular momentum of the disk to decrease and it made the angular momentum of the planet spiral inward. I have done concept maps on the migration theories and also on the planet formation. This planet was the 1st ever seen in transit.

Properties and Evolution of the planet HD209458b

Planets form in the disk that is left over from the star's formation. In one of these disk a planet formed very far from the star and because of the loss of angular momentum or energy it migrated very near the star.

Its mass is .63 Jupiters but its volume is bigger than Jupiters. When finding the Density it gave me 0.233 g/cm^3 which means it is a gas giant. This planet was discovered by Dr. Greg Henry using the telescopes in the Fairborn Observatory. This planet is the first planet that has been seen transiting its star. It is actually 90^0 angle from earth which is a very amazing discovery.

From the data collected by the telescopes you can actually see the diminishing of light. The planet decreases 1.8% of the light of the star.

This planet is orbiting the star in a very short period like 3.52 days. The planet also gives us proof that planets do exist outside our universe. By studying this planet astronomers can understand better the planets and how they have formed. By that scientists can understand our planet and our solar system.

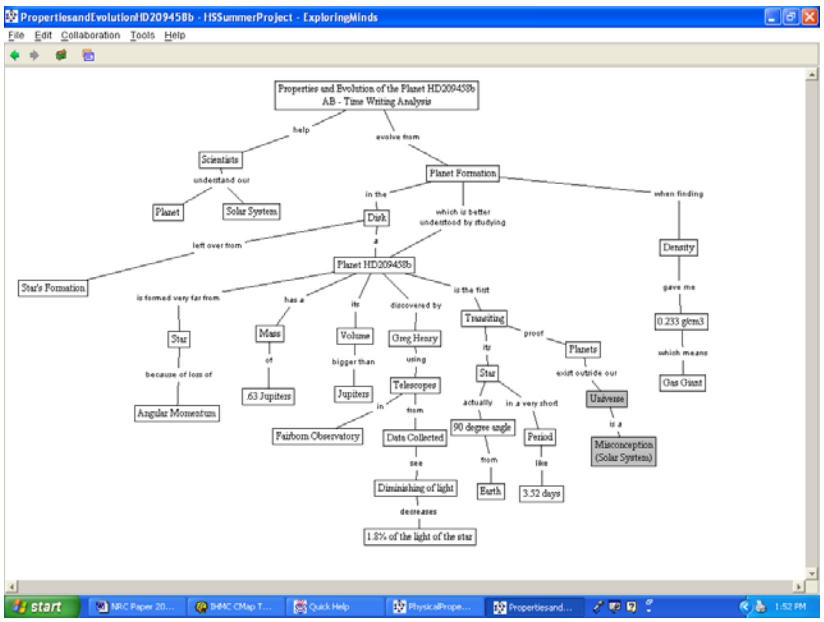
A Study of the physical properties of HD209458b

The transit is the best way to get the data of the planet around HD209458 because you get a good approximation of the size of the planet relative to the star it orbits. The stars data is already estimated because of its spectral type and its temperature. For HD209458, it is approximately the same as our own Sun. *Taylor Moulton Taylor Moulton…* [my italics] this means that the orbital radius can be calculated once the period of orbit is known. Keplers law relates T (period) and R orbital (the distance the planet orbits from its own Star). *Taylor Moulton* [my italics]. Other data can be calculated such as the planets mass (M_{pl}) and the planets radius (R_{pl}) through some basic physics relationships. Once the data is gathered and processed, *Taylor Moulton* [my italics], conclusions about the planet can be about the planet can be made. *Taylor Moulton* [my italics]. For instance, HD209458b has a mean density of less than 300 kgm$^{-3.}$ This value can be compared with other planets in our solar system. It turns out that the least dense is Saturn (p>600 kgm).

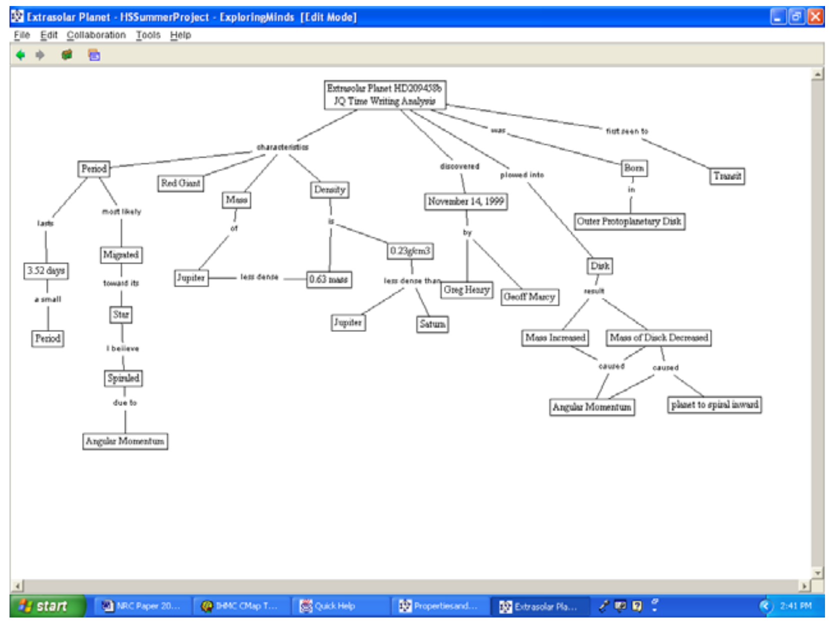
Appendix C

Concept Maps of Students' Time Writings

A Concept Map of AB's Time Writing



A Concept Map of JQ's Time Writing



A Concept Map of TM’s Time Writing