Sternberg's Multiple Intelligences: Accommodating Students' Abilities Through Advanced Technology

Bruce C. Howard, Steven McGee, Namsoo Hong, and Regina Shia

Wheeling Jesuit University, Center for Educational Technologies[1]

Abstract

The purpose of this study was to examine the effect that various intelligences (or abilities, as defined by Sternberg, 1985) have on success in using a multimedia software program for learning science inquiry skills. Over a three-week period, students used *Astronomy Village®: Investigating the Universe* as a resource to conduct research investigations concerning current astronomical questions. Due to the inquiry-oriented nature of the activities, we wondered how this non-traditional learning environment might affect students of differing abilities. In particular, we used the construct of "triarchic abilities" proposed by Sternberg (1985), which purports that human intelligence is comprised of three primary abilities: analytic, creative, and practical. Sternberg (1985) further proposed that students who are strongest in analytic intelligence usually perform the best in classroom situations because the activities conducted in classrooms require primarily analytic abilities. It was our belief that the activities in *Astronomy Village* would allow students of all three abilities to perform equally well, but that students with stronger creative and practical abilities would demonstrate improved attitudes towards science and astronomy.

Categorizing students according to their strongest ability (either analytic, creative, or practical), we examined how they succeeded at cooperative learning tasks and how their attitudes towards science were influenced. Our findings indicated that the use of *Astronomy Village* resulted in equal success for students no matter their strongest intelligence. In addition, we found evidence that students who were more practical or creative in their abilities benefited by developing more positive attitudes towards science.

[1] *Correspondence to: Bruce C. Howard: WJU- CET Bldg. 316 Washington Avenue, Wheeling, WV 26003. This paper was presented at the annual meeting of AERA in Montreal, Canada.

Theoretical Background

Historically, emerging technologies have acted as catalysts for new instructional paradigms. This is particularly the case in current K-12 classrooms, in which new computer technologies and increased computer access have fostered a rapid rise in the use of inquiry-based instructional approaches (Prawat, 1992; Yager, 1995).

Inquiry-based instruction has appealed to science educators for many years because it helps to teach both the products of science (e.g., facts, principles, laws, and theories) and the processes of science (cognitive skills and methods used for collecting, analyzing, synthesizing, and evaluating evidence). Inquiry-based instruction also parallels developments in science education standards, which emphasize problem solving and student-to-student cooperation, in addition to conceptual understanding (National Research Council, 1996, p.23).

The emphasis on learning through inquiry, problem-solving, and cooperation has generated a need for research on how to optimize such learning (Johnson & Johnson, 1996; Means & Olson, 1997). This need is all the more urgent when one considers how rapidly technological advancements—such as increased Internet connectivity, faster computer processors, and enhanced hypermedia—are changing the face of instruction. In a review of 50 research articles (1988 through 1995) on computer-based science teaching, Weller (1996) concludes that what we know about the impact of technology for science education is still in its emergent phase (see also Kuhn, Amsel, & McLoughlin, 1988 and Sivin-Kachala & Bialo, 1995 for similar conclusions).

We believe that one way of optimizing student problem solving and cooperation in inquiry-based environments is to develop software that accommodates the different abilities and learning strengths of students. Our study explored the relationships between students' analytic, creative, and practical abilities, and the outcomes of inquiry-based software use. In particular, we examined outcome variables related to problem solving, science attitudes, and cooperative learning.

Astronomy Village

Inquiry-based environments are increasingly being set up as cooperative "investigations," in which students develop potential solutions to authentic problems facing scientists (e.g., Julyan, 1991; Linn, 1995; Linn & Songer, 1991; Maor & Fraser, 1996; Means & Olson, 1997; Newman, 1990; 1992; Scardamalia & Bereiter, 1993; White & Frederiksen, 1995; 1998). One example of software that uses the investigation model is *Astronomy Village*, developed by the NASA Classroom of the Future™ (COTF) at Wheeling Jesuit University, Wheeling, West Virginia. The COTF specializes in the development and testing of software for math, science, and technology education, and in research in the learning sciences.

Our study was part of a larger program of research that examined inquiry-based instructional software developed at the COTF. With *Astronomy Village* students investigate contemporary problems in astronomy while participating in a virtual living-working environment at a mountaintop observatory (the village). Activities are designed to promote the learning of astronomical concepts and investigation skills. Students join a "research team" and choose an "investigation." For each investigation students progress through five phases: background research, data collection, data analysis, data interpretation, and presentation of results. In each phase, students select from a suite of activities such as simulations, hands-on experiments, thought questions, logbook entries, and library research. Table 1 shows the five phases and icons representing activities in the Stellar Nursery investigation.

The Triarchic Theory of Intelligence

The triarchic theory of human intelligence proposed by Sternberg (1985) distinguishes among three types of intellectual abilities: analytic, creative, and practical (see Table 1). According to Sternberg, these abilities are interdependent constructs, and every student demonstrates a distinctive blend of strengths in one, two, or all three triarchic ability categories.

Analytic abilities are those needed to analyze, evaluate, explain, and compare or contrast. Analytic thinking involves applying problem-solving processes to abstract and relatively academic problems. Sternberg notes that the United States school system is designed to foster these processes and that students with strong analytic abilities are able to excel in the United States system. In *Astronomy Village* students' investigations involve solving abstract problems such as using graphical data to determine the type of star they have found.

Creative abilities are those involved in creating, designing, discovering, or inventing. Creative thinking involves applying problem-solving processes to relatively novel and unfamiliar problems. Creative students find interest in novelty because it affords opportunities for invention. In *Astronomy Village* the research investigations and topics are unfamiliar to the average student, creating an opportunity for students' creative abilities to be expressed when inventing solutions to ill-defined, novel problems.

Practical abilities are those needed to utilize, apply, and implement. Practical thinking involves applying problem-solving processes to concrete and relatively familiar everyday problems. Practical students tend to be interested in, motivated by, and appreciative of knowledge they can take with them when they leave the classroom. In *Astronomy Village*, for example, practical abilities are used to explain difficult concepts (such as diameter of a star) in practical terms (such as how many Earth-diameters that would be).

The goal of the activities in *Astronomy Village* is not to individualize instruction to students, but to help students to capitalize on their strengths by providing them a suite of activities from which to choose. According to Sternberg (1998), providing a match between classroom activities and students' triarchic ability patterns helps students to perform better than when there is a mismatch (see also Sternberg, 1997). Other research indicates that mismatching may result in lowered motivation, especially in the case of analytic students (Sternberg & Clinkenbeard, 1995).

Although the activities in *Astronomy Village* are not matched to students' strengths as in Sternberg's research, students have the chance to select activities from the suite, and to work in cooperative groups. By having choice, and by working together, students are provided ways to apply their strengths and to depend on their cohorts' strengths to compensate for areas of weakness. Sternberg's research supports the notion that a variety of activities that require a blend of analytical, creative, and practical abilities leads to increased learning. For example, Sternberg & Torff (1998) found that students who were taught thinking and memorization in analytical, creative, and practical ways outperformed control students and students taught only in analytical ways.

Research Questions

We were interested in examining relationships between triarchic abilities and outcome measures related to problem solving, science attitudes, and cooperative learning. Our research questions were as follows:

1. How do triarchic abilities predict greater learning of content and skills related to problem solving?

In *Astronomy Village*, the activities may be completed using each student's unique blend of abilities from each of the triarchic categories. We hypothesized that students with higher scores in each triarchic ability category would demonstrate greater content understanding and problem-solving skill.

2. How are triarchic abilities related to incoming science-related attitudes?
   We sought to examine the relationships between six science-related attitudes and triarchic abilities. For example, some might argue that those high in analytic abilities might be drawn to participate in more science-related activities and therefore might develop more positive attitudes. Concerning this research question, we had no hypotheses a priori, as this area has not been researched previously.
3. How are triarchic abilities related to changes in science-related attitudes over four weeks of using *Astronomy Village*?
   Sternberg's position is that the American educational system fosters analytic abilities more than creative and practical abilities. Because *Astronomy Village* presents an opportunity for those with more creative and practical abilities to also make use of their strengths, we hypothesized that those scoring higher in creative and practical abilities would show more positive attitude changes than those who scored higher in analytic abilities.
4. How do triarchic abilities predict greater performance in cooperative learning activities?
   To complete Astronomy Village activities, students must work both individually and cooperatively. We hypothesized that those students who had higher scores within each triarchic ability category would be able to contribute more to the work of cooperative groups.

Method

Participants

Participants consisted of 95 ninth-grade students (52 Female, 40 Male, and 3 did not specify) from a West Coast high school. The ethnic breakdown included 28% Caucasian (n=27), 17% Asian American (n=16), 16% Hispanic or Latino (n=15), and 2% African American (n=2) (35 students, or 37% did not specify their ethnic background).

Procedure

Before students began using *Astronomy Village*, they completed Sternberg's Triarchic Abilities Test (Sternberg, 1991; 1992) and the Test of Science-Related Attitudes (TOSRA; Fraser, 1978). Students were then assigned to cooperative groups and spent the next three weeks pursuing investigations concerning a research question in astronomy. Cooperative learning assessment took place at the end of each week. The TOSRA post-test and a problem solving transfer measure was given after all *Astronomy Village* activities were completed.

Materials

Sternberg's Triarchic Abilities Test (Sternberg, 1991; 1992): is made up of twelve different subscales, with four questions apiece; that is, the three abilities are measured across four domains: quantitative, verbal, figural, and essay. Due to time constraints, we did not use the essay sections. The test yields three total scores for each student. See Table 1 for a description of each ability.

Problem Solving: We used an instrument that measured two problem-solving components: content understanding and problem solving skill. The Problem Solving Processes and Components Measure (Hong 1998) includes three novel astronomy-related problems presented in the form of a scenario and takes about 90 minutes to complete. To address the scenario, students first answer questions about their current understanding of the relevant astronomy concepts (content understanding), and then write answers to the problems (problem solving skill). Responding to the problem requires students to plan their approach by defining problems and goals, search and select appropriate information, organize selected information, choose a potential solution, and justify their selections. Because the tasks do not have "correct" solutions, students must depend on their acquired skills and reasoning to develop a potential solution. From the outset, the measures were developed to be a post-test only assessment of concepts and transfer skills learned from using *Astronomy Village*. Further information about the validity and utility of these measures can be found in Hong (1998).

Science-Related Attitudes: We used the TOSRA (Fraser, 1978) as modified by Smist, Archambault, and Owen (1994) to measure science attitudes. The TOSRA is made up of six subscales: (1) Career and Leisure, (2) Preference for Experimentation, (3) Social Importance, (4) Normality of Scientists, (5) Attitude toward Science Classes, and (6) Openness to New Ideas for a total of 70 test items. Items were scored on a five-point Likert scale. See Table 2 for a description of each subscale and sample items.

Contribution to Cooperative Learning: This instrument, developed by Howard (1997), consists of seven items and takes approximately 1-2 minutes to complete. Each week for three weeks the students rated themselves on a five point scale (e.g., 1=did not contribute, 5=contributed very much) according to how much they contributed to the cooperative group (self-ratings), and then rated the contributions of other members of the group (peer ratings).

Results

Problem Solving

Problem-solving components included content understanding and problem solving skill. For the multiple regression analysis, scores for each of the triarchic abilities were entered into the model simultaneously. In regards to content understanding, both analytic abilities and practical abilities were significant predictors (ß = .22, p=.031 and ß = .25 , p=.016, respectively) accounting for 21% of the variance (p=.001). In regards to problem solving skill, both creative abilities and practical abilities were significant predictors (ß = .22, p=.048 and ß = .21 , p=.037, respectively) accounting for 10% of the variance (p=.004).

Science-Related Attitudes

We had two research questions related to science attitudes. The first question had to do with the relationship between triarchic abilities and incoming science attitudes. This involved examining correlations between TOSRA pretest scores and triarchic ability scores. The second question had to do with whether triarchic abilities would be associated with changes in science-related attitudes. This involved an examination of the interaction between categories of triarchic ability and scores on the six TOSRA subscales.

Correlations between triarchic abilities scores and TOSRA pretest scores revealed significant correlations on only 1 out of 18 correlations examined (Analytic, Creative and Practical Ability scores across six TOSRA subscale scores). Practical ability was significantly indirectly correlated with Attitude Toward Scientists ($\underline{R}$= -.30, p= .013, $\underline{N}$= 68).

To examine the interaction of triarchic abilities and changes in science-related attitudes, we employed a doubly multivariate repeated measures analysis of variance (ANOVA), that used a two (factors: Pretest, Posttest) by three (factors: Analytic, Creative, & Practical ability) design with the six TOSRA subscales scores as dependent variables. We were unable to apply a multiple regression procedure to test our hypotheses in this instance because of the multicollinearity, or very high correlations ($\underline{R}$ >.70), between each of the six TOSRA subscale scores.

To sort students by triarchic ability, we categorized them according to their highest triarchic ability score. For example, a student with a score of 8 on Analytic, 5 on Creative, and 6 on Practical was categorized as Analytic. This procedure resulted in 19 Analytic students, 30 Creative students, and 15 Practical students. Students who did not have a single highest score were left out of further analyses.

Testing for interaction effects between factors (using Pallai's trace test ANOVA procedure) revealed significant interactions on five of the six TOSRA subscales, $\underline{F}$ (2,58)= 2.24, p= .014. For the five subscales where interactions were found, scores for students categorized as Analytic were significantly lower than the corresponding scores for Practical ability students. The only subscale which evidenced no interaction effect was the Social Importance of Science. Because the interaction was significant, analyses for the main effects would have been uninterpretable and were therefore not conducted. See Table 3 for details on univariate F-tests for each subscale. One way of illustrating the interaction effects is given in Table 4 and Figure 1 which represent the interaction effects as a function of the changes between pretest and posttest TOSRA scores for each of the three types of students. In examining this figure, the differences in attitude changes between triarchic abilities become clear.

Performance in Cooperative Learning

Data for performance in cooperative groups consisted of self- and peer- ratings for each of three weeks. Scores were averaged across each week to yield an overall performance score. Self-ratings were significantly correlated with peer ratings, $\underline{R}$= .55, p= .0001. This correlation was not so high, however, as to consider the two as measures of the same construct, so they were used separately in subsequent analyses. Two multiple regression analyses were conducted, one for self ratings and one for peer ratings, in which scores for each of the triarchic abilities were entered into the regression model simultaneously. For self-ratings, none of the triarchic abilities were significant predictors. For peer ratings, the regression model was significant, $\underline{F}$ (3,89)= 2.89, p= .04, but none of the three abilities was a significant individual predictor. Table X shows regression statistics for each analysis.

Based on this result, we decided to conduct an additional analysis to test whether combining the scores for the three triarchic abilities would yield a significant outcome. The combined triarchic abilities score was a significant predictor for peer ratings (ß = .27, p=.0098), but not for self-ratings (ß = -.019 , p=.858).

Discussion and Educational Importance

Our findings indicate that the use of *Astronomy Village* resulted in equal success for students no matter their strongest ability. In addition, we found evidence that students who were more practical or creative in their abilities benefited by developing more positive attitudes towards science in an environment that matched their abilities.

We believe that the use of well-chosen curricular materials can appeal to students of all abilities, and could potentially limit the mismatch between practical or creative abilities and current traditional classroom activities. This study provided evidence that such materials may be found in educational multimedia such as *Astronomy Village.*

The type of classroom environment fostered by educational software such as *Astronomy Village* may benefit Practical and Creative students by affording them optimal ways to assimilate knowledge and the means to excel academically. Although analytic students seemingly declined in science attitudes, this does not mean that they have nothing to gain from *Astronomy Village.* The apparent decline could have bee a "rebound" effect, where Analytic students were reacting to the flexi We believe that they would benefit in the long run by being exposed to the unique skills of other students and their ways of assimilating knowledge. Such exposure could broaden the way analytic students approach problems, and with time, positive attitudes toward science could recover to original levels.

Acknowledgements

This research was supported in part by grants from the National Aeronautics and Space Administration (NCCW-0012) and by the National Science Foundation (ESI 9617857). We would like to thank all of our Wheeling Jesuit University student interns who helped in analyzing the data. We would like to thank Dorothy Frew for their helpful comments on earlier drafts of the paper.

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Tables and Figures

Table 1

Definition of Each Triarchic Ability, and How They Apply to *Astronomy Village*

	Definition	Strengths	As applied to *Astronomy Village*
Analytic	Reasoning abstractly; acquiring knowledge; processing information; planning and executing strategies	• Analyze • Evaluate • Explain • Compare/ Contrast	Solving abstract problems; understanding the steps involved in solving the problem
Creative	Using experience, insight and creativity to solve new problems, create new ideas, or combine unrelated facts	• Create • Design • Imagine • Suppose	Inventing solutions to ill-defined, novel problems
Practical	Adapting to contexts; selecting or shaping one's environment	• Use • Apply • Implement	Conducting hands-on experiments; explaining difficult concepts such as light years in practical terms

Table 2

The Six Subscales of the Test of Science-Related Attitudes (TOSRA)

Scale	Sample Question
Career and Leisure	"When I leave school, I would like to work with people who make discoveries in science."
Preference for Experimentation	"It is better to ask the teacher the answer than to find out by doing an experiment."
Social Importance	“The government should spend more money on scientific research.”
Normality of Scientists	"Scientists are less friendly than other people."
Attitude Toward Science Classes	"Science classes are fun."
Openness to New Ideas	"I dislike listening to other people’s opinions."

Table 3

Interaction Effect for TOSRA Subscales:
Univariate F tests with (2,58) D. F.

TOSRA Subscale	F Value	p Value
Career & Leisure	5.95	.004
Preference for Experimentation	7.06	.002
Social Importance	1.56	.220
Normality of Scientists	4.17	.020
Attitudes Toward Science Classes	4.44	.016
Openness to New Ideas	6.63	.003

Table 4

Changes in TOSRA Subscale Scores by Triarchic Ability

	Triarchic Ability Category		
TOSRA Subscale	Analytic	Creative	Practical
Career & Leisure	-0.43	0.09	0.11*
Preference for Experimentation	-0.54	0.06	0.14*
Social Importance	-0.1	0.16	0.21
Normality of Scientists	-0.23	0.14	0.21*
Attitudes Toward Science Classes	-0.22	-0.08	0.26*
Openness to New Ideas	-0.26	0.28	0.54*

*Analytic group significantly lower than Practical group, $p < .05$.

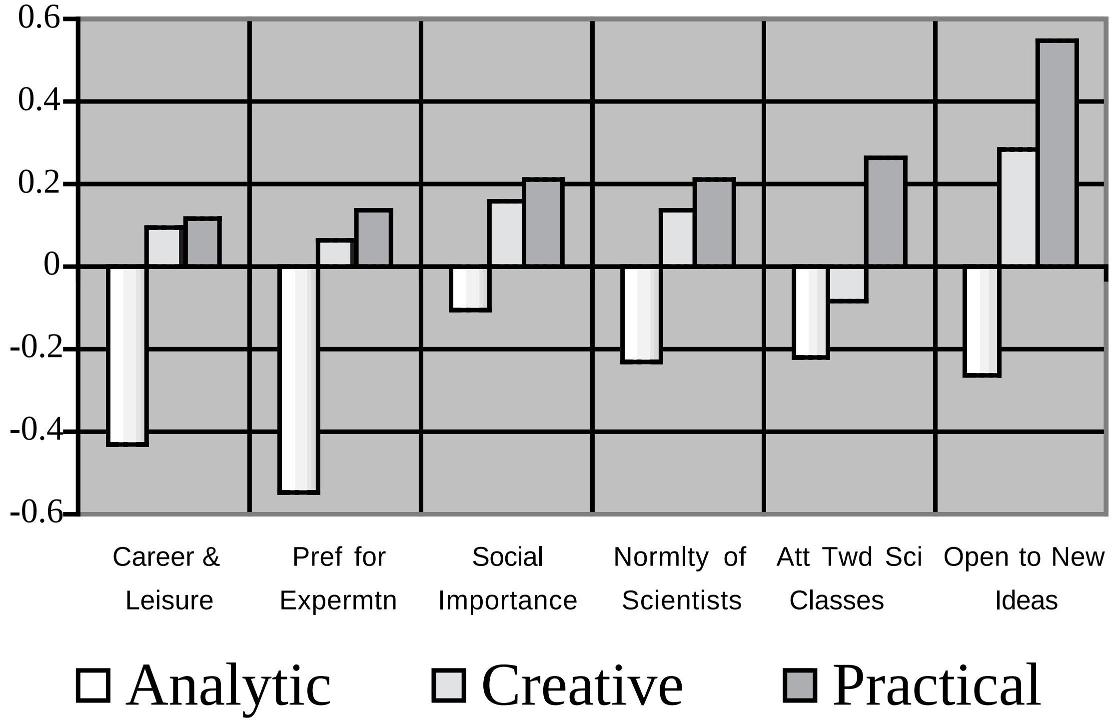

Figure 1. Triarchic Ability Type and Changes in Science Attitudes on the Six TOSRA Sub-scales