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Integrating Basic Analytical Methods and Computer-interface Technology into an Environmental Science Water Quality Lab Improves Student Attitude

Kathleen M. Carvalho-Knighton
University of South Florida St. Petersburg, USA

Joseph M. Smoak
University of South Florida St. Petersburg, USA

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The aim of this study was to investigate if integrating basic analytical methods and computer interface technology would result in a positive change in student attitude. Students' self-concept of science knowledge and skills (Capability), opinion towards science (Affect), and perceptions of the value of science (Value) were determined with attitudinal surveys administered in a pre/post test design. Three separate lab modification groups were compared based upon level of integration over three academic semesters. The main findings were student attitude toward science improved with more integration.

Key Words: computer–interface, science attitude, water quality lab

Introduction

The correlation between science attitude and achievement in science has been well documented since the 1960s (Perrodin,1966; Wick & Yager, 1966; Vitrogan, 1967; Myers, 1968; Uguroglu & Walberg, 1979; Fleming & Malone, 1983; Schibeci & Riley, 1986; Keeves & Morganstern, 1992). Students' attitude toward science is not only a strong predictor of achievement in science, but also affects the amount of science a student will choose to experience (Schibeci & Riley, 1986; Punch & Rennie, 1989; Hegarty-Hazel, 1990; Simpson & Oliver, 1990). Students' self-concept of their ability in science positively correlates with achievement (Raven & Adrian, 1978; Kremer & Walberg, 1981; Steinkamp & Maehr, 1983; Willson, 1983; Jacobson & Doran, 1985a; Jacobson & Doran, 1985b; Oliver & Simpson, 1988). Additionally, the relationship has been examined in a study involving middle and high school students in twenty countries and reaffirmed positive attitude towards science influences student success (International Assessment of Educational Progress, 1992).

The development of scientific literacy includes the development of positive attitudes toward science (Lederman, 1992; Linn, 1992). The American Association for the Advancement

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of Science (AAAS) emphasizes that science literacy includes the ability to use electronic tools (AAAS, 1993). The laboratory, as a factor in the learning environment, is central in the development of positive student attitudes toward science. Laboratory instruction enhances students' attitude toward science (Gunsch, 1972; Johnson, Ryan, & Schroeder, 1974; Dickinson, 1976; Mallinson, 1976; Fraser, 1980). Research relating laboratory, attitude toward science, and achievement in science has been well documented by science educators and researchers (Gabel, Kagen, & Sherwood, 1980; Blosser, 1980; Hounshell, 1985; Renner, Abraham, & Burnie, 1985; Lawson, Costenson, & Cisneros, 1986; Okebukola, 1986; Shymansky & Kyle, 1988; Bryant & Marek, 1987). The use of computers for the collection, analysis and display of data is a fundamental element of scientific investigations according to the National Science Education Standards (NRC, 1996). Accordingly, the use of computers to acquire, process, and analyze data has become standard in most science laboratory courses.

The University of South Florida St. Petersburg began offering science courses in the Fall 2001. Introduction to Environmental Science (EVR 2001) was one of the first science courses taught on the campus. EVR 2001 is a three-credit hour lecture course with a mandatory one-credit hour laboratory (EVR 2001L) Introduction to Environmental Science Laboratory. In the Introduction to Environmental Science Laboratory, students perform laboratory experiments, engage in fieldwork, and explore the environment through field trips. In addition to fulfilling the General Education Science requirement at the university, these courses are required for students who are interested in pursuing a degree in Environmental Science (the only science degree offered on the campus). EVR 2001 is the only science course with a required lab that many non-science majors at the university take before graduation. Because of the diverse academic backgrounds of students who enroll in the course, adjustments in the delivery of content, especially in the laboratory, were made to ensure a thorough experience in a science laboratory was had by all students.

Water quality is one of the concepts covered in the lecture course. Therefore, students also participate in a water quality lab in the laboratory course. During the water quality lab, students compare three different types of water: tap water, lake water, and seawater from an estuary. In the initial water quality lab in Fall 2001, students utilized water quality kits and a water quality meter. Parameters students examined included salinity, nitrate, ammonia, total hardness, iron, phosphate, and chlorine. The parameters examined were obtained by performing titrations and color chart comparisons using the kits. Several problems with this lab were observed. The sensitivity of some parameters examined with the kits was not low enough for students to make comparisons among the three different types of water samples. Due to the lack of sensitivity, the color comparisons students were expected to make with the kits were difficult at best, especially when concentrations were similar. Students expressed frustration with the color charts because they did not feel confident in their numerical answer based upon their ability to differentiate between shades of color. If the concentration in the samples from the water systems was similar, it was almost impossible to determine a difference. Finally, it was evident through laboratory discussions that students had a lack of understanding of the analytical procedures when using the kits. Students followed the "cook book" type directions carefully adding drops of required reagents and then compared colors to the color chart provided. However, students did not have a grasp of the actual science behind the color changes and were discouraged by the uncertainty in their answers. These problems prompted modification of the water quality lab by incorporation of computer-interface ion-selective electrodes.

Computerized interface systems involve connecting one or more sensors to a computer so that the sensor's relayed signal can be viewed on the computer's screen as calibrated data either in tabular or graphical form. In the past decade, the advantages of incorporating computer-interface laboratory technology in biology, chemistry, and physics courses have been explored (Soares & Creevy, 1995; Adamson, Zimmerman, & Nakhleh, 1997). Studies have shown that although the computer does the technical work, it is expected that the student is more able to think, solve problems, and employ higher order thinking skills (Lazarowitz & Tamir, 1994; McRobbie & Tobin, 1995). One study found that students using computer-interface technology achieved larger positive gains in differentiation and integration of their knowledge of acids and bases compared to traditional bench method users (Nakhleh & Krajcik, 1994). Additionally, it has also been shown that using computer-based technology has a positive effect on the development of scientific inquiry skills for students (Friedler, Nachmias & Songer, 1989; Friedler, Nachmias, & Linn, 1990). This study emanates from research that attitude toward science has an impact on achievement in science knowledge.

Experimental Design

Sample

The participants were students enrolled in an introduction to environmental science laboratory course at the University of South Florida St. Petersburg. A sequential integration of the computer-interfaced ion-selective electrodes was implemented in the Spring 2002 for three consecutive semesters. One section was offered each semester with the same professor. Sixty-four students participated in our research. This sample contained 21 (33%) males and 43 (67%) females. Of these students, 25 (39%) reported themselves as science majors and 39 (61%) reported themselves as non-science majors. Thirty four percent were freshman and sophomores respectively, twenty three percent juniors and eight percent seniors. Eighty three percent of the participants were between 18 and 30 years old.

Lab Modification #1 - During the Spring 2002, students examined water quality parameters using both the water quality kits and ion-selective electrodes. The parameters examined with the ion-selective electrodes included pH, ammonia, nitrate, copper, and lead. The water quality lab was extended from a single lab to two labs over consecutive weeks. During the first lab period, students used the water quality kits to determine salinity and hardness. During the second lab period, students utilized ion-selective electrodes. The ion-selective electrode lab portion consisted of five lab stations, one for each ion-selective electrode (pH, copper, lead, nitrate, and ammonia). Students were divided into five groups of no more than four students per group. Each group had two unknown water samples. Once students were at a station, each group was responsible for calibrating the ion-selective electrode at its station. Each group then produced a calibration curve for the parameter at that station. The group then determined the concentration for two unknown samples. Each group then took their two unknown samples to the next station and determined the concentration of the next parameter. The groups continued to rotate stations until all five parameters were obtained for their two unknown samples. At the end of the lab period, the class data were collected. The type of water for each unknown was revealed and the results obtained from the class were discussed.

Lab Modification #2 - In the Fall 2002, the water quality lab was modified based upon feedback from the previous semester. During Lab Modification #1, 20 students simultaneously utilized the ion-selective electrodes, which was difficult for all students to be involved. Therefore, the first change this semester was to split the class into two equal sections of students. The first section stayed in one lab room and performed Mohr titrations to determine salinity. The kits were omitted in favor of the single titration to focus on the students' understanding of the analytical chemistry involved. The second section went to another lab where the ion-selective electrodes were setup. This section utilized the ion-selective electrodes to determine lead, nitrate, calcium and ammonia measurements from unknown samples. The number of stations was reduced to four by omitting pH. The pH station was omitted to allow enough time for students to generate a five-point calibration curve at each ion-selective electrode station. The first group at each station still calibrated the ion-selective electrode at that station and generated a calibration curve at each station. Approximately half-way through the lab period, those in the ion-selective electrode lab moved to the other lab to perform the Mohr titration and vice versa. The same task was performed in each lab room as before. At the end of the lab period, the class gathered together and the results were discussed.

Lab Modification #3 - The last adjustments to the water quality lab were made in the Spring 2003. The first change was that the water quality lab was increased to include 3 lab periods over three consecutive weeks. During the first lab period, students performed the standard Mohr titration and concentrated on understanding the chemistry. During the second lab period, students learned how to calibrate the ion-selective electrodes and generated a calibration curve. During the third lab period, the class was split into two sections. The first section went to Bayboro Harbor and used a water quality probe to obtain pH, salinity, turbidity, and temperature data. The University of South Florida St. Petersburg is a waterfront campus located on Bayboro Harbor of Tampa Bay. The second section remained in the lab and utilized the calibration curves generated from the previous week to determine lead, nitrate, calcium and ammonia measurements from unknown samples. Approximately half-way through the lab period, the two sections switched tasks. Finally, at the end of the lab period, the class gathered together and the results from each section were discussed.

Table 1. Concentration comparison of water quality kits and ion-selective electrodes

Parameter	Water Quality Kit Concentration	Ion-Selective Electrode Concentration
Ammonia	0 – 2 ppm	$0.1 – 1.8 \times 10^4$ ppm
Nitrate	1 – 5 ppm	$0.1 – 1.4 \times 10^4$ ppm
Salinity	0 – 40 ppt	
Total Hardness	0 – 200 ppm	
Iron	1 – 10 ppm	
Phosphate	0 – 2 ppm	
Chlorine	0 – 10 ppm	
Copper		$6.4 \times 10^{-4} – 6.4 \times 10^3$ ppm
Lead		$0.2 – 2.07 \times 10^4$ ppm

Water Quality Lab Improvement

The incorporation of the Mohr titration, water quality meter, and ion-selective electrodes into the water quality lab resolved several problems incurred while using the water quality kits alone. The ion-selective electrodes have a higher sensitivity needed for some of the samples analyzed. Table 1 compares the sensitivity between the water quality kits and ion-selective electrodes.

By incorporating the Mohr titration, water quality meter and ion-selective electrodes, the importance of calibration is reinforced. Once the water quality meter and ion-selective electrode is calibrated, students are able to visually read a numerical concentration value rather than make an educated guess between shades of color. If students acquired a concentration that did not make sense, the possibilities for error, including improper calibration, were discussed. Utilizing the computers with ion-selective electrodes enabled students enough time to gather data in order to make comparisons among the three different types of water.

Assessment

A pre-survey (PRS) and post-survey (POS) was administered to students enrolled in the Introduction to Environmental Science Laboratory to identify changes in attitude. Our survey was a modification of the Evaluations Team from the ModularCHEM Consortium and ChemLinks Coalition Systemic Reform Projects survey. At the beginning of each semester, students enrolled in the Introduction to Environmental Science Laboratory were asked to complete a PRS used to obtain demographic information, student expectations, and previous science course experience. In addition, students were asked twenty four questions related to their science knowledge and skills and their perceptions of the value of science according to agreement or disagreement in a Likert type questionnaire. Students used the following seven point scale to answer questions: (1) Strongly disagree, (2) Disagree, (3) Neutral, (4) Agree, (5) Strongly agree, (6) Not Applicable, and (7) Don't Know. Each response was scored on a scale of 1 to 7, with a 5 corresponding to the most favorable response and 1 to the least favorable. Upon completion of the revised Water Quality Lab each semester, students were given a POS to determine any significant changes in student attitude toward science. The questionnaire consisted of nine of the same questions from the PRS and fourteen additional questions. It should be noted that no students chose (6) or (7) as a response for any of the questions on the PRS or POS. Therefore, the scale used to answer questions was a true five point scale. Questions from the PRS and POS are included in Appendix 1.

Results

Science Attitude Improvement

The effect of the water quality lab modifications on science attitude was determined using the results obtained by the PRS and POS. First, the same nine questions asked on the both the PRS and POS were compared for each semester (Table 2).

A t-Test: Paired Two Sample for Means, at a 95% confidence level, was performed comparing the same nine POS and PRS questions for each semester. After lab modification 1 (spring 2002), a statistically significant difference was only observed for questions 4, 5, 6, 8 and 9. For both lab modifications 2(fall 2002) and 3 (spring 2003), all nine identical questions asked on both the PRS and POS showed a statistically significant improvement in attitude.

Overall improvement in attitude was measured using the POS administered each semester. In addition to the same nine questions asked in the PRS, the POS contained seventeen additional questions related to the students' self-concept about their science knowledge and skills (Capability), their opinion towards science (Affect), and their perceptions of the value of science (Value). The averages of each of these categories for each semester were analyzed by a t-Test: Two-Sample Assuming Equal Variances at a 95% confidence level (Table 3). The first comparison was for each category from lab modification 1 to 2. Next, the difference for each category from lab modification 2 to 3 was determined. Finally, comparison from the lab modification 1 to 3 was calculated.

Table 2. Comparison of pre and post survey mean values for same nine questions

	Spring 2002 (n=20)		Fall 2002 (n=22)		Spring 2003 (n=22)	
Question #	PRS Mean	POS Mean	PRS Mean	POS Mean	PRS Mean	POS Mean
1	4.45	4.55	4.18	4.59	4.18	4.59
2	4.60	4.80	4.09	4.77	4.09	4.77
3	4.55	4.65	4.27	4.77	4.27	4.77
4	2.95	4.05	3.05	4.27	3.09	4.27
5	2.45	3.50	2.59	4.18	2.64	4.18
6	3.75	4.70	3.64	4.68	3.68	4.68
7	3.05	3.35	2.91	3.50	2.95	3.50
8	4.20	3.15	4.50	2.86	4.36	3.23
9	2.80	3.45	2.91	3.67	2.86	3.78

Disscusion

The expansion of the laboratory to three labs was necessary to expose students to traditional methods, collecting field data and utilizing computers. Incorporating both the Mohr titration and ion-selective electrodes provided linkage between basic and computer assisted chemistry labs. Students are shown the relationship as both techniques are based on comparison to a standard. Students see this relationship to the standard in the titration by the relative volume used. In calibrating the ion-selective electrodes students see the relationship on the monitor as the output of volts. From this students also gain an appreciation for the importance of an accurate calibration.

Results from the PRS and POS provide evidence that expanding the water quality lab to include a Mohr titration, water quality meter, and ion-selective electrodes resulted in a favorable improvement in student attitude. Our results indicate that revision of the water quality lab improved student attitude towards environmental science. When asked if students “would recommend this course” and if they “enjoyed using computers”, the results are both positive and improve each semester. When students were asked to respond to the statement “Often in lab I don’t understand the concept behind the lab experiment” on both the PRS and POS, each semester students were more confident after completion of the revised water quality lab. Lab modification 1 (spring 2002), the average Pre-Survey was 4.21 and Post-Survey was 3.18.

Table 3. Post-survey average category mean, difference between semesters, t-test values

		Affect	Capability	Value
Mean values	Spring 2002	3.12	3.79	3.28
	Fall 2002	3.93	4.39	4.21
	Spring 2003	4.50	4.68	4.70
Differences	Spring 2002 to Fall 2002	0.81	0.60	0.93
	Fall 2002 to Spring 2003	0.57	0.29	0.49
	Spring 2002 to Spring 2003	1.38	0.89	1.42
t-test value	Spring 2002 to Fall 2002	3.76*	3.11**	4.58***
	Fall 2002 to Spring 2003	3.87*	3.17**	6.06***
	Spring 2002 to Spring 2003	5.87	6.43**	6.59***

Lab modification 2 (fall 2002), the average Pre-Survey was 4.52 and Post-Survey was 2.84. Lab modification 3 (spring 2003), the average Pre-Survey was 4.37 and Post-Survey was 3.22. The decrease shows that students are disagreeing with the statement and their perception of understanding concepts has improved. In examining the overall student attitude improvement based upon the three categories (Capability, Affect, and Value), a statistically significant difference was observed for each category each semester (Table 3). The difference increases with increasing technology incorporation. When comparing each category from lab modification 1 to 3 the statistically significant difference is considerable.

Conclusion

The correlation between student attitude toward science and achievement in science has been investigated for years (Schibeci & Riley, 1986; Keeves & Morganstern, 1992; Oliver & Simpson, 1988; O'Connell McManus, Dunn, & Denig, 2003; Turner & Rios, 2008). The primary goal of this research was to examine students' attitude toward science resulting from revising a laboratory experiment to incorporate computer technology. The lab revision combining basic and computer chemistry techniques emphasized fundamental chemistry concepts while providing additional time for an improved learning process. Based on evaluation of the PRS and POS for each semester, modifications of the water quality laboratory improved student attitude toward science significantly. Consequently, improving students' attitude toward science was accomplished and based on previous research must accordingly have a positive impact on achievement in science.

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Authors

Kathleen M. Carvalho-Knighton is an Assistant Professor of Chemistry at the University of South Florida St. Petersburg. Her research interests include water quality, phytoremediation of heavy metals by aquatic species, remediation of organic and chlorinated compounds, and chemical education. **Correspondence:** University of South Florida St. Petersburg, Department of Environmental Science, Policy, and Geography, 140 Seventh Ave South, St. Petersburg, FL 33701, USA. Email: carvalho@mail.usf.edu

Joseph M. Smoak is an Associate Professor of Geology at the University of South Florida St. Petersburg. His research involves the use of naturally occurring radionuclides as tracers of water and sediments. He has worked in a variety of interesting places including Antarctica, Brazil, Mexico, Puerto Rico, and Venezuela. Email: smoak@mail.usf.edu

Appendix 1. Same Questions from the PRS and POS

Question #1	It is important to me that a course provides time for discussing ideas.
Question #2	I like courses that encourage me to discover some of the ideas for myself.
Question #3	Being able to ask questions is important to my learning.
Question #4	I value being able to apply science ideas to everyday situations.
Question #5	It is important to me to be able to use mathematics to solve science problems.
Question #6	It is important to be skeptical about the results of scientific experiments.
Question #7	I prefer problems that have one right answer to problems that are open-ended.
Question #8	Often in lab I don't understand the concept behind the lab experiment.