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ABSTRACT

This study focuses on the results of an open-ended questionnaire on positive and negative science experiences and the preliminary findings for the development of a survey instrument based on those results. The primary objective of the study was to determine if there are detectable differences in prior science experiences between those who become science majors and nonmajors. Several factors such as teachers, overall learning environment, and perceived success in learning contribute to the overall positive or negative nature of the prior science experiences. Knowledge gained from this study can be translated into greater understanding of the types of experiences that foster positive attitudes toward science as well as how these experiences can be integrated into science education to foster greater success for more students. Contains 17 references. (Author/DDR)

Investigating the Importance of Prior Science Experiences for Majors and Nonmajors

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Abstract

Investigating the Importance of Prior Science Experiences for Majors and Nonmajors

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The present study focuses on the results of an open-ended questionnaire on positive and negative science experiences and the preliminary findings for development of a survey instrument based on those results. The primary objective of the study was to determine if there were detectable differences in prior science experiences between those who became science majors and nonmajors. Several factors, such as teachers, overall learning environment, and perceived success in learning contributed to the overall positive or negative nature of the prior science experiences. Preliminary results of a survey instrument of prior positive and negative science experiences are encouraging. Continued development of the instrument will provide science educators with an additional tool for assessing the prior science experiences of respondents and aid in assessing the influence of such experiences on science course and career choices. This knowledge also can be translated into greater understanding of the types of experiences that foster positive attitudes toward science as well as how these experiences can be integrated into science education to foster greater success for more students.

Investigating the Importance of Prior Science Experiences for Majors and Nonmajors

Introduction

Research in the areas of beliefs, perceptions, and attitudes toward science, and their influence on the pursuit of science careers has received attention given the importance of refilling the so-called "pipeline" with science and engineering majors (Seymour, 1995; Sullins, Hernandez, Fuller, and Tashiro, 1995; Tobias, 1990; 1992). Several of the questions that developed from a three year study of change in science teaching self-efficacy for elementary teachers (Ramey-Gassert, Shroyer, and Staver, 1995) related to the influence of prior positive and negative science experiences on decisions to take additional science courses. The decision to enroll in more science courses, of course, impacted whether a student became a science major or choose to pursue another career path or academic discipline. Understanding the process of selecting a major and the effect of prior experiences on such choices becomes increasingly important as scientists and science educators try to widen the science, mathematics, engineering and technology "pipeline", to maintain a steady stream of students, particularly underrepresented groups, interested in careers in these fields (Seymour, 1995).

Study of the effects of prior experiences on beliefs, self-efficacy, and decision-making behaviors and their connections with later interest and involvement in science is an area of science education that warrants investigation. Self-efficacy belief, as a psychological construct, is based on Bandura's social learning theory (1977, 1981). Bandura theorized that beliefs are rooted in prior experiences and are closely linked with subsequent behaviors. Self-efficacy beliefs are as, "judgments of how well one can execute courses of action required to deal with prospective situations" (Bandura, 1982, p. 122). According to Dembo and Gibson (1985), "The problem of identifying antecedents of efficacy and developing ways to enhance teachers' sense of efficacy is critical. . . . Researchers must consider many variables as well as the complex manner in which they interact" (p. 177). So, to improve science education, we must explore and begin to understand how classroom teachers, particularly elementary and middle level, have developed their beliefs about science and science teaching by first investigating the effects of antecedent science experiences.

This study is a step in that direction, first describing a six year qualitative study of positive and negative experiences of science majors and nonmajors, including preservice teachers, and secondly, reporting preliminary results of the development of a survey instrument developed from that initial research questions and qualitative analysis of questionnaire data.

Methods and Results

The present study focuses on the results of an open-ended questionnaire on positive and negative science experiences (Figure 1) collected from nearly 1000 respondents over five years.

Figure 1. Prior Science and Science-Related Experiences Questionnaire

Name ____________________________ course _____________

After some thought, describe in some detail, your most negative science experience.

How old were you?

How did this experience make you feel? Describe your feelings during this experience.

Did this experience take place in school? or out of school?

If it was in school, what grade were you in?
Was it elementary, junior high/ middle school, high school, or college?

Was there an adult present? Who? Teacher Parent other
If so, what was the role of that person?

What science discipline? chemistry physics biology geology _________
What did you do (or fail to do)?

What do you feel you learned or gained from this experience?

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After some thought, describe in some detail, your most positive science experience.

How old were you?

How did this experience make you feel? Describe your feelings during this experience.

Did this experience take place in school? or out of school?

If it was in school, what grade were you in?
Was it elementary, junior high/ middle school, high school, or college?

Was there an adult present? Who? Teacher Parent other
If so, what was the role of that person?

What science discipline? chemistry physics biology geology _________
What did you do (or fail to do)?
What do you feel you learned or gained from this experience?

The primary objective of the study was to determine if there were detectable differences in prior science experiences between those who were science majors and nonmajors, what were the differences, and what was the overall effect of those antecedent science experiences. Of interest also was the question of differences between scores of male and female respondents, if any. What were the experiences that shaped a person's choice to pursue science? What experiences could turn one away, never to return? Were the experiences different for females and males, or could a similar experience have the same engaging or disengaging effect in terms of future science, no science or minimal science choices or involvement?

The Initial Questionnaire

In 1991, I began asking preservice and inservice teachers about their prior positive and negative experiences in science. I developed a simple questionnaire that was basically open-ended with a few guiding questions and asked for detailed information relating to prior science and science-related experiences in and out of the classroom. Several hundred respondents completed the information on these questionnaires over the course of five years. The information was qualitatively analyzed using techniques such as clustering (Miles and Huberman, 1984) to identify patterns and trends in the data. Several trends became apparent.

It appeared that those who were presently science majors or who choose to become science teachers had somewhat different prior experiences than those who elected not to go into science fields or who took the absolute minimum science course work. Broad themes in the data indicated that teachers often played an essential role in shaping classroom science experiences. Teachers may have also provided an out-of-the-classroom science experience, but more often informal science experiences were with another influential adult. The interest shown and time shared with an influential adult (parent, grandparent, teacher, mentor, etc.) appeared to be significant in making later science-related choices. Whether that adult fostered deeper curiosity or helped the respondent develop needed confidence is unclear. The overall learning atmosphere, particularly within the context of the classroom, also contributed to the positive or negative nature of the science experience.

According to the data, teachers could provide students with the most memorable science learning experiences, or their absolute worst. Often the same words were used by majors and nonmajors to describe negative science experiences, "embarrassing", "humiliating", "made me feel stupid", but one recurring theme was the role of the teacher. One pattern in the data was of the teacher who singled out students and made inappropriate comments or made them feel out of place or self conscious. Many recalled feeling inadequately prepared because the teacher went over the material too quickly and then called on them when they were already confused, which made them feel uncomfortably "put on the spot".

The data indicated that this type of incident seemed to be particularly distressing for females, who often stated that they had studied the material and felt that they were beginning to understand when the teacher, generally male, made them feel very uncomfortable. This degrading experience, -- the traditional model of "only the strong and brilliant go into science, weed out the rest", was frequently enough to turn them away from science permanently. The apparent difference between majors and nonmajors was in their reaction to these negative experiences. The majors found ways to overcome the experience and learn from it, or more often, they simply had another, overshadowing experience which was a stronger, more positive influence.

Similar differences in the prior positive experiences for majors and nonmajors were also evident. In-school science was stated as a positive experience when the teacher provided interesting examples that helped students make connections to their own lives and to the world around them. The teacher also was cited as a factor for having a enthusiastic attitude toward science and/or when they allowed the students to engaged in interesting experiments and activities.

Often, for many respondents, the positive science experience was memorable because the teacher engaged the students in an exploration outside the classroom. The questionnaire data indicated that focused field trips and/or long-term investigations such as a butterfly garden or a study of the seashore were not only their most memorable, positive learning experiences, they were also enjoyable. This enjoyment in learning was stated in terms of working with others to explore a question, having an element of discovery, having time to learn, and to make connections to build on prior knowledge without the pressure to "memorize words and study for a test". It is important to note that many of the characteristics that contributed to positive science experiences for both majors and nonmajors are the same or very similar to characteristics of informal science education environments (Ramey-Gassert, 1997; Ramey-Gassert, Walberg, and Walberg, 1993).

Development of a Survey Instrument

Of course each respondent expressed an individualized reaction to these prior science experiences, but several coherent patterns, as discussed above, developed from the data. These patterns or themes, apparent throughout the data, led to the question of whether an instrument could be developed to more concisely assess prior science experiences. The next step was development of a quantifiable survey instrument using a Likert scale based on the data from the qualitative study.

The initial instrument has 24 items and following review by a panel of qualified judges, field tested with 393 respondents (primarily in biology courses), both science majors and nonmajors, including preservice and inservice K-8 teachers. Preliminary results were favorable. Examination of the correlation of the survey items for all respondent revealed a Cronbach's coefficient alpha of 0.777. For the science majors only the Cronbach's coefficient alpha was 0.782, and for the nonmajors group the value was 0.746. These results indicated that the items held together reasonably well; coefficients above 7.0 are considered acceptable for new instruments (Nunnally, 1978). Exploratory factor analysis revealed that factors sorted on four subscales for the total group (all respondents), three subscales for the nonmajors group, and two subscales for the science majors group. Further refinement of the instrument was necessary to identify and clarify of the various subscales (see Figure 2).

Figure 2. Sample of the Survey of Prior Science Experiences Instrument

Survey of Prior Science Experiences

Please complete all information and circle appropriate responses on both pages page 1

LAST FOUR DIGITS SSN ____ ____ ____ ____ Gender: M F

Science Major or Nonmajor

Please indicate:

(5) Strongly Agree
(4) Agree
(3) Undecided
(2) Disagree
(1) Strongly Disagree

1.	Science has always been hard for me because of the technical terms, the formulas and the mathematics involved.	5	4	3	2	1
4	The experiences where I was able to really "do" science in a hands-on manner were the most enjoyable	5	4	3	2	1
3.	I enjoy learning about the science of the natural world -- plants, animals, and the environment.	5	4	3	2	1
4.	Watching someone else do a demonstration, reading, memorizing terms, hearing a lecture makes science boring.	5	4	3	2	1
5.	My best science learning has happened outside of the classroom.	5	4	3	2	1
6.	Science teachers have always intimidated me and made me feel uncomfortable.	5	4	3	2	1
7.	Learning how and why things work makes me feel "connected" and helps me to make sense of the world around me.	5	4	3	2	1
8.	I had a teacher or parent who was very influential in my learning to enjoy science.	5	4	3	2	1
9.	Dissecting an organism (an animal) was the worst science experience for me.	5	4	3	2	1
10.	When examples from real life are used, it helps me to better understand the more abstract concepts in science or to better visualize what I can't see.	5	4	3	2	1

Based on the factor analysis, the survey was slightly modified and the survey data analyzed a second time. The results were again favorable. Examination of the correlation of the survey items for all respondent revealed a Cronbach's coefficient alpha of 0.789. For the science majors only the Cronbach's coefficient alpha was 0.804, and for the nonmajors group the value was 0.741, once acceptable values for new instruments.

Data analysis, using a two-way analysis-of-variance (two-way ANOVA, SAS version 6.12), indicated that there were differences between prior science experiences for majors and nonmajors, and for males and females in both groups (see Table 1). Prior science experiences differed significantly based on gender and/or major (p=0.0001). It also appears that gender and selecting science as a major has a joint effect on prior science experiences (p=0.0141). This joint (interactive) effect between gender and major and nonmajor groups warranted further investigation.

Table 1. Two-way Analysis of Variance of Majors, Nonmajors, and by Gender

	Major	Nonmajor
Male	3.60 ± 0.46 (n=59)	3.43 ± 0.34 (n=69)
Female	3.64 ± 0.42 (n=81)	3.24 ± 0.42 (n=184)

To determine the nature of this joint (interactive) effect, means and standard deviations of the total scores where calculated by major/nonmajor, gender, and major and gender combined. Figure 3 shows a plot of the mean scores for males (M) and females (F) for science majors and nonmajors.

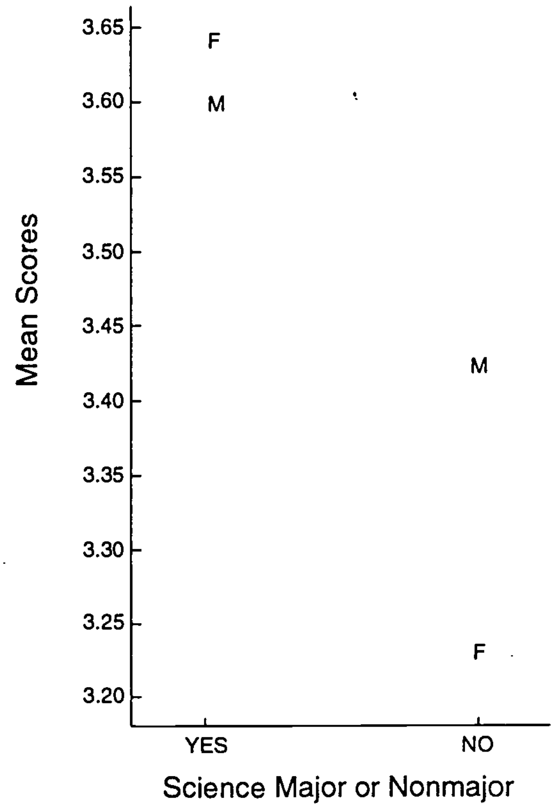

Figure 3. Plot of the Means for Male (M) and Female (F) by Major and Nonmajor

Independent samples t-tests were conducted by gender and the analysis indicated that prior science experiences differed by major for males and for females. Independent samples t-tests were also conducted by major/ nonmajor and the results indicated that prior experiences do not differ between male and female science majors (p=0.6163), while among nonmajors, results for males and females differed significantly (p=0.0010). While the survey instrument continues to be refined, these preliminary results are notable; but what does it mean?

Discussion

Some of these findings are information that makes sense intuitively upon reflection, such as the significant statistical difference between majors and nonmajors. If one chooses to major in science, one has had experiences that have been to some degree comfortable, if not wholly enjoyable, and successful. But the larger, more important point to consider is what does this mean? What does it say about how we are teaching science? How we are preparing the next group of teachers? How are we working with today's teachers to enhance the science teaching and learning that is happening in classrooms and school buildings? What do we do to make the needed changes?

Many of the results of this study confirm what we already suspected--one teaches as one was taught. Unfortunately, those who had the worst, the most negative science experiences are the vast majority of today's teachers, female, nonmajors. And are they, for the most part teaching as they were taught? Are they slighting the amount of time spent on science, are they focused on teaching from the text in fear that their apparent disinterest or lack of science background will come to light? Figure 3 illustrates that science majors, both male and female have had very different prior science experiences than the group that now comprises the science nonmajors. And that female nonmajors--the majority of our K-8 teachers--have had very different experiences from male nonmajors as well as those who selected to be science majors. How do we remedy this? How do we ensure that the K-8 students of today have more favorable, more equitable science learning experiences?

There is another aspect of this which is also helping me to better understand the apparent dichotomy between secondary science teachers and the majority of elementary and middle level teachers. If we hold to the above premise as to one's model for teaching, then it makes intuitive sense that those who succeeded in high school and college science courses, those who could retain information purely from lectures, memorized well, and could recall it on subjective tests, were the ones who went on to become our high school teachers. Not interested in the science process, but more concerned with content coverage. The cycle continues. How do we break this repetitive science-learning-or-not learning cycle that perpetuates the gulf between the majors and nonmajors?

Some might argue that it is a matter of aptitude to learn science, others some type of science learning intelligence, still others might say it is individual reaction or perceptions of science learning experiences, but aren't we, as science educators, charged with the responsibility to ensure that science is taught so that all students can learn? So, regardless of the individual differences, we need to focus on how do we improve the quality and provide more positive science learning experiences for all children. And we do this by paying particular attention to those females who in the past had negative science experiences which may have had an impact on their decision to pursue science courses or a science major. How well have science educators been heeding the call of *Project 2061: Science For All Americans* (Rutherford and Ahlgren 1990), and genuinely implementing the *NRC Standards* (1996)? That would indeed be a good starting point. Another important aspect of this is to also implement what we know from the informal science education side of the house about less restrictive learning environments that are more inclusive and that provide children with interactive involvement in science exploration in a nonthreatening manner (Ramey-Gassert, 1997; Ramey-Gassert, 1996).

Conclusions and Future Endeavors

The Survey of Prior Science Experiences instrument (Figure 2) continues to undergo refinement; one item has been deleted, another item reworded based on the preliminary data analysis. In 1998, 606 respondents, 320 science majors, 286 nonmajors were surveyed. Cronbach Alpha values are acceptable (0.817 overall). Preliminary scanning of this most recent data appears to indicate that the items cluster around two subscales, one relating to science being viewed as relevant, enjoyable experiences with active involvement, the second relating to the science learning environment in general. Many of this second group are the negatively or reverse worded items. This run also pointed out more clearly a distinct between majors and nonmajors as to items that related to more traditional science teaching delivery methods and being successful in those class experiences. As that data is analyzed and the subscales identified, the additional data should aid in clarification of the answers to the research questions posed in this study.

Following continued development, and further field testing of the instrument will provide science educators with an additional tool for assessing the prior science experiences of respondents and to evaluate the influence of such experiences. It is the researcher's hope that this data can be translated into greater understanding of the types of experiences that foster positive attitudes toward science and that these experiences can be integrated into science education to foster greater success for more students while those experiences that turn students away can be extinguished or, as nearly as possible, eliminated. The resultant expansion of effective science teaching, by providing more positive science experiences, will hopefully result in more students choosing science courses whether they are a science major, or have continuing interest to in science beyond required courses. Hopefully this will also be the case for preservice teachers preparing to teach science more effectively perhaps because of constructive, efficacy-building prior experiences in science and development of positive science beliefs and attitudes.

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Figure 2. Survey of Prior Science Experiences Instrument

Survey of Prior Science Experiences

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LAST FOUR DIGITS SSN ____ ____ ____ ____ Gender: M F

Science Major or Nonmajor

Please indicate:
(5) Strongly Agree
(4) Agree
(3) Undecided
(2) Disagree
(1) Strongly Disagree

1.	Science has always been hard for me because of the technical terms, the formulas and the mathematics involved.	5	4	3	2	1
4	The experiences where I was able to really "do" science in a hands-on manner were the most enjoyable	5	4	3	2	1
3.	I enjoy learning about the science of the natural world -- plants, animals, and the environment.	5	4	3	2	1
4.	Watching someone else do a demonstration, reading, memorizing terms, hearing a lecture makes science boring.	5	4	3	2	1
5.	My best science learning has happened outside of the classroom.	5	4	3	2	1
6.	Science teachers have always intimidated me and made me feel uncomfortable.	5	4	3	2	1
7.	Learning how and why things work makes me feel "connected" and helps me to make sense of the world around me.	5	4	3	2	1
8.	I had a teacher or parent who was very influential in my learning to enjoy science.	5	4	3	2	1
9.	Dissecting an organism (an animal) was the worst science experience for me.	5	4	3	2	1
10.	When examples from real life are used, it helps me to better understand the more abstract concepts in science or to better visualize what I can't see.	5	4	3	2	1
11.	Science is taught too quickly in class. I need more time to understand the more complex information.	5	4	3	2	1
12.	I have always felt comfortable using science equipment and materials.	5	4	3	2	1

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13.	I enjoyed learning about the parts of the body and dissecting an animal helped me to learn.	5	4	3	2	1
14.	Simply reading the science textbook was enough to steer me away from science.	5	4	3	2	1
15.	I feel that I have forgotten most of the science I was expected to memorize when I really didn't understand the overall concepts.	5	4	3	2	1
16.	My most enjoyable science learning experience was on a field trip, camp out, or similar experience.	5	4	3	2	1
17.	My science teachers always took the time to give me the help I needed to learn and to make sense of the science topic.	5	4	3	2	1
18.	I have always enjoyed solving problems in science, trying open-ended experiments, learning from "failures" and trying to find answers to my questions.	5	4	3	2	1
19.	My science teachers often made me feel that I had no control over my learning, uncomfortable and/or confused because they went fast & presented material at a level beyond my comprehension.	5	4	3	2	1
20.	I feel frustrated when I am just going through the science book or doing a "cook book" lab exercises because I really want to understand why something is the way it is.	5	4	3	2	1
21.	I have enjoyed science experiences where I have been successful -- it makes me want to learn and do more science.	5	4	3	2	1
22.	Science has to be presented in a lecture format so I know what the teacher wants me to know.	5	4	3	2	1
23.	Doing related activities helps me to better understand the science I am learning.	5	4	3	2	1

Figure 3. Plot of Mean Scores for Male (M) and Female (F) by Major and Nonmajor

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