Study of Factors Affecting Attitudes of Young Female Students Toward Chemistry at the High School Level

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Santonino K. Banya

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The University of Southern Mississippi

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Santonino K. Banya

Abstract of a Dissertation
Submitted to the College of Science and Technology
of The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

May 2004

ABSTRACT

A STUDY OF FACTORS AFFECTING THE ATITUDES OF YOUNG FEMALE STUDENTS TOWARD CHEMISTRY AT THE HIGH SCHOOL LEVEL

by Santonino K. Banya

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Chemistry is a human endeavor that relies on basic human qualities like creativity, insights, reasoning, and skills. It depends on habits of the mind: skepticism, tolerance of ambiguity, openness to new ideas, intellectual honesty, curiosity, and communication. Young female students begin studying chemistry with curiosity; however, when unconvinced, they become skeptical. Researches focused on gender studies have indicated that attitudes toward science education differ between males and females. A declining interest in chemistry and the under representation of females in the chemical science was found (Jacobs, 2000).

This study investigated whether self-confidence toward chemistry, the influence of role models, and knowledge about the usefulness of chemistry were affecting the attitudes toward chemistry, of 183 high school young females across the United States. The young female students surveyed, had studied chemistry for at least one year prior to participating in the study during the fall semester of 2003. The schools were randomly selected and represented diverse economic backgrounds and geographical locations. Data were obtained using Chemistry Attitude Influencing Factors (CAIF) instrument and from

interviews with a focus group of three young female students about the effect of self-confidence toward chemistry, the influence of role models, and knowledge about the usefulness of chemistry on their decision to study chemistry. The CAIF instrument consisted of a 12-items self-confidence questionnaire (ConfiS), 12-items each of the influence of role models (RoMoS) and knowledge about usefulness of chemistry (US) questionnaire. ConfiS was adopted (with permission) from CAEQ (Coll & Dalgety, 2001), and both RoMoS and US were modified from TOSRA (Fraser, 1978), public domain document.

The three young female students interviewed, gave detailed responses about their opinions regarding self-confidence toward chemistry, the influence of role models, and knowledge about the usefulness of chemistry on their attitudes toward the study of chemistry.

Both quantitative (a Likert-type Scale questionnaire) and qualitative (open-ended questions) items were used to investigate the views of young female students. Results of the survey were analysed using a correlation test. Significant differences were found in the Likert-type scale scores, providing evidences supporting literature that suggests, self-confidence toward chemistry, the influence of role models, and knowledge about the usefulness of chemistry affect the decision of young female students about the study of chemistry. Interview responses corroborated the results from the survey. Strategies for addressing the problems and recommendations for further studies have been suggested.

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Approved

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Director

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Dean, College of Science and Technology

May 2004

DEDICATION

To Aburijina Lapura, my late mother. You never had the opportunity of studying chemistry in a school setting, but you knew more cooking and medicinal chemistry without any balancing of chemical equations! Aburi, you are gone, but you will always be loved and missed very dearly.

ACKNOWLEDGMENTS

I would like to thank Drs. Theresa Eyerman, Daniel Gordis, David Lieber, Hannan Alexander, Norman Tarnor (late), Mrs. Sherry Cohen (my adopted mother), and the University of Judaism for guiding me to the academic world.

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LIST OF ABBREVIATIONS

AAUW, American Association of University Women

CAIF, Chemistry Attitude Influencing Factor

CAIF-Confis, Self-confidence scale

CAIF-RoMos, Role Model scale

CAIF-US, Knowledge about usefulness scale

CAEQ, Chemistry Attitude and Experience Questionnaire

C & EN, Chemistry & Engineering News

NCES, National Centre for Education Statistics

NSES, National Science Education Standard

NSF, National Science Foundation

RSSC, Role Specific-Self-Concept

S & E Act, Science & Engineering Equal Education and Opportunity Act

TOSRA, Test of Science Related Attitude

ZPD, Zone of Proximal Development

CHAPTER I

INTRODUCTION

Problem Statement

The established association between courses taken in high school and later educational outcomes, resulting into lower representation of females throughout the science, mathematics, and engineering pipeline, remains a cause for concern (Smith, 1996; Sells, 1978). The concern is two fold: first, much of the science important for a person's life in the 21st century will be discovered after the person has left formal education (Glaser, 2003). Moreover, it is recognized that future economic prosperity and global competition will depend on scientific progress and adaptability in the fields of science and technology. These fields are directly linked to national growth and they serve to drive social and economic trends (Sheriff & Svenne, 1993). Second, society is experiencing a technological shift from a resource-based to a knowledge-based economy, making it critical for all citizens to have the knowledge and the skills to contribute positively to continued prosperity.

Our nation needs to attract all the academically gifted female students into the pursuit of chemistry. There is also the need to maximize the scientific literacy of young female students, and to achieve equity in participation in chemistry. Blosser (1990), argued that girls and boys start off on equal footing in mathematics and science, but once physical science and mathematics become optional at the secondary school level, there is a downward spiral of female enrollment, accompanied by decrease in achievement and interest. This implies that there are underlying factors affecting the attitudes of young female students toward chemistry that need to be addressed at the high school level. The

vast majority of research investigating attitudes toward science has been confined to the identification of predictors of attitudes and/or attitude intentions and comparing their importance.

Interests in the attitudes of students toward science have been the foci of gender studies over the past 30 years. Researchers have shown that female students are taught similar amounts of science and receive grades that are similar to (or better than) male students (Hanson, et al., 1996, & Baker & Jones, 1993). It has been consistently determined, however, that attitudes toward science and mathematics differ between male and female students in high school. Some of the reasons for these differences are, 1) the problem of culture, sex stereotypes, and school science that suggest science is a male endeavor (AAUW, 1992; Kahle, et al., 1993; Kelly, 1988; Samuels, 1999), 2) parental expectations of their daughters and sons (Eccles & Jacob, 1986), 3) girls being directed away from physical science by parents, peers, and teachers due to the un-feminine nature of the discipline (Foster, 1992), and 4) differing brain structures and functions between males and females (Barash & Lipton, 2002).

Fraser (1994) listed approximately twenty of these kinds of studies conducted since 1976 related to attitudes towards science education (pp. 507-508). Recent reports indicate that despite the increase in the number of states requiring at least 2.5 years of mathematics and science for high school graduation (NSF, 2002), participation rates in advanced placement or honors science courses are still lower: only 5 percent for chemistry, 4 percent for physics and 16 percent for biology. This indicates that despite the studies done, and the recommendations made, the attitudes of young female students toward science and chemistry are still less than positive.

According to Weinberg (1995), the majority of these studies assumed that the predictor variables act directly on attitudes. Realizing that research has not addressed the underlying causes of attitudes toward science, Weinberg (1995) called for a practical need to continue research that examines strategies for improving the attitudes of all students toward science, especially those of female students. This study identified the inter-relationship between self-confidence toward chemistry, the influence of role models, and knowledge about the usefulness of chemistry as possible factors that could be influencing the decisions of young female students toward the study of chemistry at the high school level.

Research findings have also indicated that girls consistently match or surpass the achievements of boys in science and mathematics (NSF, 1990). Given their curiosity, fresh perceptions, senses of wonder at the workings of their surrounding, and their immense joy of discovery as young children, it is not surprising that girls should be out performing boys. However, during the ages of 12 through 16, young females begin to lose significant interest in science as it starts to play a conflicting role with adolescent pressures and expectations (Eccles & Jacob, 1986). It is the cause of this lack of interest in chemistry among young female students that this study addressed.

Purpose

The purpose of this investigation was to conduct a survey, supplemented by a short interview section to study the relationships between factors that could be affecting the attitudes of young female students toward chemistry at the high school level. Attitudes of young female students toward chemistry and science are important. Studies have shown that attitude toward science influences behaviors like courses selection,

museum visits, and continuation with science studies (Koballa & Crowley, 1985).

With the attitudes of young female students toward science having been shown to be less favorable, contributing to less likelihood of their taking science elective courses in high school (Hykle, 1993), it was necessary that a study focusing on other factors, other than gender, be conducted. The objective was to explore whether self-confidence toward chemistry, the influence of role models, and knowledge about the usefulness of chemistry were inter-related and thus, were contributing to the unfavorable attitudes of young female students towards chemistry at the high school level.

Science and Engineering Equal Opportunity Act of 1980 declared: "It is the policy of the United States to encourage men and women equally, of all ethnic, racial, and economic backgrounds to acquire skills in science, engineering and mathematics, to have equal opportunity in education, training, and employment in scientific and engineering fields, and thereby to promote scientific literacy and the full use of the human resources of the Nation in science and engineering" (S & E Act, 1980, P.8).

The preparation of young females for jobs in the chemical, engineering, and other scientific fields will require that chemistry, the base of all other sciences, absorb more females so that they can gain the knowledge and the skills necessary for technical careers. Equally important, Foster (2003) quoted Shirley Tilghman, the president of Princeton University saying: "In planning and in problem-solving – both in trying to understand what has happened in the past and what should happen going forward – it is helpful to have a science background" (p. 4). Hence, being a part of the global economy, the intellectual potential of all the young people, especially, that of young female students should be engaged in the study of chemistry. It is equally important because as young

adults, these young female students may lose opportunities in the chemical field and/or other prizes awarded on the basis of knowledge of chemistry due to early disinterest in studying chemistry.

A case in point, during one of the televised prime time program "The Weakest Link," on September 30, 2003, a chemistry question stood between Paula, a female contestant, and twelve thousand seven hundred and fifty dollars. She was asked: "which element in the Periodic Table has atomic number two?" She responded: "Hydrogen." The correct answer is helium. Paula admitted afterwards that she had talked with her husband before coming to the show, and that he expressed some concern if she were to be asked a chemistry question. She stated that she knew that she would not give a correct response if she were asked a chemistry question (Paula, 2003).

She was asked a chemistry question, and that cost her the prize. Failure to address the root cause of the unfavorable attitudes of young female students towards chemistry is akin to jeopardizing their chances of attaining professional careers that might lift them from the cycle of low participation of females and their under-representation in the scientific fields and of winning such prizes like the one Paula lost.

Chemical & Engineering News' survey of corporate boards and top executives at 42 U.S. chemical companies show what Tullo (C&EN, 2003) referred to as an "embarrassingly low representation of women." Noting that there has been some progress over the previous year, Tullo stated that of the 432 directors found for 2003, only 12.5% are women, up by 1% from 2002. The survey found that of the 409 executive officers, only 7.3% are women (C&EN, 2003).

According to Marasco (C&EN, 2003), in Academic Year 2003-2004, women

represent 12% of the total chemistry faculty at the top 50 chemistry departments, a modest increase of 1% from the 2002-2003 academic year (Marasco, 2003). Overall, women comprise almost half of the US workforce, but hold 12% of science and engineering jobs in business and industry (Wiesel, 2002). Data has also shown that only 16% of all the scientists, 6% of engineers and 4% of computer scientists in the U.S. are female, despite being 45% of the national workforce and 51% of the nation's population (Pearl, et al., 1990).

Although long-term trends show that the proportion of women enrolled in all graduate sciences and engineering fields is increasing (NSF, 2002), the alarming rate at which females are leaving science and engineering careers, twice as frequently as males (Brodie, 1996), is a matter of great concern. This trend is similar to that of female students opting out of chemistry and science courses in high school. Females miss those they can relate to, in the pursuit of chemistry and science education and Career. "I miss being around a lot of other women who are your colleagues," confesses Angela B. Papling, a John Chapman Associate Professor of Material Science and Engineering (Morrisen, 2002). Noting the challenges that affect the participation of females in science, Shirley Ann Jackson, the president of Rensselear Polytechnic Institute stated: "I think there are some obstacles, but the fact that you now have women scientists in leadership positions at the highest levels of academia and in senior positions at other places should itself let young women know what is possible" (Foster, 2003, p. 2).

Theoretical Framework

The theoretical frameworks for this study are 1) cognitive/constructivist theory of Piaget and Bruner, 2) Vygotsky's socio-cultural psychological theory, 3) the

social/situational orientation learning theory of Bandura/Lave and Wenger, and 4) Eccles expectancy-value model. The Piagetian tenet is that the learner starts with simple schemes and constructs more complex schemes as various experiences result due to encounters with their environment. The learner builds meaning out of these experiences. For Piaget, the structure of the mind is the source of our understanding of the world (Venn & Walkerdine, 1977). He suggested that our interpretive schemes evolved as a result of successively more complex interactions with the world. Thus, as young female students weigh their confidence toward chemistry, the value of studying chemistry and look at those they should emulate, their attitudes toward chemistry change.

A major theme of Bruner's (1997) framework is that learning is an active process in which learners construct new concepts based on their present/past knowledge. Information is selected, it is transformed, hypotheses are constructed, and decisions are made based on the cognitive structure. Bruner stated: "the best way to create interest in a subject is to make the knowledge useable in one's thinking beyond the situation in which the learning has occurred" (p.31). In the event of young female students finding difficulty in constructing knowledge of chemistry, self-confidence are lowered with subsequent alteration of attitudes toward chemistry.

Vygotsky's socio-historical cultural theory agrees with cognitive and constructivist theories, but goes farther to argue that the learner is an active participant in the construction of knowledge. Unlike the Piagetian, Vygotsky believes that meaning was best constructed in cohort with another (peer, teacher, parents). Role models are, therefore, a part of Vygotsky's learning theory. He states that human thinking has to be understood in its concrete social and historical perspectives. For instance, students can

learn some information by themselves, but the other amount of information can only be learned with the assistance of the teacher.

Self learned materials represent the lower end of the proximal development. The gap between what a student can learn by himself/herself and what he/she can learn with help is the zone of proximal development (ZPD) (Vygotsky, 1987). According to Vygotsky, the only way of reaching high level of thinking is through ZPD. Social context, Vygotsky asserts, has a major influence on how we think, and culture provides or at least shapes many of the lenses by which we view the world. Learning, therefore, cannot be separated from its socio-cultural context.

Bandura's social learning theory is based on the premise that the behavior of an observer changes after viewing the behavior of a model. According to Bandura (1986), individuals have a self-system that permits them to control their thoughts, feelings, motivation, and actions. This self-system provides mechanisms and sub-functions for perceiving, regulating, and evaluating behavior, resulting from the interplay between the system and the environmental sources of influence. Observations allow people to see the consequences of the behavior of others, giving them some ideas of what might flow from acting in such a manner.

"Learning would be exceedingly laborious, not to mention hazardous, if people had to rely solely on the effects of their own actions to inform them of what to do. Fortunately, most human behavior is learned observationally through modeling. From observing others, one forms an idea of how new behaviors are performed, and on later occasions, this coded information serves as a guide for action" (Bandura, 1977, p. 22).

Bandura stated that what people know, the skills they possess, or what they have

previously achieved, are not always good predictors of subsequent attainment because the beliefs they have about capabilities "self-confidence" (Banya, 2004), powerfully influence the ways in which they will behave (Bandura, 1986). Consequently, the behaviors of people are mediated by their beliefs about capabilities/self-confidence, and by the results of their previous performances.

Bandura contends that through observation, the learner forms meaning which will serve as a social prompt to initiate similar behaviors in others, strengthen or weaken internal models used for performance of particular behavior, and construct new symbolic representation. Behavior that is positively rewarded (vicarious reinforcement) will be repeated and modeled, but a behavior that is negatively rewarded (vicarious punishment) will be discarded (Bandura, 1986). Social learning theory views humans as cognitive beings, actively engaged in constructing meaning, and whose behaviors are affected by what they believe will happen (Shaffer, 1993). According to Hergenhahn, attending to behaviors and remembering them as possible paradigms, are key aspects of observational learning (Merriam & Cafarella, 1991).

Situational orientation learning, as advanced by Lave and Wenger (1991), states that learning is a process of social participation, and that the nature of the situation impacts significantly on the process. This would imply that involvement of young female students in class activities during their study of chemistry would have an impact on their attitude toward chemistry. As William Hanks (Lave & Wenger, 1991) puts it: "Rather than asking what kinds of cognitive processes and conceptual structures are involved, they ask what kinds of social engagement provide the proper context for learning to take place" (p.14). A person's intention to learn is engaged and the meaning of learning is

configured through the process of becoming a full participant in the socio-cultural practice (Lave & Wenger, 1991).

The focus is a relational view of the person and learning. In the absence of a relationship between concepts being learned and the person, the pursuance of knowledge becomes irrelevant and the decision to discontinue is inevitable. Tennant (1997) states that this orientation has the definite advantage of drawing attention to the need of understanding knowledge and learning in context. There must be an intimate connection between knowledge and activity. Hence, how young female students view chemistry at the high school level is an important influence on whether they will want to study it or not. Secondly, the community of learning should attract young females and offer relationships that are meaningful to the learners. This will provide young female students with the self-confidence to pursue the study of chemistry.

According to Eccles expectancy-value model, "achievement choices link achievement-related beliefs, outcomes, and goals to the input of socializers (parents and teachers), self-perceptions and self-concepts, gender-role beliefs, and individual perceptions of the task itself" (Eccles, 1994 p.587). The model places the inter-relationships between self-confidence toward chemistry and the influence of role models, self-confidence toward chemistry and knowledge about the usefulness of chemistry, and the influence of role models and knowledge about the usefulness of chemistry at the center of this study.

Research Questions

1. Are young female students who are knowledgeable about the usefulness of chemistry

more likely to have self-confidence toward chemistry in high school?

2. Are young female students who have positive role models in their lives more likely to have self- confidence toward chemistry in high school?
3. Are young female students who have positive role models more likely to be knowledgeable about the usefulness of chemistry in high school?

Hypotheses

1. Young female students who are knowledgeable about the usefulness of chemistry have self-confidence toward chemistry at the high school level.
2. Young female students who are influenced by role models have self-confidence toward chemistry at the high school level.
3. Young female students who are influenced by role models are knowledgeable about the usefulness in chemistry at the high school level.

Delimitations

This study was confined only to young female students who had taken at least a year or two of chemistry by the time of the survey. Students who had not yet been exposed to chemistry were excluded from the investigation. Three students completed the open-ended interview questions and were later interviewed. Face to face interview with the three young female students followed over two sessions, each lasting for about one hour each.

The survey was conducted among 183 young female students who had studied chemistry at randomly selected schools. Since the survey was conducted at the beginning of the academic year, students in first year chemistry, who had very limited experience