In Their own Words: What Girls say About Their Science Education Experiences

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Abstract

The purpose of this phenomenological study was to identify and describe the essential components of the current science education experience as constructed by female high school physics and advanced chemistry students. The participants identified five major factors as salient components of the science education experience: (a) mathematics, (b) interest in science, (c) previous experiences, (d) instructional strategies, and (e) the teacher. Unfortunately, participants recalled very few school-related elementary experiences. As a result, out-of-school experiences emerged as crucial to interest development. Further, students related teacher attributes closely to course attributes. In addition, instructional strategy preference varied widely. Mathematics (i.e., the quantitative nature of science) was described as a key factor in the determination of future science participation. Apparently, in high school, as the quantitative nature of science emerges, students must adjust their personal perceptions of science. This adjustment may determine the likelihood, and type, of future science participation.

Introduction

While attitudes, achievement levels, and the other gender-related components of the science education experience of students have been quantitatively examined, very little qualitative research exists to describe the educational experiences of females, in American high school classrooms, from the perspective of the female student. A description of the nature of this phenomenon, as constructed through the experiences of female students, certainly represents a worthy pursuit. Moreover, science education research can benefit from qualitative approaches that attempt to provide a voice for marginalized individuals and all students (Brickhouse, Lowery, & Schultz, 2000). In pursuit of such efforts, researchers should consider the social and cultural structures of schools in order to facilitate understanding of how students actually perceive their experiences. Through such processes, enlightenment can serve as a means to improvement, success, and understanding (Rop, 1999). According to Howes (2002):

> Adult experts have spent a good deal of time and effort putting forward our views on science education in the form of standards, teaching recommendations, and teacher education recommendations. In these efforts, we have drawn from the history and philosophy of science; we have consulted with practicing scientists; we have pulled on the national enthusiasm for science as a way to improve the world and our place in it. However, little mention is made in these documents of children's or adolescents' perceptions of the content and practice of science and science education, or of young people's ideas concerning what the role of science is (or should be) in our society. As is often the way with expertise, specifically that aimed at improving the education of children, science education reforms fundamentally ignore the very people they are meant to benefit. (p. 13-14)

Purpose and Context of the Study

Essentially, "there remains a dearth of information pertaining to students' knowledge and opinions regarding what science is and what it should be" (Howes, 2002, p. 1). The purpose of the present study was to identify and describe the salient components, or factors, of the phenomenon known as current science education experience, as constructed by female high school physics and advanced chemistry students.

The participants in this study represent a unique set of individuals. However, while unique, these girls do represent a subset of the high school population. In essence, the 12 girls in the present study represent the many female students with varying career interests who, for a variety of reasons, are compelled to pursue advanced science study at the high school level. Ironically, many of these individuals, although interested enough in science to pursue advanced science study in high school, do not continue science study at the collegiate level. In the present study, of the 12 participants, only two anticipated careers in science, while 7 aspired to science-related careers and 3 planned for non-science careers. Nevertheless, despite their own misgivings, all were excellent math and science students.

Theoretical Framework

According to Colburn (2000), from a theoretical perspective, constructivism dominates science education. Essentially, this orientation assumes that individuals construct personal views of knowledge and reality. Social constructivism asserts that learning is a sociocultural process resulting in the personal construction of knowledge through human interaction. From this perspective, learning may be perceived as sense-making (Oldfather, West, White, & Wilmarth, 1999). Thus, teaching science should involve helping individuals to refine, develop, and understand personal perceptions of science. A primary step in this process is the illumination of current belief systems and cognitive structures in relation to science education experience.

Specifically, social constructivism offers a framework for interpreting individual behavior and action (Rop, 1999). In relation, students should be taught that individuals are “co-constructors of knowledge, that they can make sense of things themselves, and that they have the power to seek knowledge and to attempt to understand the world” (Oldfather et al., 1999, p. 16). Thus, all individuals develop unique knowledge and reality through personal algorithms and processes (i.e., psychological constructivism). However, as society members, individuals produce constructions that exhibit commonalties. Thus, common perceptions shared by individuals should reflect the needs and preferences of society as perceived by these individuals (Hunt, 1997). “This perspective is particularly important in American high schools and classrooms. Because fellow students share common experiences and a social unit or structure, processes and constructs of schooling have commonsense character” (Rop, 1999, p. 222).

As a result, “a social constructivist view focuses on learning as sense-making within particular sociocultural contexts, rather than acquisition of knowledge from some external source” (Oldfather et al., 1999, p. 89). From a social constructivist point of view, societies consist of patterns of beliefs that may be applied to niches of the society (Hunt, 1997). For instance, chemistry students must process and understand classroom situations, expectations, norms, and beliefs for themselves. “Because student sense making, or the formation of meaning, is intrinsically, inevitably, and profoundly social, each student comes to know what it means to be a student in chemistry and to understand chemistry in the context of social relationships” (Rop, 1999, p. 223).

Review of Related Literature

In elementary school, boys and girls demonstrate similar proficiency in math and science. However, in middle school, a gap in science scores emerges (U.S. Department of Education, 1997). “When young girls and boys entering puberty lack the same science experiences and begin to encounter their peer's stereotypic beliefs about areas of study, the potential for the gender gap to widen is enormous" (Jones, Howe, & Rua, 2000, p. 187). This gap seems to have recently narrowed as males and females reach graduation. Yet, males still outscore females on standardized math tests, science achievement tests, and AP (advanced placement) exams. Further, while male and female 7^{th} and 10^{th} graders have similar positive attitudes toward science, high school seniors demonstrate a greater gap in attitudes toward science (U.S. Department of Education, 1997). Most importantly, "women and ethnic minorities are far from having the same opportunities in science education as white men" (Bianchini, Cavazos, & Helms, 2000, p. 516).

With respect to careers, gaps are more alarming. As early as middle school, differences in career aspirations of males and females, with respect to science and engineering, begin to develop. Obviously, these aspirations become self-fulfilling by influencing course selection and effort. Course selection is crucial since high school science participation seems to determine future science study and participation (U.S. Department of Education, 1997). Very simply, "the courses students take in high school and the degree to which they master these subjects affect the choices open to them for years to come" (American Association of University Women [AAUW], 1999, p. 11). According to Taylor and Sweetnam (1999), males usually enroll in the biology, chemistry, physics sequence (i.e., the traditional path to advanced science study). Women leave this sequence after chemistry. Thus, the greatest gender differences occur in physics. According to the AAUW (1999), girls are not as likely as boys to enroll in physics and computer courses. Unfortunately, this deletion blocks the pathway to advanced science study. In fact, "failing to take science electives in high school may lead to few students majoring in science in college or choosing to pursue science-related careers" (Cavallo & Laubach, 2001, p. 1030).

In the past, science achievement has been equated with enrollment in a variety of science courses in high school. However, in reality, the ultimate gauge of success may be equitable career choice and opportunity for females. "If girls are to achieve economic independence and participate in cutting-edge fields of knowledge, more of them need to prepare for jobs in fields likely to create interesting and well-paid positions, at various skill levels, in the next century" (AAUW, 1999, p. 124).

Shamai (1996) asserts that science course selection is a function of gender-related stereotypes that exist in society. These stereotypes, along with school-related factors, dissuade girls from pursuing science. These influences encourage girls to become passive and males to become aggressive. Obviously, these student attitudes are extremely important in the determination of future course selection. Also, appropriate course selection at the end of middle school is crucial to future success in science. However, attitude toward science may not be as crucial as attitude toward occupations.

According to Francis and Greer (1999), males show more positive attitudes toward science than females. Also, younger students have more positive attitudes toward science than older students do. Moreover, a variety of factors (including class size, anxiety, and teaching style) are assumed to affect attitudes. Unfortunately, these less favorable attitudes of females often translate into less interest in science careers. Ironically, "young women begin to lose interest in science even when they perform as well, or even better, in this subject as their male classmates" (Catsambis, 1995, p. 252). Likewise, as girls mature, confidence in science ability and science career aspirations begin to wane. As a result, girls simply self-select out of science curricula (Farenga & Joyce, 1998). In the end, experience, attitude, and career interest combine to impact science achievement and participation. However, males are much more likely than females to obtain these science-impacting experiences (Joyce & Farenga, 1999).

The knowledge and experience attributes and levels of students are crucial factors in the learning process. Likewise, a strong tenant of most learning theories, including constructivism, is the belief that prior experience plays a major role in the assimilation and accommodation of new knowledge. In fact, good teaching necessitates the provision, utilization, and identification of these key experiences (Farenga & Joyce, 1997b). However, "in the United States, women and ethnic minority students do not have the same opportunities to succeed in science as European American men" (Bianchini, Whitney, Breton, & Hilton-Brown, 2001, p. 44). As asserted by Farenga and Joyce (1997a), males and females encounter vastly different science experiences.

Farenga and Joyce (1997b) offer socialization as a plausible cause of gender-based differential science experiences. Behavioral and activity choices tend to increase gender disparity in relation to science experiences. As a result, "schools need to identify science-related experience deficits and provide remediation to students prior to middle school" (Farenga & Joyce, 1997a, p. 563). Further, "treating all students as if they were the same will only lead to further inequities. Because young boys and girls are socialized differently, they come to school with vastly different science-related experiences" (Farenga & Joyce, 1997b, p. 250).

According to Farenga and Joyce (1997a), early participation in out-of-school, science-related activities is an important factor for future success. These experiences facilitate the development of a science cognitive structure. Gender-based, differential experiences in science place females at a distinct disadvantage. Thus, "it is . . . of primary importance that young girls are exposed early in life to physical science experiences" (Farenga & Joyce, 1997a, p. 566).

Verna and Campbell (1999) believe that society, including educators, contributes to differential science achievement of males and females by creating and perpetuating gender role stereotypes. Girls are socialized to exhibit characteristics or qualities that are juxtaposed to qualities associated with science (i.e., masculine qualities). These feminine qualities include "dependence, nurturance, and passivity" (Jones & Wheatley, 1990, p. 862). However, the concept of gender is a socially based, flexible construct. Thus, in order to participate in science, girls may have to alter beliefs, behaviors, and personal qualities. Yet, science and science education must change in order to embrace, value, and utilize the qualities that women exhibit (Howes, 1998).

Of course, while society greatly impacts development, social factors do not totally determine destiny. Obviously, an interplay occurs between intrapersonal factors or traits and the environment. This interplay produces personal identity. "We know that individuals are not free to be anyone they wish. However, we also know that society does not totally define a person" (Brickhouse, Lowery, & Schultz, 2000, p. 444). Yet, by nature, identity development and self-perception reflect behaviors and responses to behaviors. Thus, "individuals have some control over identity yet are also constrained by structure and power relations that may limit the kinds of identities that are available" (Brickhouse & Potter, 2001, p. 966).

Social expectations and practices translate to psychological issues for individuals. For females, these psychological issues in relation to science education focus upon lack of self-esteem and confidence. Differential societal expectations that belittle women with respect to science ability and achievement create lack of confidence, achievement, and esteem. Essentially, females tend to conform to expected gender roles. In this case, femininity is assumed contradictory to, or incompatible with, science achievement and science careers (Erwin & Maurutto, 1998).

With respect to cultural and structural factors, perhaps the most significant barrier to women in science is the nature of science proper (Kennedy & Parks, 2000). According to Kleinman (1998), science, as a discipline, can be considered masculine in nature. As asserted by Brickhouse, Carter, and Scantlebury (1990), "popular images of science and gender created by our culture often serve to label science, particularly the physical sciences as 'masculine'" (p. 116). Thus, "the ideology of science constitutes and influences the practice of science in many ways that are disadvantageous for prospective and practicing women scientists" (Kleinman, 1998, p. 837). Unsurprisingly, women who participate in science are systematically marginalized. In fact, many feminists assert that the products and processes of science are inherently discriminatory toward women (Bianchini et al., 2000).

"The portrayal of Western science as a masculine subject in the classroom has a powerful effect on girls, especially when they are at an age when they are developing their own beliefs about femininity and about career options" (Brickhouse et al., 1990, p. 116). According to Erwin and Maurutto (1998), a conflict exists between the feminine identity and the nature of science. Thus, academic structures and cultures discriminate against women. "In the United States today, the science establishment diffuses subtle and overt messages to the public via the mass media and the educational system that construct and propagate a masculinized ideology of science" (Kleinman, 1998, p. 840). In this climate, a dichotomy exists between femininity and the attributes, characteristics, and processes of science. Science and males are socially defined as, or assumed to be, impersonal, objective, logical, analytical, and rational. Conversely, women often are perceived by society to be personal, subjective, intuitive, emotional, and irrational. Thus, female students must manage a duality of being feminine and scientific. Sadly, being a scientist, for a woman, means sacrificing femininity (Brickhouse et al., 1990). Moreover, science involves a culture that embraces an epistemology of affluent Western, male origin (Howes, 2002).

Methods

The present study employed a phenomenological approach designed to provide a description of the construct known as science education experience. Data sources included autobiographies, student and researcher journals, individual and group interviews, and researcher anecdotal records of observations and interviews. While the primary data source was the interview, other sources were triangulated to identify themes. Data from student interviews were recorded, transcribed, coded, and synthesized. Journal entries and observations were coded and synthesized in a similar manner. The design utilized salient attributes of the analyses promulgated by Brickhouse et al. (2000) (interviews, observations, journals), Brickhouse and Potter (2001) (autobiographies), Ledbetter (1993) (phenomenological approach with open-ended questioning), and Rop (1999) (interviews, observations, field notes, audio taping). These studies collectively offer options for "listening" to students and additionally illustrate the philosophical and methodological listening orientation promulgated by Howes (2002). This approach involves a focus on being attentive and receptive to what students say.

"In a phenomenological study, the participants may be located at a single site, although they must be individuals who have experienced the phenomenon being explored and can articulate their conscious experiences" (Creswell, 1998, p. 110). The participants in this qualitative study were 12 female high school science students enrolled in Physics I and Advanced Placement Chemistry at a Southeast Texas High School. All participants were students enrolled in courses taught by the primary researcher. These students were typical lower middle-class, high achieving, female high school students from Southeast Texas. Their ages ranged from 16 years to 18 years. Participants were all upper level, honors, or gifted and talented students. Of the pool of potential participants (i.e., female students of the primary researcher), the first 12 who returned parental consent forms were selected to participate.

The uniqueness of the participants arose from their membership in advanced science courses. All were female science students who had navigated the biology-chemistry-physics conduit to higher-level science study. Yet, ironically, not all were planning science or science-related careers, despite fairly high interest in science (i.e., at least enough interest to enroll in an upper level science elective). Only 2 communicated the desire to pursue pure science or engineering careers, while 3 others planned for non-science careers and the remaining 7 students were planning for science-related careers (i.e., medicine, health care, animal science).

The data collection period lasted approximately 10-12 weeks. The length of the study was determined by the time required for the emergence of trends, generalizations, and redundancy required to construct the phenomenon. In accordance with the methodology utilized by Brickhouse et al. (2000), participants were asked to write short autobiographies and to keep journals. Unstructured interviews, though, were the primary data source.

Specifically, interviews were recorded and then transcribed. During the interviews, the primary researcher made notes in the researcher journal. Within 24 hours of an interview, the primary researcher wrote reflections in relation to the experience. This feedback was utilized for interpretation and analysis. Researcher notes, reflections, and transcripts were read by the primary researcher. Passages perceived as important were underlined and identified with short topic or thematic descriptors (e.g., math, interest, teacher attributes, instruction).

The interviews were unstructured. “Tell me about your science education experiences” was used to initiate the interview process, and prompts perpetuated the discussion. Structure was limited in order to allow participants the opportunity to express the boundaries of their personal perceptions. Prompting involved asking participants to elaborate upon issues and topics that were initiated by them.

The uniqueness of this study lies in the fact that the participants were allowed a clear voice and opportunity to identify and describe the factors or elements (i.e., essential factors) that they perceived as key components of the science education experience. Once these factors were identified, follow-up interviews and questions were structured to offer participants opportunities for elaboration and interpretation. This process was naturally extended into discussions of personal science education experiences, science achievement, opportunities in science, and abilities in science. A further extension was made so that these factors could be discussed in relation to performance and achievement enhancement. In essence, rather than being questioned or surveyed in relation to particular issues (i.e., where a framework for thinking is provided), participants were allowed to identify, describe, and refine personal concerns and factors related to science education experiences.

For science autobiographies, participants were asked to describe their personal histories related to science (i.e., in- and out-of-school experiences, people and events, interest, and activities). Each autobiography was analyzed through a process of identifying and labeling key passages with descriptors. These passages were then analyzed across autobiographies and interview data to identify key themes.

Journal entries made by students were coded in a manner similar to the transcripts of interviews. Data were coded to label emerging themes, concepts, ideas, and categories. Moreover, the researcher journal was utilized to identify potential researcher biases.

In general, qualitative data were coded according to standard methods suggested by Rubin and Rubin (1995). “Coding is the process of grouping interviewees’ responses into categories that bring together the similar ideas, concepts, or themes you have discovered, or steps or stages in a process” (Rubin & Rubin, 1995, p. 238). Secondary analysis focused upon data comparisons across categories, because linkages are often pointed out by participants. Initial themes, concepts, ideas, and categories were refined on an ongoing, continuous basis. Comparisons were made between statements of participants so that themes could emerge. Lastly, students were asked to provide feedback on the appropriateness of identified themes.

Results and Discussion

The purpose of this study was to identify and describe the salient components of the phenomenon known as the science education experience as perceived by female high school physics and advanced chemistry students. As a group, the girls described their educational experiences as adequate. One claimed that these experiences were lacking in some respect. Several others asserted that their experiences were exceptional. All had difficulty recalling their elementary experiences. Further, all found their middle school experiences somewhat inadequate. As for high school, the girls offered mixed comments. Some found all of their courses to be exceptional. Others found their experiences lacking. However, a general trend was the belief that experiences improved with increasing grade level. In addition, for the girls, teacher attributes and teacher behaviors were cited as integral components of experience. Also, the girls reported a wide range and variety of out-of-school science education experiences.

While a variety of factors were identified by the participants as being influential to science participation, achievement, and interest, five major factors emerged as significant components of the science education experience. These factors were: (a) mathematics, (b) interest in science, (c) previous experiences (d) instructional strategies, and (e) the teacher.

Mathematics. According to the participants, math ability and achievement exert significant influence on science education and participation. Through journal entries and during interviews, participants described mathematics as an impacting factor on achievement and participation. According to some, the more science education becomes associated with math, the more some people disdain science. As Edith said: “I used to want to do science when it was fun. Now, it’s a lot of math.” Jan claimed: “I like math but not as much as the animal sciences and plant sciences.”

Nevertheless, 8 of the 12 participants reported liking science and math. Moreover, those who embraced science in high school desired to do so because of the quantitative nature of the courses. “I really like math, I really understand it and I am actually good at it” (Niki). However, some reported simply tolerating the mathematical nature of science or avoiding math while continuing to participate. Several others declined to participate in more science and cited math as a contributing factor. As Edith stated: “I don’t enjoy the science where math is required. I’m not very good at math or long drawn out equations.” Meg claimed: “There is way too much math involved in science. I don’t like all of the equations and problem solving.” Moreover, 4 of the girls reported not liking math despite achieving well in math classes. These participants asserted that they would like sciences such as physics without the math. In relation to physics, Toni claimed: “I think I like physics. Sometimes the equations and math scare me. I mean I do okay but I don’t really like them. There’s something about it I just don’t like.”

Three of the 4 girls who claimed to not like math, or to not be good at math, were actually very good math students. Jada claimed to like math, but questioned her background. “I like math but my background as far as my teachers is pretty low. My past teachers did not teach. I still excel in math but I don't have a great foundation. My teacher now is great." Ann alluded to the certainty of importance of math to science achievement:

> Some people have trouble with math and it handicaps them in science. I believe if people excel in math, they are more likely to pursue science. Math is important for science. But I think it is possible to pursue chemistry with basic understanding of math.

Toni stated: "Math is a big factor in most science classes. If you are not strong in math, you won't be strong in science." However, as Niki rebuffed: "If you can't do math, there are still some areas of science you can be successful in."

Interest in science. According to the girls, interest greatly impacts motivation, achievement, work ethic, and actual participation. Interest appears to be an integral component of the science education experience. As Meg asserted: "If you are not interested in something, you are not going to want to do it. Also, your mind will wander while the teacher is talking and will affect your learning abilities." In essence, "it helps if you are interested in the class because then you want to succeed" (Terri). Abbey suggested: "I really tend to do better when I am interested in what they are teaching. That doesn't happen all of the time and so they have to make me interested by how they teach it." Finally, Loni claimed:

> Your interest determines how well you do your assignment. Your interest level can do a lot. To a student who is not interested, they're not going to want to try to do their work. But if they want to do the work and it interests them, then they will do well.

Previous experiences. With respect to past science education experiences, in-school and out-of-school themes emerged. With regard to in-school experiences, the girls cited teacher qualities and instructional strategies as impacting most, while out-of-school experiences were reported as not necessarily being perceived as science-related at the time of experience. However, in retrospect, the girls asserted that these out-of-school experiences may have played a role in fostering interest in science. This fact may be especially salient since elementary experiences were described as non-influential. In general, the girls had more recall of early out-of-school science experiences than in-school experiences. However, most of these experiences, although science-related, were performed for leisure or enjoyment.

For example, many of the girls recalled trips to the zoo and to natural history museums. Jan claimed: "I had many science experiences outside of school. In elementary, we went to the zoo and to Old McDonald's Farm. We learned about the different animals. It made me realize how much I love animals." As Abbey said: "I took a trip with my family to NASA and I really enjoyed it. I find the solar system and space very interesting. And I took numerous trips to the zoo and I learned all about the wildlife animals." She further claimed: "I have been helping my dad plant flowers in our yard and he teaches me all about plants and how they survive." Nevertheless, some students claimed that the seemingly science-related experiences may or may not have been actually science-related. Also, the actual influence may never be known. "I went to the zoo a lot when I was a kid. But it wasn't science. I just like to look at animals" (Toni).

However, several students did report out-of-school experiences that, in their opinions, directly related to science. Jenny asserted:

> I volunteered at a wildlife reserve in the 9th grade. It was one of the most exciting parts of my life. All I did was clean up after the animals and feed them. But just being around those wonderful animals just moved me. I love animals.

Jan claimed: “The vets worked on our horses and explained the answers to my questions. And once I got to help a vet float my horse’s teeth.” In fact, as Toni reported: “Once I kept a journal on a spider outside our house. I made a spider cake and my brother dressed as a spider and we had a spider party. We invited our friends and presented the results.”

Television may have been the most significant out-of-school experience of all. All the participants recalled watching science programs on TV. Some described these experiences as impacting, while some found these experiences to be innocuous. Jenny retorted: “Discovery Channel has very interesting shows. And Bill Nye used to fascinate me, but not now, now it’s dumb.” Jan claimed:

> When I was little, my grandmother used to send me Animal Planet and Discovery Channel movies. My mom always made me watch them and then call my grandmother to tell her what I had learned. At the time I did not like the movies, but now I am thankful that I watched them.

With respect to elementary science, the participant group generally described their experiences as nonexistent or as isolated projects. However, most events were positively recalled. Moreover, 9 of the participants indicated that these elementary experiences might play a role in interest development and future science participation. Ten participants recalled elementary science as disjointed science fairs, projects, and simple activities. Niki claimed: “I don’t remember anything about science in elementary school.” “In elementary, I don’t remember lessons being difficult” (Loni). Terri said: “In elementary, I remember learning the parts of flowers and about dinosaurs. I liked it up until the 5th grade when I had to memorize a bunch of junk. Since then I’ve hated my science classes.” “I don’t remember much about science in elementary school besides reading out of a book once in awhile. We didn’t do any experiments until I was in the 6th grade” (Edith). In essence, these girls had difficulty recalling experiences. They recalled enjoying science. Yet, few recalled organized science lessons.

The group offered a variety of reasons for lack of memorable elementary science experiences. Essentially, the students felt that they were too young to remember much. Secondly, they felt that actual experiences were limited and infrequent. And, thirdly, the students felt that science was perceived by educators as being unimportant in elementary school. As Jada said: “It was so long ago. And we were so young and most people don’t remember things when they are really young. And the experiences are usually little simple ones and most people remember big things not little ones.”

Ten of the participants accounted the recollection of the transition from middle school to high school science positively. In general, the girls suggested that high school was the first time they felt as if they were actually learning “real science.” As Rona claimed:

> Before high school, I was always unhappy with my science classes. I liked the idea of science experiments, but when we had them I never enjoyed them. I didn’t understand how it could help to do everything the paper says but still not understand why it worked out, if at all. For a lot of people, experiments are the only part of science class they enjoy. They don’t really care if they understand the actual science behind them. It wasn’t until high school that I really felt I knew what was actually happening in experiments.

And, as Jada claimed: “High school is a lot better than middle school. I don’t even remember middle school.”

Of course, generally, high school science is more content oriented than earlier experiences. As a result, for many of the participants, the science discipline nature of the curriculum is an issue. In the present study, the participants showed preferences for specific science courses. Likewise, they exhibited preferences for teachers and for particular activities. Also, interactions between these factors were evident. Abbey claimed:

> I liked the material in biology but the teacher wasn’t very good. I did not like the way it was taught. It was abstract; we never did anything to help us understand it. And I did not like chemistry, the teacher or the material. Physics is better. You can understand what’s happening, it’s not abstract. You can see what’s going on.

Still another claimed:

> My experience was not good. At the academy it was hard. I mean I learned, but they were not good teachers. They were not good teachers and would not give help or have feelings. They were doctors. They were not teachers. (Loni)

Terri added: “I did not like chemistry because it was difficult. The teacher didn’t teach clearly.”

Yet, many positive experiences were accounted. As Niki stated: “I loved biology. The teacher was great. We were never bored.” Edith claimed:

> I enjoyed physical science, biology, and physics so far. Biology was the best science class I’ve had. Biology had a fun learning environment. I liked the creative involvement. We always did fun projects consisting of things we could do at home.

Another claimed: “Biology was okay--I think it’s interesting how the human body works” (Terri). Very simply, according to Jan: “Some year’s class was good, some year’s not. Like 9th grade, we did not learn anything.”

Instructional strategies. Likewise, instructional strategies were described as significant. The students described a variety of approaches and emphases. No doubt, personal preferences and individual strengths were influential. In fact, the participants offered a variety of personal choices. Jada claimed: “I like seeing or hearing something more than reading information. I learn a lot better when the teacher lectures and explains things or when we have experiments. Sometimes, it is simply a matter of interest.”

Meg, though, claimed: “I learn better when I can see how something works. It is much better than just listening to the explanation of the teacher.” Loni suggested: “In science class, I learn more through discussion and working in groups to talk about how we get answers and the process.” Still another offered, “I like taking notes, working problems, and working directly with the teacher” (Niki). Yet another claimed: “I am a visual person. So I like projects and labs. I also need examples done for me so I can check to see if I understand” (Jenny). Abbey offered: “I do better with group work. And I also prefer hands-on activities where I can learn what I’m doing by actually doing it.” Ann summarized the importance of instructional strategies very well: “Students learn in many different ways. So it would be most beneficial for students if the teacher had a wide variety of teaching methods."

The teacher. Regardless of type of instruction or type of course, the teacher was consistently reported as the integral component. "Good teachers help you understand science concepts. They are people who are understanding and willing to help you" (Toni). Another student claimed:

> A good teacher is someone that knows their subject well and has that occupation because they really want kids to learn. If they know what they are doing, they will be able to help the student learn easier. Then when you really understand the subject, you'll do fine. But it also helps if it is an interesting subject to the student. (Terri)

This interaction between teacher, student, student interest, instructional factors, and course content represents a significant aspect of the science education experience of the students.

> It also helps if it is an interesting subject to the student. Science doesn't really interest me, at least what they teach in the high school science courses, so even if it's a good teacher, it might not be interesting. But a good teacher would help me do better. (Terri)

According to Toni: "It's hard to hate the teacher and love the subject. Normally, if you don't like the teacher because of the way the teacher has presented himself, that's how you see the subject." And, as Niki stated: "Even if you do like it, the teacher can make you not like the subject." However, as Jenny said: "If you really like a subject, the teacher can't drive you from it." Very simply, the participants implied the belief that a good teacher can help make an unwelcomed course fairly enjoyable.

Student views were mixed, though, in relation to ability and willingness to overcome bad teachers. Moreover, students had mixed opinions about the ability of a really good teacher to make an unfavorable subject tolerable. "You may not like the class or the teacher and you may not learn it" (Ann). "Yes a bad teacher can make you not like a class. If it's unpleasant, you won't want to do it. But you might be persistent if you like the subject" (Niki). Toni proclaimed: "If I really like the class, I'll take it. Even if I don't like the teacher." Rona suggested: "Maybe a bad teacher can make you hate a subject for a while. But it will be impossible for you to hate it forever. One day, when you get a better teacher, you will hate it less." Conversely, Jada said: "A teacher can make a class a lot more tolerable. But if you really hate a class, you just hate it. And if you really like a class, the teacher can't make you hate it."

Essentially, according to the participants, personal attributes of the teacher and rapport can overcome most obstacles and difficulties. In short, the teacher can make a course tolerable. Likewise, the teacher can, at the other extreme, make the course intolerable. In fact, according to the participant group, teacher attributes and student-teacher rapport are much more powerful short-term influences than interest, mathematics, comfort level, and even instructional strategies. While the long-term effects might not be as great, the girls claimed that, in the short term, the personal attributes of the teacher can make or break a course. At the same time, though, the girls exhibited, at times, the inability to separate personality factors from instructional skill factors or teaching ability. However, in general, personal qualities were reported as being the more influential. Of these personal qualities, the girls found teacher attitude toward the subject, and attitude toward students, to be most salient. As Ann commented: "Your teacher's attitude and instruction are very important because their views reflect on you. Your experience in their class and around the teacher ultimately adds up to whether you choose to continue science." Loni simply stated: "If you don't get along very well, then you will not learn as much." Ann further stressed, "The teacher's attitude towards the subject helps determine students' attitudes toward a subject."

On more climatic terms, Toni claimed: "The teacher has to make class interesting and create a learning environment." "The teacher is important because if they don't make the class interesting, the students will lose interest. They make the class. If the teacher is bad and has bad strategies, you hate the class" (Jenny). However, the issue of teaching style or instructional approach was also reported. "The teacher is important because if the teacher's teaching style helps you learn, then you can participate more in class. But if you don't get what she is teaching, you have less interest" (Edith). Loni claimed: "If the teacher knows the material well and how to teach the lesson correctly, then that's what makes teachers important."

Conclusions

General nature of the science education experience. From a social constructivist standpoint, the perceptions of the factors impacting and compromising the collective science education experience as described by the participants are indicative of a unique and intriguing construction of science and science education experiences. This construction, according to the participants, acknowledges the role of interest, teacher qualities, instructional strategies, in-school and out-of-school experiences, and mathematics. In the present study, the collective significance of these factors lies in the fact that the participants recognized and promulgated these factors as the major themes in the collective construction of the science education experience.

Mathematics and the quantitative nature of science. As a result of limited science education experience, the participants likely entered high school with limited, unrealistic perceptions of science and science education. Unsurprisingly, the girls in the present study recalled a sort of epiphany in which the true nature of science emerged to them as science education experiences became more mathematically, technically, and analytically oriented (i.e., probably chemistry for most students). At this point, mathematics, personal interest, teacher qualities, and instructional attributes become cogent, integral components of the science education experience. At this time, the nature of science emerges as an altering experience. For some, personal constructions of science do not correspond to science as empirically perceived through their science education experiences. This anomaly creates a need for action. This action may result in several paths. Obviously, some individuals accept and embrace their new science experiences as the true nature of science and then pursue further science participation. Others reject the nature of science and their new experiences. Still others tolerate discord between their personal perceptions of science (i.e., based on their unique past experiences), and then attempt to accommodate and adjust to the new nature that emerges through their personal experiences. Some of these individuals may pursue science-related choices or choose niches of science that are personally tolerable. Lastly and ironically, some may disdain the new revealed nature of science and their science education experiences but still continue to participate in science.

The perceptions of participants' in relation to mathematics point to several conclusions. Primarily, and most obviously, female students recognize math as a significant factor, and potential barrier, in relation to science education experiences. Moreover, the comments of the participants reinforce the importance of mathematics to science study. Also, the findings suggest that mastery of mathematics and the use of mathematics in science are separate entities. Most importantly, the results specifically point to a possible discrepancy between the perceptions of science by girls and the actual nature of science. Specifically, in high school, courses seem to move from a qualitative orientation to more traditional, quantitative courses such as chemistry and physics. From a social constructivist perspective, high school thus represents a state of flux with respect to science study. Essentially, individuals must accept or reject the nature of science and the role of mathematics. The degree of acceptance may determine future levels, and types, of science participation. This fact may explain why some of the participants in the present study, although enrolled in upper level science electives, indicated a preference for non-science related careers. Very simply, to participate in science, in social constructivist terms, individuals must be willing to accept and master the mathematical nature of science. Degree of acceptance may predicate participation. For instance, some participants recognized that some areas of science are less quantitative than others. While the impact of mathematics upon science participation is well known, the interesting aspect of the mathematics findings in the present study lies within the variation of individual constructions of the science-math relationship. Collectively, the participants recognized the role of mathematics in science. Moreover, the participants recognized, to some extent, the varying quantitative nature of different science disciplines. Clearly, these recognitions point to some type of socially-based construction and acceptance of science and science education as suggested by Rop (1999).

From a social constructivist view, math exists as an integral component of science as perceived by the scientific community. High school students gain an awareness of this collective perception through enrollment in courses such as chemistry early in their high school careers. As a result, students must accommodate and adjust previous conceptions of science (i.e., qualitative conceptions) to more realistic conceptualizations. Obviously, some people resist this process. In the end, only those individuals who make such adjustments and accept and embrace the mathematical nature of science actually continue to pursue science. Others who are not so accommodating or, at least, accepting may avoid science or choose science-related career paths.

As Harcombe (2001) suggests, we all must construct our own personal understanding of knowledge. Further, as unique individuals, we all confront learning situations in unique ways. For any given learning situation and for any group of learners, each individual presents a unique set of strengths and weaknesses in relation to existing cognitive structures and abilities to assimilate new knowledge. Of course, however, social constructivism asserts that learning is impacted to some degree by social interaction and collective meaning.

Interest in science. The girls reported that by high school, because of lack of science opportunities, interest in science had extinguished for many. Yet, the girls reported interest in the areas of science study emphasized during their limited early experiences. These areas, while still of some interest to the participants, were less quantitative than the science disciplines constructed in high school. Also, apparently, interest in these areas was more casual for some participants in comparison to other non-science interests. Further, the girls did recognize the role of interest in the perception of activities as science or non-science related (e.g., a trip to the zoo may be science or simply a fun outing).

Interest may be impacted by opportunity, the nature of science, and societal expectations. These factors may combine to quash interest for girls. In the study, the girls seemed cognizant of the traditional role expectations of society. These expectations, although subtle, seem pervasive. Such role expectations may steer girls from science, directly and indirectly. These expectations may limit opportunities for females to experience science related activities outside the classroom. As a result, the only opportunity for science interest development may arise from in-school experiences--which may not exist. In the worst case scenario, in the absence of quality elementary science experiences, science interest cannot develop.

Previous experiences. The participants additionally focused on in-school and out-of-school experiences when asked to describe past science education experiences. In relation, interest and intent were issues. The girls described a wide range of out-of-school experiences. However, apparently, "beauty is in the eye of the beholder." In retrospect, all individuals identified science-related out-of-school experiences. Some asserted that these activities were performed from a scientific point of view or with a scientific concern. Conversely, several asserted that the activities, although science-related, were simply performed for fun. Nevertheless, the girls asserted that these experiences were somehow impacting on perception of future science experience.

In-school experiences, obviously, are highly impacting with respect to shaping perception of the science education experience. Elementary and middle school science experiences were recalled as sparse and non-existent. High school experiences were more organized, frequent, and intense. These recollections of the participants with respect to early in-school experiences indicate haphazard, minimum exposure to science. Moreover, the descriptions of science recollections through middle school reflect a very qualitative, thematic approach to science. Such limited, informal experience likely produces science education constructs far removed from any realistic representation of the actual nature of science.

The collective science education experience of the participants consisted of various, numerous, discrete events involving natural interest in nature topics such as animals, plants, rocks, and insects. However, these experiences did not transmit the actual nature of science. In middle school, events become a little more formalized but no less vague and no more memorable than elementary science experiences. Yet, these activities do continue to transmit a misleading representation.

Instructional strategies. The comments made by the participants indicate a construct of educational experience in which teaching or instructional strategies are fairly inseparable from the personality attributes of teachers. With respect to instructional preference, students reported a variety of desires. This variety might be attributable to the range of learning styles of the participants. The significance of such findings lies in the fact that, in some respect, the construct of science education experience includes some cognizance of meta-cognition and some focus upon instructional strategies. Moreover, these strategies apparently are perceived as highly influential to the science education experience.

The teacher. According to the girls, teachers, especially high school teachers, personify scientific disciplines. In fact, students may equate a scientific discipline with a teacher. For the participants, teacher attributes were difficult to separate from course attributes. Yet, in general, the girls recognized an interplay between course or discipline attributes, teacher attributes, and student interest. This phenomenon indicates a construction of science education experience in which the perceptions made by the girls in relation to science disciplines chiefly reflects their personal class experiences.

According to the girls in the present study, a high level of interest in a subject such as chemistry can transcend teacher qualities or bad teaching. Likewise, regard for the teacher can produce the ability to tolerate unfavorable course content**.** In the present study, participants reported the latter situation more frequently than liking the content to the point of transcending a bad teacher. Also, participants suggested that negative experiences with teachers could produce future long-term avoidance of science or specific courses. Most importantly, the admonition of the ability to tolerate a course because of a great teacher (e.g., I loved my teacher and the class was fun, but I still hate chemistry) represents the only situation in which participants recognized, or at least verbalized, a separation between perceptions of a scientific discipline and the course experience and the teacher. Nevertheless, all of these admonitions point to the central importance of teachers.

Recommendations

The female participants in this study described a variety of aspects of the science education experience. Interest emerged as a key mitigating factor related to science education experience. A second obvious impact encompasses teacher attributes and instructional approaches. In relation to the latter factors, teachers can assure positive, non-discriminatory science experiences through approaches that meet the needs of a diverse group of individuals with a wide range of learning styles. Approaches involving Multiple Intelligences Theory (Gardner, 1983), or other multifaceted approaches, would be highly adequate.

Most alarming, though, is the inability of the participants to recall elementary and middle school science experiences. As high school juniors and seniors, the participants were in elementary and middle school during the decade of the 90's. Hopefully, current practice provides elementary students with more significant science instruction. Nevertheless, examination of current elementary and middle school practices would be wise.

Early experiences are crucial for the development of science interest (Farenga & Joyce, 1997a; Joyce & Farenga, 1999). In the absence of out-of-school science experiences, in-school activities are the key experiences related to the development of science interest. This interest was reported by the participants of the present study to be the key factor controlling their decision of whether or not to continue science pursuits. Obviously, the role and development of interest in relation to continued science study should be examined.

Most importantly, perceptions of the mathematical nature of science should be examined. Also, the educational practices that lead to unrealistic images of science should be considered. The communication of the true nature of science early in the development process seems crucial to interest development. The lack of transmission of a realistic conceptualization of science may lead to the development of interest in pseudo-disciplines. A gradual development of the quantitative nature of science, as opposed to a high school level culture shock, might foster more positive attitudes, create interest, and lead to more realistic perceptions of science.

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