ANALYTICAL CHEMISTRY INSTRUMENTATION FOR SCIENCE EDUCATION: A REPORT

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ABSTRACT--Preservice science teachers' attitudes toward analytical chemistry and chemistry in general were measured using a 25-item Likert scale before and after an anlytical chemistry experiment involving operational amplifier thermometry. Twenty students enrolled in a science education methods course in an urban private university in the United States took part in the experiment. Initial findings indicate a significant change of attitude in 21 attitude categories of which eight are analytical chemistry-related. The results indicate that preservice science teachers might be interested in learning modern analytical chemistry instrumentation if they are given the opportunity. Teaching analytical chemistry to prospective science teachers might better equip them with the necessary skills for developing their own hands-on science experiments in precollege classrooms. The research also raises the question of whether it is practical to integrate hands-on analytical chemistry concepts into precollege science curricula.

The importance of hands-on experiences in chemistry instruction has often been emphasized by science educators (Fuhrman et al., 1982). Wise and Okey (1983:434) concluded after a meta-analysis that in effective science classrooms "students get opportunities to physically interact with instructional materials." Okebukola (1987) found that opportunities for students to engage in practice-oriented learning experiences in the chemistry laboratory made the greatest contribution in influencing students' attitudes toward chemistry and chemists. From the previous attitude studies of Sherwood and Herron (1976), Kyle et al. (1979), Shymansky et al. (1982), and Okebukola (1987) involving hands-on instruction, it is possible to predict that students' attitudes would also be influenced by analytical chemistry experiments involving instrumentation. However, according to Demers and Shrigley (1990:739), "the teacher is central to the science teaching environment," and teachers' attitudes toward science could affect their students' feelings about science (Gabel and Rubba, 1979). Therefore, in this context, it is critical to assess the science teachers' attitudes toward analytical chemistry experiments involving instrumentation before making plans for integrating such hands-on experiences into the precollege chemistry curriculum.

The purpose of this study was to measure the influence of an analytical chemistry instrumentation experiment involving an operational amplifier thermometer on the attitudes of preservice science teachers toward analytical chemistry and chemistry in general. In this study, science education students were provided with opportunities and guidance to construct an analytical instrument (operational amplifier thermometer) and apply the instrument in problem solving. It was assumed that the experiment would provide a very brief outlook on modern analytical chemistry instrumentation and would positively influence the subjects' attitudes toward analytical chemistry and chemistry in general. After exposing the students to the hands-on nature of analytical chemistry, attempts were made to determine how they perceived analytical chemistry and consequently chemistry in general.

MATERIALS AND METHODS

A null hypothesis was proposed in which there will be no significant change of students' attitudes in all 25 attitude variables (Table 1) between pre- and post-tests. The research hypothesis states that the hands-on nature of analytical chemistry instrumentation will have a positive effect on science education students' attitudes toward analytical chemistry and chemistry in general.

The sample was composed of preservice science teachers (both males and females) enrolled in a science education methods course in an urban private university in the southern United States. They have all had a year of general chemistry and physics courses including the corresponding laboratories and had no analytical chemistry courses. The sampling was done on a voluntary basis. Due to equipment and space limitations, the sample size was limeted to the first 20 volunteers.

The study proceeded through the following stages. The first stage involved pre-testing students' attitudes toward analytical chemistry and chemistry. The attitude instrument employed was a Likert scale survey containing 25 attitude statements (Table 1) modelled after already tested and validated attitude instruments of Eggleston's science pupil opinion poll (National Foundation for Educational Research in England and Wales, 1968), Bauman (1970), Fisher (1973), Brown (1975), and Fellers (1972). The Likert scale ranged from 1 (strongly disagree), 2 (disagree), 3 (undecided), 4 (agree) to 5 (strongly agree). The reliability of the instrument was determined using the "test-retest reliability" method suggested by Borg and Gall (1989) and was found to be 0.82 (*SD* = 0.16). This reliability value is within 97% of the average reliabilities of all the five instruments (0.84) it was modelled after and well within the range of reliabilities (0.47 to 0.98) of attitude instruments reported in the literature (Helmstadter, 1964; Borg and Gall, 1989).

In the second stage, the participants performed an analytical chemistry experiment involving operational amplifier (op-amp) thermometry. The basic circuitry for the op-amp used in the present study to construct the thermometer was borrowed from Cooke and Kumar

TABLE 1. List of attitude variables, means (n = 20 for pre- and post-tests), and t-scores. Variables 1, 6, 8, 9, 10, 12, 17, 18, 19, 20, and 24 have a negative meaning.

Variable number	Attitude variable	Mean score		t-score
		Pre-test	Post-test	
1	Thinking of being a chemist is complex	3.75	2.20	4.61
2	Working on a chemistry problem is interesting	2.35	3.70	4.61
3	Following a chemistry laboratory procedure is easy	2.50	3.60	4.40
4	Working in a chemistry laboratory is good	2.90	4.10	4.86
5	Only future chemists should have to learn chemistry	2.30	3.05	2.07*
6	Chemistry is of no use to a would be school teacher	2.00	1.50	2.24
7	Aknowledge of analytical chemistry is useful in chemistry problem solving	3.35	4.80	8.54
8	Analytical chemistry would be very difficult if we had no expensive equipment	3.15	1.45	6.03
9	I have no knowledge of analytical chemistry	3.80	2.40	4.63
10	Analytical chemistry is no use to ordinary people	2.55	1.70	3.66
11	I wish we had more chemistry in school/college	2.65	4.75	6.84
12	Chemistry lessons are a waste of time	2.30	1.15	5.51
13	It is fun to guess the outcome of chemistry experiments	3.30	4.30	3.34
14	I would like to work with people who make discoveries in chemistry	2.80	4.10	4.95
15	The kinds of experiments I do in class are useful to me outside classroom	3.10	4.25	4.72
16	What we do in chemistry laboratory is a scaled down version of what a chemist will do	3.25	3.65	1.71*
17	Chemists are narrow minded people	2.20	1.25	4.50
18	The laws and principles of chemistry we now know are fixed and will not change	2.10	1.55	2.15
19	Designing an analytical chemistry experiment is time consuming	3.25	2.50	2.03*
20	Analytical chemistry experiments cannot be taught at school level	2.75	1.30	6.87
21	Analytical chemistry is a branch of chemistry	3.25	4.65	9.20
22	Role of analytical chemistry extends far beyond academic and industrial laboratories	3.15	4.35	5.08
23	Analytical chemistry methods and principles can be applied to find solutions to societal issues of scientific origin	3.15	4.10	5.60
24	Results of chemistry experiments do not depend on the experimenter	2.00	1.85	0.51*
25	Most students like chemistry classes	2.15	2.80	2.29

*Not significant ($P \geq 0.05$).

(1989). The schematic diagram of the circuitry is shown in Fig. 1. The participants were guided through assembling an operational amplifier on a breadboard, converting the op-amp into a thermometer, calibrating the op-amp thermometer, and applying the calibrated thermoneter in thermochemistry experiments. The participants were not expected to learn or perform detailed electronic operations. Instead, they were provided with every assistance in assembling the amplifier. A brief description of each component involved in the amplifier was provided. Directions were given regarding identifying the eight terminals of the integrated circuit, the layout of the bread board, and testing the resistors involved.

Calibration of the operational amplifier thermometer was performed against a standard mercury thermometer in a paraffin bath. The calibrated op-amp thermometer was used to detect temperature changes involving reactions such as that of hydrochloric acid and sodium hydroxide. The temperature change was measured in volts and then equated to Celsius. The end point was then determined graphically.

The third stage of the experiment involved post-testing the participant's attitude using the same attitude instrument used for the pre-test. While interpreting the results one should keep in mind that there are some attitude variables in the instrument which are negative. A negative variable might score high in the pre-test and low in the post-test, and a positive variable might score just the oposite in order to show significant difference. In other words, it is the extent of the "difference between the scores of the pre- and post-tests" that is important to determine the significance.

Students' responses in each category of the attitude instrument were subjected to separate t-tests. The level of significance for t-score was set to 0.05, the standard alpha-level.

RESULTS AND DISCUSSION

The hands-on nature of the analytical chemistry instrumentation involved had a significant ($P < 0.05$) effect on the subjects' attitudes in the following manner. The null hypothesis failed to be rejected in the case of all the variables except 5, 16, 19, and 24 (Table 1). Eight attitude categories produced t-scores of 5 and above, of which five are analytical chemistry-related. The participant's understanding that a knowledge of analytical chemistry is useful in chemistry problem solving increased. Their belief that expensive equipment is required for analytical instrumentation decreased. They agreed that analytical chemistry is a branch of chemistry and it can be taught at the pre-college level. Also, they began to realize that analytical chemistry methods can be applied to find solutions to societal issues of scientific origin and that its role extends far beyond academic and industrial laboratories.

The analytical chemistry instrumentation experiment had a significant effect on the preservice teachers' attitudes toward analytical chemistry and chemistry in general. The participants began to realize how interesting it is to work on a chemistry problem and especially in a laboratory-based approach. They increasingly agreed with the statement "I wish we had more chemistry in school/college" and disagreed

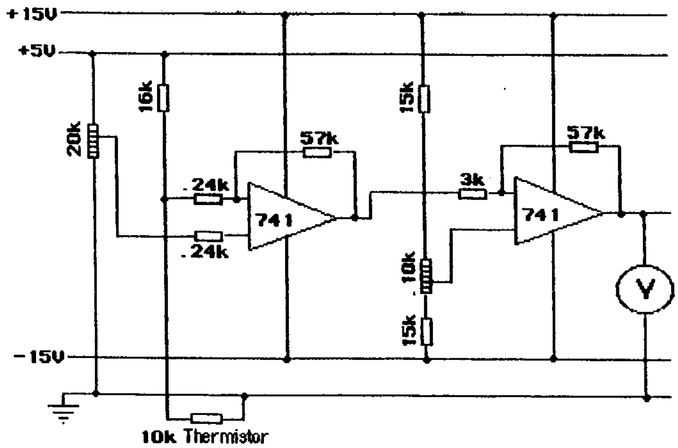

FIG. 1. Schematic diagram of the electronic circuitry.

with a generally stated feeling among students that "chemistry lessons are a waste of time."

One of the major limitations of this study was volunteer sampling, and the participants were not selected randomly. Also, all the sujects were from higher socio-economic backgrounds and predominantly from the southern portion of the United States. Lack of a short training session to introduce the subjects to the analytical chemistry experiment was another limitation. The sampling may be extended to include non-chemistry students in disciplines outside teacher education. Also, samples from chemistry majors may be chosen in order to determine if there are any interaction effects.

The findings of this study indicate that preservice science teachers might be interested in learning analytical chemistry instrumentation if they are provided with the appropriate opportunity. The participants registered a significant change of attitude towards not only analytical chemistry but also chemistry in general. For example, they showed an increasing level of agreement with the statement "working on a chemistry problem is interesting" and disagreement with "thinking of being a chemist is complex."

Teaching analytical chemistry instrumentation to prospective science teachers might provide them with the ideas, insights, and skills necessary for developing their own hands-on experiments in their pre-college chemistry classrooms. In light of the fact that analytical chemistry involves more application-based problem solving, it could be used to provide more hands-on learning experiences in chemistry in order to draw more students into learning chemistry. However, this research needs to be replicated with a larger sample population at the college and pre-college levels before deciding whether school chemistry should include specialty subjects like analytical chemistry instrumentation.

ACKNOWLEDGMENT

Financial support for this study was provided by the Royal Society of Chemistry, United Kingdom.

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