Career Orientations for American Chemistry Olympians

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Abstract

This paper deals with descriptions and evaluations of the Chemistry Olympiad program in the United States. The study isolates the factors that contribute or hinder the development of highly gifted individuals chemistry students. The Inventory of Parental Influence (IPI) was used to measure five family processes. The Self-Concept Attribute Attitude Scale (SaaS) measured the student's attribution level, and the Family Influence Scale and School Influence Scale measured the student's opinion of the importance of positive family influences and school hindrances on the development of one's talent. The results show that 49% of these Olympians earn doctorate degrees. In terms of productivity, the Olympians produced 778 publications, patents or soft-ware products. Several factors are shown to contribute to the development of the Olympians' talent. Hindrances experienced by the Olympians are discussed.

Introduction

Talented individuals are sought in the science and technical fields. Industrialized nations depend upon these career oriented people for economic growth. Guiding youngsters into these fields is one responsibility of educational establishment. In order to achieve this goal talented students must be identified at an early age and given the opportunity to expand their creative energies through specialized school programs. High schools offer advanced "college level" courses in Organic Chemistry, Inorganic Chemistry, and Biochemistry for this cohort of students. However, Welch, Harris and Anderson (1984) reported that only 0.7% of students enroll in such courses. In 1990, The College Board indicated that the number of advanced placement chemistry exam numbered 19,765, which was lower than for the biology exams but higher than the physics exams.

Longitudinal data collected during 1985-86 indicated that during grades 6-10 students' attitudes toward science decreased, yet the males had better attitudes than the females. Motivation also declined but in this case the females were more motivated (Simpson & Oliver, 1990). Although, the home and individual influences contribute to involvement in science courses, it is the school environment that furthers the student's interest in science (Simpson & Oliver, 1990).

The student's science self-concepts was the strongest predictor of science achievement and also predicted subsequent enrollment in the number and type of science courses taken. Students who in an early grade take advanced science courses are more likely to embark upon science research projects and compete in science fairs and contests (Lynch, 1990).

One way to encourage the early involvement of young people in the technical areas is to sponsor academic competitions in science and math. Academic contests were started in the 1930s in the USSR as a means of identifying the most gifted math and science students so that they could be encouraged to pursue careers in math, science, and engineering. America adopted similar initiatives in the 1940s and 1950s with the intention that these talented individuals would make contributions in a number of critically needed technical fields.

The assumption underlying these competitions is that young people needed to make early career decisions in order to accumulate the advanced training that is necessary. Studies of award-winning scientists (Roe, 1952) stressed the early commitment to research.

The three national competitions in the United states that are most prominent are the Intel Talent Search, formerly the Westinghouse Talent Search, the Junior Science and Humanities Symposium (JSHS) and the International Science and Engineering Fair. The students with the most highly developed research skills submit original research papers to these contests. Often, the Scholastic Aptitude Test (SAT) scores of this group exceeds 1300 (Campbell, 1991).

Description of the American Chemistry Olympiad Program

The same line of reasoning has led many countries around the world to sponsor academic contests as a way of identifying and developing their most talented science and math students. One of these international competitions is the Chemistry Olympiad. This competition began 1968 among European countries. The United States commenced participation in 1984. Over 20 countries send representatives to this competition. The students compete in written and laboratory examinations that include problems in analytical, organic, inorganic, physical and biochemistry. Points are awarded for each section of the competition by a panel of international judges. Students are ranked upon the total number of points they receive.

The selection of students begins at the local level. The local high schools select their best chemistry candidates. These candidates take an initial national-wide exam sponsored by the American Chemical Society. Based on the results of this examination, 20 students are invited to spend two weeks at a chemistry study camp at the Air Force Academy in Colorado Springs, in June. Four students are then selected from the camp participants to represent the United States in the International competition. In the sixteen years that the United States has participated, the competitors have won 15 gold medals, 26 silver medals, and 19 bronze medals. Included in these totals were the 1999 winning medalists. Of the 199 high school age competitors representing 51 countries, Lisa Carlivati won a silver medal, Alexander Ho and Wei Ho each won a gold medal, and Timothy Jones had the highest individual score in the competition earning him the top gold medal. Thus, the U.S. team finished first worldwide (American Chemical Society, 1999).

The goals of the United States National Chemistry Olympiad (USNCO) are multipurpose. USNCO views the program as a means of investing in the future of young chemists. The program is a way to stimulate all young people to achieve excellence in chemistry; to recognize and challenge the knowledge and skills of outstanding chemistry students; to recognize the achievement of the teachers of these students and the importance of the school environment in which they learn.

Theoretical Framework

Bloom (1986) posited that the home environment had significant effects on the level of student learning. The home environment exerts direct (Gyles, 1990; Song & Hattie, 1984) and indirect effects on the child's achievement (Keith, Reimers, Fehrmann, Potterbaum & Aubrey, 1986) Walberg (1984) expanded on Bloom's framework in his meta-analysis of studies dealing with these factors. Iverson and Walberg (1982) found that the sociopsychological environment and intellectual stimulation in the home are prominent in influencing academic ability and achievement. Walberg (1984) (see Figure 1) proposed a nine factor model in which he considers the home environment to be one of the major causal influences on student learning.

Campbell and his colleagues have enlarged Walberg's model by specifying a number of variables within some of his general factors. For example, in this study, the home environment factor includes: socio-economic status, the structure of the family (one or two parents) and several family processes. Other factors within this model are also expanded (ability, motivation, quality of instruction) (see Figure 2).

Walberg (1984) believes that family processes are one of the only alterable sets of home variables that can positively enhance achievement. These processes can be changed, thereby, affecting children's behavior. Within the past three decades the home environment has been identified as being a contributing factor in a child's educational and cognitive development. Campbell and Wu (1994) found children's academic achievement to be affected by specific family processes. Excessive amounts of parental pressure exerted on children, were found to be dysfunctional to achievement, whereas, support and high levels of exposure to intellectual resources were found to have positive effects.

The home environment and family processes provide a network of physical, social, and intellectual forces and factors which affect the student's learning. Schneider (1993) hypothesized that parental involvement can counteract the negative effects of low socioeconomic background and significantly improve students' performance. Parental involvement involves numerous family processes which in turn create opportunities for learning (Muller & Kerbow, 1993; Verna & Campbell, 1999).

Family processes also depend upon the number of parents in the home. One-parent families might use different family processes than two-parent families (Campbell, 1994). For example, in studying Japanese children, Campbell and Uto (1994) found that two-parent families had a positive direct effect on parental help, parental pressure, and on the intellectual resources available in the home. All of these variables affect children's achievement.

The objectives of the study were: 1. To ascertain if the Chemistry Olympians fulfill their high potential by determining the number of awards received, doctoral degrees earned, and their academic productivity. 2. To determine what factors helped or hindered the development of the extraordinary talent. 3. To determine the set of parental processes used. 4. To determine the Olympians' effort and ability attribution. 5. To discover the Olympians' and parents' evaluation of the Olympiad program.

Design and Procedures

Subjects

This study was conducted with United States high school Chemistry Olympians from the years 1984-1998. Since the inception of the United States participation in the Olympiad program there have been 300 Chemistry Olympians. However, once the Olympians go to college, and then to graduate school and beyond, they become increasingly difficult to find. Americans have a high rate of mobility and these Olympians relocate frequently. Consequently, our research team was able to derive 177 addresses where packets could be mailed. This number was reduced by 44 cases because the Olympian and or their parents had moved again without providing a forwarding address. Therefore, stable addresses were available for 133 Olympians.

Repeated mailings to the Chemistry Olympian resulted in responses from 93 (70%). There are 82 males and 11 females and 102 parents, (52 fathers and 50 mothers). The Olympians range in age from 16 to 34. Ninety-five percent of the Olympians were born in the United States. The ethnic composition of the students was 86% Caucasian and 14% Asian.

Operational Definitions

Chemistry Olympians: Students who were participants in the summer training chemistry camp, and those students who participated in the international competitions. Socioeconomic Status: This was a composite variable of father's education, mother's education, father's occupation, mother's occupation, and family income. Occupational status was defined operationally by assignment of a numerical value determined by the Nam-Powers Scale (1983). Each job has been assigned a social status score from 0 to 100.

Instrumentation and Methods

Each Olympian was asked to respond to the Self-Confidence Attribute Attitude Scale (Form O) (SaaS) (Campbell, 1994) which measures the student's attribution level. The SaaS contains 29 Likert scale items. A high score is achieved for the attribution scale if the student agrees or strongly agrees with such statements as: "You need a lot of ability in a subject to do well." and "If I studied enough, there was nothing I couldn't learn." Principal Components analyses produced two distinct scales, effort and ability. Olympians who viewed success as an outgrowth of effort received high scores on the effort scale. Those Olympians who linked ability as a reason for success received high scores on the ability scale.

Each student and his parents were asked to respond to the Family Influence Scale and the School Influence Scale (Campbell, 1996) which measures the student's opinion of the importance of positive family influences and school hindrances on the development of one's talent. The Family Influence Scale contains 14 Likert scale items and the School Influence Scale contains 11 Likert scale items. Principal Component factor analyses were conducted on these instruments. The Family Influence Scale items produced one factor which was labeled the conducive home factor.

The parents were asked to respond to the Inventory of Parental Influence (IPI) (Campbell, 1994). This instrument was designed to identify a family member's perception of selected family processes. The first two family processes (Part I) are measured by factor scales that have been developed from Likert statements (Parental Pressure, Parental Psychological Support). The respondents express their degree of agreement or disagreement with each statement (a. strongly disagree; b. disagree; c. uncertain; d. agree; e. strongly agree). Part II of the IPI contains the next three factor scales (Parental Help, Parental Press for Intellectual Development (resources), Parental Monitoring/Time Management). Each family member specifies how often each practice occurred (a. never; b. rarely; c. sometimes; d. usually; e. always).

To operationally understand the meaning of these scales, it is useful to examine some of the items that make up each scale. For example, a high score is achieved for the pressure scale (13 items) if the parent agrees or strongly agrees with such statements as: "My child was afraid to come home with a poor grade." "I was only pleased when my child got a 100% on a test." "I did not feel that my child did his/her best in school." All of these items suggest a demanding parent who exerts pressure to retain high levels of performance. For the support scale (13 items), the parent agrees or strongly agrees with these statements: "I was satisfied if I knew my child did his/her best." "I wanted my child to go to a good college." "I am proud of my child." These items suggest a psychologically-supportive atmosphere at home.

The press for intellectual development scale (9 items) measures how often the parent encourages the child to read books, buys books as presents, stresses the value of the local library and educational TV. Families with high scores on this scale emphasize the importance of intellectual resources.

The help scale (9 items) measures how often the parent went over mistakes from a test, helped with schoolwork, and helped the student before a test. The emphasis here is upon the parents giving the time that is needed to help the child complete the school work. The monitoring scale (8 items) determines if the family sets rules on the kind of TV watched, insists on setting aside time for reading, and requires the child to do his/her homework at the same time each night. Families with high scores for these two processes offer a great deal of help and have distinct rules about homework, studying, TV and reading. The elementary school control scale isolates how often the parents managed the child's school related activities during the elementary school years.

Validity/Reliability

The instruments used in this study were developed by a series of test administrations with international samples and with samples of different American ethnic groups. For each sample separate Principal Component analyses were calculated to isolate the factors. The final scales involve a synthesis of items which loaded on the different national and international analyses. These testings were done to construct instruments that could be used with cross-cultural and cross-national samples. Coefficient alpha reliability coefficients were calculated for each of the different scales: Reliabilities were: Student's perception family influences r=.95., school influences r= .90, ability attribution r=.93, effort attribution r=.96, parents' perceptions of parental pressure r=..99, parental psychological support r=.96, parental help r=.97, parental press for intellectual development r=.98, parental monitoring r=.98, family influences r=.96, school influences r=.98

Information regarding the parents' occupational and educational background, and family income was collected from both the parents and the Olympian. The Nam-Powers Scale (Nam & Powers, 1983) was used to convert the parents' occupational information into an interval scale. The parents' educational data, occupational status, and income comprised the composite variable of socioeconomic status.

Results and Discussion

Family Background

Forty percent of the Olympians were the first born children in families that averaged 1.5 children per family (see Table 1). Twenty-two percent were Protestants while 54% specified no religious preference. The socioeconomic status was higher than the average U.S. household. The average SES was 76.8 with a range of 20.4 to 97.8. The results of the questionnaires indicated that the Olympians owned a dictionary (69%), reference books (59%), an atlas (58%), an encyclopedia (55%), and had books that totaled more than 100 (84%) (see Table 2). While growing up half of the Olympians learned to play a musical instrument. Some of the students had the role model of a family member who won awards or was recognized for distinguished achievement.

School Background

Seventy-two percent of the Olympians attended public school and the remaining students attended religious private and non-religious private schools (see Table 3). T-test results indicated that there was a significant difference in general grade point average (GPA) between males and females. The females in the study had a higher GPA than the males. Thirty-six percent of the Chemistry Olympians were the valedictorians of their graduating class. The rank of students in their graduating class ranged from 1 to 47. The median high school size was 352 graduating students. Most of the students graduated at age of 17 or 18 but there were 7 students who graduated at age 16. During their high school careers the Olympians took advantage of the advanced placement (AP) courses. On the average they enrolled in 4 AP courses. The Scholastic Aptitude Test (SAT) scores for the verbal portion ranged from 520 to 800, and for the quantitative portion a range of 660 to 800, with 26 students receiving 800 (maximum score). Thirty-four students received 800 on the chemistry SAT. They also took part in extracurricular activities and participated in many competitions. The most popular competition was the National Merit Exam. Half the students received a scholarship in order to attend college.

College Life

The transition from high school to college was found to be easy for this population of students (see Table 4). The undergraduate colleges provided special programs or individualized programs for 16% of the Olympians, in addition, 33% received mentoring during those years. One fourth of the subjects found the transition from undergraduate school to graduate school to be easy. This may be due to the fact the one fourth of the Olympians had mentors during their graduate years. Of the Olympians surveyed, 60% have completed their undergraduate course of study. Forty-nine percent of the Chemistry Olympians have either received their doctorate degree or are currently enrolled in a doctorate program (35 Ph.D.; 9 MD; 1 Law) (3 have Ph.D. and MD degrees). Twenty-two students are now in full time employment.

Computer Literacy

The computer literacy of the Olympians varied (see Table 5). Fifty-nine Olympians indicated that they own either a PC or Macintosh computer, 68% have access to a mainframe, and 92% have e-mail accounts. They average 11 hours per week on the computer. Most of them use the computer for word processing, although, 71% of the Olympians work with Math/Statistical programs, spreadsheets and 92% use the internet. Half of the Olympians use the computer for games, while only a few work with graphic design and desktop publishing software. This data are far lower than that reported by Campbell (1996) for the Math Olympians but equaled that of the Taiwanese Math Olympians (Wu, 1996).

Characteristics of Achievement

Gender difference in science achievement was studied by Simpson and Oliver (1990). These researchers found, that although, males achieved higher scores and possessed a more positive attitude than females, the females were significantly more motivated to achieve in science. In this study, the Olympians expressed the view that effort is linked to ability as a reason for achievement. Although, they may have the necessary intellect to succeed, the Chemistry Olympians believe in working hard and employing self-discipline to their endeavors. There was a small significant difference between the males and females in the study with regard to ability. The females considered ability to be a more important factor for success than the males. There was no difference for the effort factor. This finding is opposite to Wu and Chen's (1999) findings of Taiwanese Chemistry and Physics Olympians. Wu's Asian population attributes their achievement more to effort than to ability.

Some Chemistry Olympians felt impaired by their school environment. Factor analysis of hindrance questions revealed two factors. One factor was labeled a lack of challenging environment. This factor included items that related to the teacher's lack of knowledge of subject matter and an inability to motivate these talented students. The second factor was labeled a confining environment. This factor included items that related to the flexibility of class work. The Chemistry Olympians viewed their classes as rigid, boring and almost “prison-like.”

To overcome this negative school situation, the home atmosphere offered positive influences. A significant difference was observed between the males and the females with regard to the conducive home atmosphere. The females viewed the home as a place of educational productivity more than the males. The females felt that the parents recognized their talent and provided more stimulation to foster the development of this talent. Parents provided books, magazines, and association with inspiring peers and relatives. Parents actively encouraged their children's success.

Academic Productivity

Overall the Chemistry Olympians have published 788 items including 28 computer software products; 170 presentations at conferences. The female Olympians produced more publications than the males.

The Olympiad Experience

The Olympians expressed their views on their Olympiad experience. Their experience in this competition had a more positive than negative impact on their lives. Although, one-third of the Olympians felt they would have succeeded without this experience, however, it did make them more aware of the educational opportunities available to them and helped them in accepting their talent.

Path Analysis

Two separate path analyses using Partial Least Square Path Analyses (PLSPath) (Sellin, 1983) were conducted. The first analysis used Scholastic Aptitude Test scores (SAT) as the endpoint; the second used the total number of publications as the endpoint. Three exogenous variables were specified (gender, family structure, SES) together with seven endogenous latent variables (positive home influences – including degree of help provided and the number of resources available [Pos1]; level of psychological support [pos2]; negative home influences – parental pressure and monitoring [Neg]; school hindrances [Spii]; prior achievement [AA]; computer literacy [Comp]; effort attributions [Eff]. For these analysis, the order of variables and factors in the path model was determined by three criteria: time, logic, and previous research (Campbell, 1997).

The PLSPath program includes Jackknife procedures that omitt one case at a time (blindfold) and re-estimate the model parameters on the remaining cases. The output included Jackknife standard errors and R^2 values. Direct and indirect influences were determined by the path analyses. The significance of the path coefficients was determined with a formula developed by Keeves (1996).

In all, 48 paths were tested in these analyses. For the SAT path analysis the only significant direct effect was for SES. High SES Olympians had higher scores (.32). However, for the total publications path analysis there were several significant paths (see Figure 3). In this diagram the dotted lines indicate negative results and solid lines represent positive path coefficients.

There were two significant direct paths on productivity. One involved computer literacy (.41) and the second concerned negative home influences (-.22). Those Olympians with higher computer literacy had more publications. Furthermore, those Olympians coming from homes with low levels of pressure and monitoring went on to be more productive in their careers.

Gender had a significant total effect on productivity by having strong effects on computer literacy and effort attributions. The females had higher computer literacy and more of a belief that effort was important for their success. They also produced more publications.

Conclusion

The Chemistry Olympiad program is one of several academic competitions held yearly in the United States. Our analysis indicates that this program does succeed in adding scientists to the technical workforce in the United States. We believe that more academic competitions should be initiated to expand this objective.

Finally, the gender findings show that females can pursue careers in technical areas and become productive. Further follow-up studies (perhaps qualitative studies) should be done to determine the factors that are responsible for the female Chemistry Olympian’s enhanced scholarly productivity. Such studies might uncover important ways to encourage females to excel in the technical areas. This information could be useful in diversifying the technical workforce in the United States.

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Table 1

Family Background of Chemistry Olympians in the United States

Family Size	Birth Order	
1. 5 children/family	only child	36%
	1 st child	40%
	2nd child	19%
	other	5%

Religious Preference	Olympian	Parent
No preference	54%	9%
Protestant	22%	17%
Jewish	9%	11%
Roman Catholic	6%	8%
Other	9%	8%
No response		47%

SES (Family Income + Father's Occupation + Mother's Occupation + Father's Education + Mother's Education)

Mean = 76.81 SD = 12.65 Range = 20.4 to 97.8

Olympians Who Played Musical Instruments 52%

Parents or Relatives Who Won Awards 22%

Parents or Relatives with Distinguished Honors 12%

Table 2

Socioeconomic Resources of Chemistry Olympian Families in the United States

Number of Books in the Home

0-9	2%
10-24	`3%
25-99	8%
100-249	18%
over 250	66%
No response	3%

Type of Resource Books

	Olympian	Parent
Reference	59%	50%
Encyclopedia	55%	45%
Atlas	58%	50%
Dictionary	69%	53%

Table 3

School Backaround of Chemistry Olympians in the United States

Type of School Attended		Most Influential Person	
Public	72%	Parent	44%
Private Religious	6%	Student Himself	28%
Private Non-Religious	22%	Teacher	10%
		Parent and Teacher	10%
		Parent and Student	8%

Age at High School Graduation		Top 10% in Graduating Class	
16 Years	11%	Valedictorian	36%
17 Years	43%	Second Place	6%
18 Years	46%	Top Ten	9%

Number of Advanced Placement Courses Taken

Mean = 4.22	SD = 3.44	Range = 2-13

Participation in Competitions

National Merit	54%
Westinghouse	10%
SMPY	9%
JSHS	2%
Scholarships Received	55%

	Mean		Range
	Male	Female	
General Grade Point Average	6.14	6.87	
SAT-V	698	745	520 to 800
SAT-M	747	780	660 to 800
SAT-Chemistry	793	693	500 to 800

Table 4

College Experience of Chemistry Olympians in the United States

Transition	High School to College	College to Graduate School
Easy	66%	55%
Average Transition	23%	10%
Difficult	11%	35%
College	Graduate School	
Mentored	33%	26%

Table 5

Computer Literacy of Chemistry Olympians in the United States

Own a Computer	63%
Access to Mainframe	68%

63%
68%

	Mean	Median	Range
Hours Per Week Using the Computer			
PC	11	15	2 to 80
Mainframe	5	2	1 to 30
Number of Computer Languages Known	3	2	1 to 12

Software Programs Used	Percent
Word Processing	95%
Internet	93%
Math/Statistical	71%
Spreadsheet	65%
Games	48%
Database	29%
Graphic Design	18%
Desk Top Publishing	17%
E-Mail Accounts	92%

Table 6

Means and Standard Deviations of the Study's Variables

Variable	Mean	Standard Deviation
Grade Point Average (GPA)	6.91	.38
Awards	1.91	.96
Extracurricular Activities	3.84	2.34
Advanced Placement Courses (AP)	5.96	1.61
Total SAT	1349.31	234.81
GRE Verbal	743.68	17.70
Parental Pressure	2.10	.43
Parental Support	4.48	.27
Parental Help	3.00	.52
Parental Monitoring	3.00	.57
Intellectual Resources	3.69	.41
School Hindrances	2.33	.84
Effort (EFF)	3.29	.45
Ability (ABIL)	2.98	.40
Failure Due to Lack of Effort (EFAIL)	3.37	.48
Success Due to Effort (ESUC)	3.17	.69
Success Due to Ability (ASUC)	2.96	.42
Socioeconomic Status (SES)	74.68	15.40
Total Publications	12.22	17.65