Science Interests and Experiences for High School Girls in a Summer Integrated Program.

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Recruitment of female students in engineering and other physical science fields becomes difficult at the college level since they often lack advanced high school science and mathematics courses. The 1986 National Assessment of Educational Progress noted that a large percent of high school students elect not to enroll in advanced science and mathematics courses (Dossey, Mullis, Lindquist, & Chamber, 1988). Wilson, Stocking, and Goldstein (1993) reported that female and male adolescents selected different courses which follow traditional gender stereotypes. Males prefer mathematics and science courses because they viewed these classes as being useful for future education.

Jones and Kirk (1990) reported that physics students were more interested in applications involving people, with female students being more interested in medical applications. However, physics textbooks focus on applications without a human context. Evans, Whigham, and Wang (1995) recommend the use of female role models in science classes to change attitudes toward science-related careers.

Weinburgh (1995) conducted a meta-analysis of gender differences in attitudes toward science and relationships between attitudes toward science and science achievement. She reported that boys have a more positive attitude toward science and achievement in biology and physics. Terry and Baird (1997), studying 844 high school biology students, reported that females and males had different views of women in science. They identified four significant factors (student gender, science ability, level of education the student planned to complete, and career interest) which accounted for almost 25% of the total variance. Dweck and Licht (1980) concluded girls have greater learned-helpless orientation in mathematics and science than boys. Li and Adamson (1995) noted that gifted girls attributed their successes and failures in mathematics, science, and English to effort and strategy, as opposed to ability. Burkham, Lee, and Smerdon (1997) noted that hands-on laboratory activities are related to all students' achievement, but especially to girls'.

The goals of the Newton Academy (**N**ew **E**xperiences for **W**omen in Science and **T**echnology) were formulated to address the above research findings. The Academy was designed to provide:

1. Hands-on integrated physics, engineering, and mathematics experiences for motivated female students.
2. Opportunities for the participants to interact with women scientists who may serve as

role models, and

3. Peer groups of female students who are interested in the physical sciences.

The 1997 Academy was a one-week long, non-residential program where 21 students who had completed grades 9-11 gathered to participate in the above activities and to ultimately design and build a factory to manufacture bouncing polymer balls. The students were assigned to groups of three or four based upon diversity of grade-level and school. Each member of the group had a designated role for the factory, but all members were expected to contribute to plant design, construction, and reports.

A summary of integrated activities and skills utilized are presented in Figure 1 below:

Figure 1. Summary of interdisciplinary learning	***Skills utilized***
Students encountered the **mathematics** of the problem in determining the optimal mix of glue and borax required to get the highest bounce out of their balls. This problem was solved by a graphical method using Mathematica.	*Computer programming, graphing.*
The **engineering** focus was on system design and factory layout. The construction of a material handling system involved the **physics** of gears, pulleys and electrical systems.	*Drafting, drawing, designing, design accuracy, wiring, construction skills such as hammering, drilling etc.*
The **chemical** concepts encountered were polymers, acid-base chemistry, absorbance spectrophotometry, and waste generation.	*Measuring, calculating dilutions, spectroscopy.*
To understand the concepts of **economy** and **cost-benefit analysis** a construction store was utilized. Each item in the store cost money (Newton dollars).	*Managing and planning a budget, patent development.*
A patent bulletin allowed students to encounter the **legal issues** of patents and intellectual property.	*Evaluation of design for completeness and novelty.*

Methodology

The evaluation of the Newton Academy was based upon three instruments completed by the 21 participants at the start of the Academy, observations of the program, and interviews with participants and project staff.

The Attitude Toward School Science Assessment (ATSSA. Germann, 1988) is a 14 item instrument with a unidimensional view of attitude. Each item has a five-point Likert scale; 10 items are positively stated and four items are stated negatively.

Mason and Kahle (1988) developed the Science experience Survey (SES) to identify common science activities and materials used by students outside school. The original 40 items were modified by Farenga (1995) resulting in 32 items with four foils. Twenty-eight items from the modified instrument were used in this study. These items were grouped by subject area into the following categories: five questions described reading about or watching science-related material, 11 described visiting places where science activities were being shown or conducted, six described hands-on activities in an academic setting and six described hands-on mechanical or electrical activities.

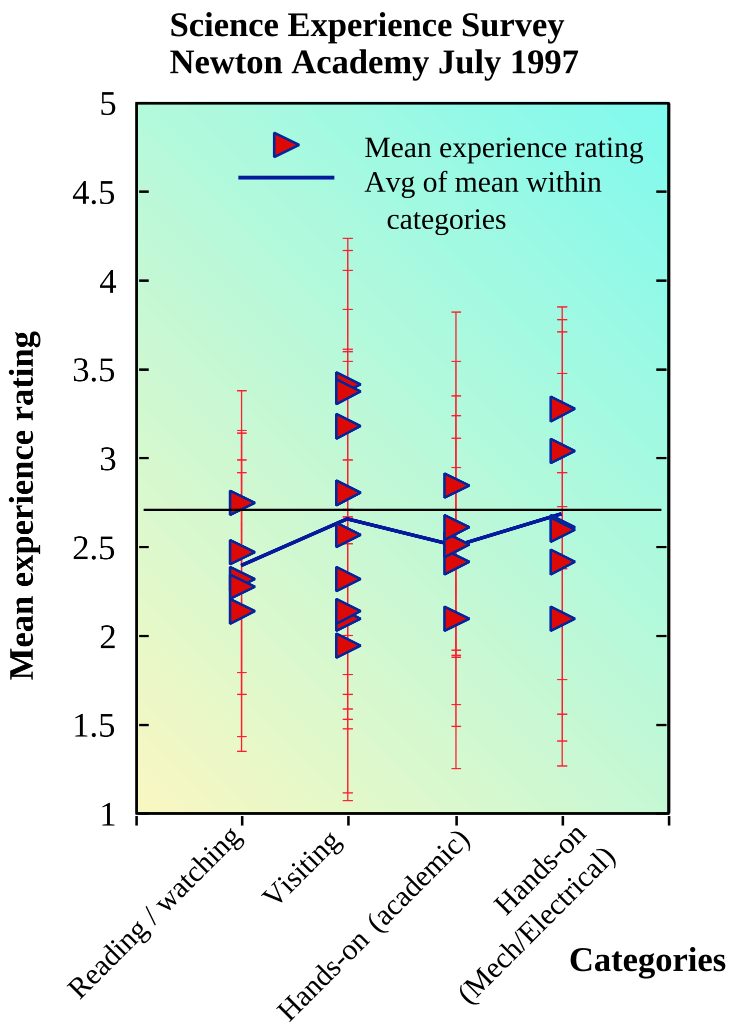
The Course Selection Sheet (CSS) was developed by Farenga (1995) to determine the types of subjects that were of interest to the participants. The CSS was modified for each participant to rank eight courses she would like to study in high school. The modified CSS consisted of 12 science and 12 non-science courses. The "priority" rating for a given course was calculated by taking a weighted average based on the rankings given by the students. In other words, if five students rated a subject as first, fourth, third, eighth and second in their priority of taking courses, the rating was (8 + 4 + 5 + 1 + 7)/5 = 5.0.

Findings

The scores on the ATSSA ranged from 49 to 69, where the maximum score was 70. The students' overall positive attitude toward school science was reflected in a mean of 60.25 (S.D. = 6.03).

Figure 2 presents the results of the SES. Students rated the frequency of their experiences on a scale of 1 to 4, with 4 being frequently and 1 being never. We grouped the questions in categories and plotted the mean rating of questions in different categories, as indicated above. We found that ratings were distributed around a mean of 2.5 for all categories. The mean for the category designated Reading and Watching rated slightly below the 2.5. The Visiting and Hands-on Academic categories rated somewhat above the mean, with some of the activities scoring as high as 3.4. The Visiting category had a large spread in the means, as well as large standard deviations on some questions. This spread indicates that the students, although relatively homogeneous in their interests in science, had large disparities in their experiences, particularly when it came to visiting science-related places such as animal hospitals and wildlife refuges.

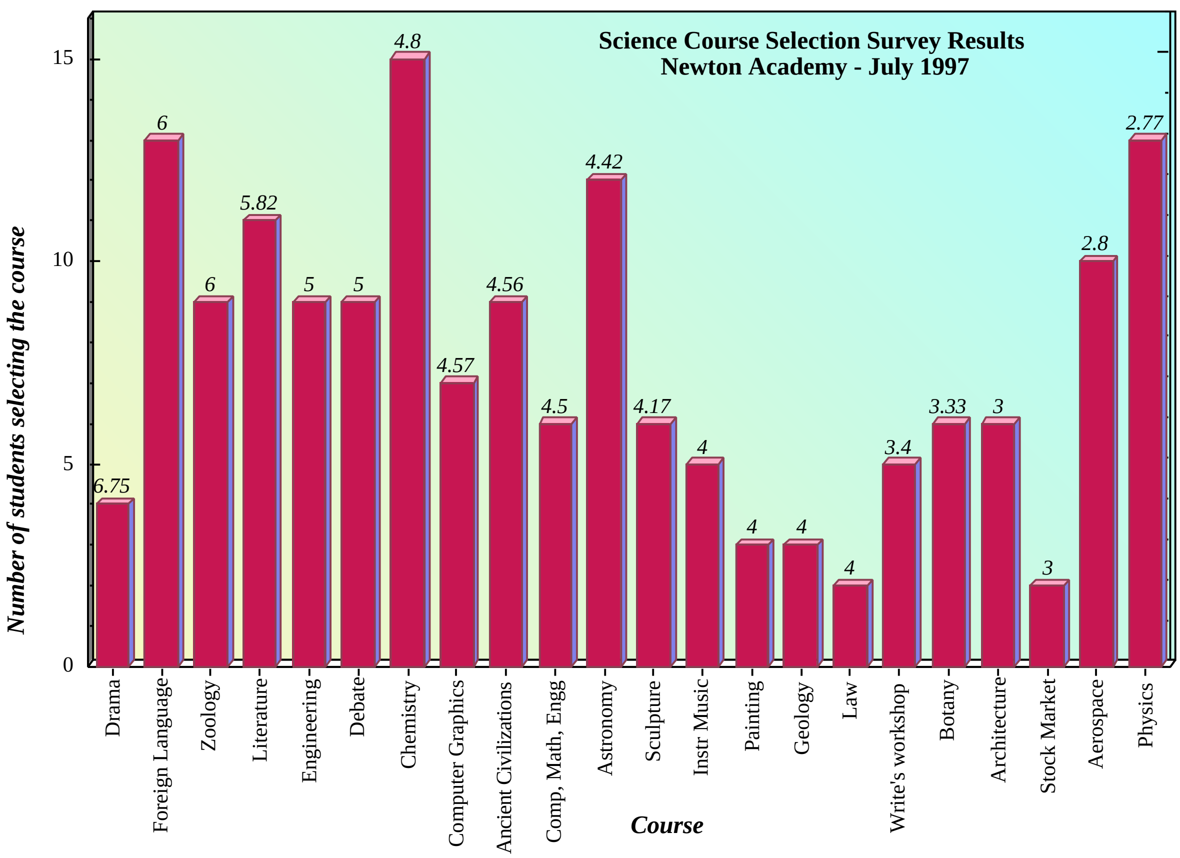
Figure 2. Results of the Science Experience Survey. The questions were grouped into categories (shown on the horizontal axis) by the types of activities they described. The means and standard deviations for all questions are indicated by the symbols. The mean of the means within a category is indicated by the thick line.



In contrast, the Hands-on Academic category had a relatively small spread, indicating similar experiences, which is not surprising as this student population was drawn from the same school system. The large spread in the Hands-on Electrical / Mechanical is also not surprising, although we expected this group to have more incoming experience. However, it was gratifying that in spite of their lack of experience, they did attend the Academy, and their initial behaviors with tools such as electric drills, hand saws and hammers were positive.

The results of the <u>CSS</u> are listed in Table I and presented in Fig. 3 in graphical form. The sixteen courses listed in the survey are shown on the horizontal axis of the graph. The height of the bar shows the number of students who have interest in that course. The “priority” ratings (Table I) are shown as numbers above the bars and the horizontal axis is ordered by rating. Thus, Drama enjoys the highest average rating of 6.75 out of a possible score of 8 among the four students who are interested in taking the class. Chemistry was chosen by the largest number of students, 15 out of 21, with an average rating of 4.8. slightly above average. We find it interesting that even among students enrolled in an Academy based on physical science, Physics was the lowest ranked course among their selected courses. However, not reflected in this quantitative data are statements from one student who decided to enroll in Physics who had not planned to do so and another who upgraded her Chemistry course to an honors level class.

Figure 3. Results of the Science Course Selection survey.



Discussion

The Newton Academy, an extracurricular experience, provided high school females with an opportunity to apply science, engineering, and mathematics concepts in the development of a factory to build polymer balls. Several components were noted by the participants as facilitating the Academy, including the frequent opportunities to interact with women scientists and engineers in social events and formal educational settings. This role modeling (Evans, Whigham & Wang, 1995) and the field trip were experiences to which most students had not been previously exposed. We hope that these experiences will counteract the science learned-helplessness as described by Dweck and Licht (1980). The field trip and the interactions with the practicing engineers provided opportunities for the participants to see the human applications as noted by Jones and Kirk (1990).

Students were assigned to groups of three or four based on diversity of grade level and school. Each group built their own factory. The students chose a name for their group from a list describing the lives and achievements of eight female Nobel Laureates. Most of these names were unfamiliar to the students. Each group designated members as Plant Manager, Design Engineer, Chief Financial Officer and Materials Engineer. While each member had specific duties, all members were to expected to contribute to plant design, construction and report preparation.

The project staff were impressed with the level of motivation of the students. The two K-12 teachers were amazed that no classroom management statements were needed. Students were ready with paper and pencil, busily taking notes when at the polymer class on the first morning. Their motivation and involvement stayed high through the week. The students began the week quiet and reserved. By the second day they had become much more assertive and interactive within their groups. There was a certain level of competition built in because of the patents and the production challenge. The groups were, however, cooperative and supportive of one another, often teaching each other to use unfamiliar tools. The projects that they built exceeded staff expectations. They were required to automate at least two components of their factories, and several groups automated many more components. Their designs were very creative, and they requested materials that sometimes could not be provided for them.

The designs for the six factories were quite different. Some factories focused on measuring and mixing, while others focused on extruding and tumbling. Some factories were vertical, others horizontal, and yet others circular in layout. Tumbling drums, extruders using large size syringes, and conveyor belts were features of several factories. Most of the motorization was done with reducing gears and large torque motors. The students were particularly taken with using DPDT (double pole double throw) switches to reverse the direction of a motor. The main deterrent was that there was not enough time to modify the designs.

In addition to the academic experience, students participated in team building activities, discussed gender issues, had dinner with women scientists and engineers, heard a talk by a female chemist from the local 3M plant, toured the Chesebrough Ponds' factory in Jefferson City MO, and went to Six Flags amusement park for Physics activities. We plan a follow up tracking study on these students to gauge the influence the Academy had on them in the long term.

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Table I. Statistics of Science Course Selection Survey. These data were used in Figure 3.

Subject	Number of students choosing subject	Average score	Standard deviation	Rating = Average score /Number of students
Drama	4	6.75	1.5	1.25
Foreign Language	13	6	2	2
Zoology	9	6	1.8	2
Literature	11	5.82	2.18	2.18
Engineering	9	5	2.69	3
Debate	9	5	2.06	3
Chemistry	15	4.8	2.11	3.2
Computer Graphics	7	4.57	1.13	3.43
Ancient Civilizations	9	4.56	2.01	3.44
Computers, Math, Engineering	6	4.5	2.26	3.5
Astronomy	12	4.42	2.35	3.58
Sculpture	6	4.17	1.94	3.83
Instrumental Music	5	4	3.67	4
Painting	3	4	1.73	4
Geology	3	4	2.65	4
Law	2	4	4.24	4
Writer's workshop	5	3.4	2.07	4.6
Botany	6	3.33	1.21	4.67
Architecture	6	3	2.61	5
Stock Market	2	3	2.83	5
Aerospace	10	2.8	1.81	5.2
Physics	13	2.77	1.74	5.23

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