Myrna A. Whigham

GENDER-RELATED DIFFERENCES IN ENGINEERING STUDENTS

The following study compared academic achievement traits of men and women to determine why women are underrepresented in certain curricula, especially engineering. Math-related attitude and anxiety factors were examined via a questionnaire, and a number of ACT test scores were studied. The results may surprise some readers and should be of interest to all advisors working with science and/or engineering students, especially women students.

INTRODUCTION AND REVIEW OF THE LITERATURE

Women who choose engineering may be a unique group in that they have chosen a field in which they are underrepresented. However, little research data that is specific to engineering is available to confirm this. In an effort to explain why women are underrepresented in certain curricula, many variables have been examined. For example, it has been suggested that since math and physical sciences are an important and essential part of any engineering curriculum, attitude and anxiety factors toward these fields may result in underrepresentation of women in engineering. Empirical studies involving these variables provide conflicting results, with some authors reporting gender differences (Bleyer, 1980) and others reporting none (Warman, 1981). Thus, it is unclear whether anxiety and attitude factors related to math are more prevalent among women than men (Dreger and Aiken, 1957). No data are available to evaluate differences between women and men engineering students.

Whether or not women have skill deficits in math and science is contradictory in reported findings. Some report that skill levels of males and females were the same until puberty (Hilton and Berglund, 1974; Fennema and Carpenter, 1981), after which females did not compete as well. Males reportedly elected to take more math courses in high school (Pedro, Wolleat, Fennema, and Becker, 1981; Iker, 1980). Even when the number of math courses taken was controlled, there were still differences in ability reported by some (Fennema and Carpenter, 1981) and none by others (Stones, Beckmann, and Stephens, 1982). Thus, the literature did not support or refute the societal expectation that males are superior in mathematics achievement.

Research specific to engineering conducted at Purdue and Cornell indicated that women appear to be more academically qualified than men (Jagacinski and Lebold, 1981; Ott, 1976). More research specific to gender-related differences in engineering is needed.

Another variable that may explain the underrepresentation of women in engineering is the influence of teachers, advisors, counselors, and parents. These individuals have been shown to be influential in this nontraditional choice. Teachers have been cited as an important fat-

★ *MYRNA A. WHIGHAM is the Coordinator of Women's Programs in Science and Engineering, College of Engineering Administration and Academic Affairs Administration, at Iowa State University. She was formerly an academic advisor in the Freshman Engineering Department at Iowa State.*

tor in women students pursuing and achieving success in math (Becker, 1981; Aiken, 1970; Ernest, 1976; Dutton, 1965; House, 1975), and subsequently being able to pursue careers similar to engineering. Also, parents are an important variable in why women choose engineering (Lebold, Linden, Jagacinski, and Shell, 1981; David, 1971; Ott, 1978a). Thus, one might infer that teachers and parents who do not offer a positive influence may be responsible for a portion of the underrepresentation.

PURPOSE OF THE STUDY

The purpose of this study was to answer the following three questions:

What are the academic achievement traits of female engineering students?
How do these traits compare to those of male students?
What are the attitude and anxiety factors toward math of female engineering students compared to male engineering students?

SUBJECTS

Data from two groups of subjects were used to address the questions listed above. Both groups were used to examine achievement, whereas, only the latter group was used to study attitude and anxiety factors toward math. The first group of subjects was comprised of 144 women and 150 men who were first semester engineering freshmen at Iowa State University during the fall semester of 1981. This represents all women engineering students and a random sample of 150 men from a population of 971 male engineering students.

The subjects used for achievement information as well as information relating to attitude and anxiety factors were 437 new students in engineering who were enrolled in two of the five sections of the Freshman Orientation class in fall of 1983 (n = 382 males and 50 females). For the most part, this group was comprised of first-time freshmen but some transfer students were enrolled. Transfer students were used in the study if they were still taking freshman level mathematics courses.

PROCEDURE

In order to address the question concerning academic achievement, the following variables were selected for analysis: sex, high school rank, ACT-English, ACT-Math, ACT-Social Studies, ACT-Natural Science, ACT-Composite score, math and science courses taken, math placement scores, and grades in various math courses. A questionnaire was developed to measure anxiety and attitudes toward math. This was done in order to determine how attitude and anxiety relate to the academic achievement factors mentioned above. In addition, questions asking for some of the academic achievement information that had been obtained with the 1981 group were also included on this questionnaire. This also provided an opportunity to assess the stability of the 1981 data.

INSTRUMENTS

A questionnaire (see Appendix—Math Questionnaire) was developed to address the questions to be answered. The first section of the questionnaire was academic achievement data. The academic achievement data were used to ascertain if these academic traits were related to attitude and anxiety factors.

In the section on academic achievement, students were asked to provide math placement test scores received on two of five math placement tests (based on extent of high school background) taken during summer orientation. The five tests were three algebra tests (AA, AB, AC) of increasing difficulty levels, trigonometry, and calculus.

Students were also asked to report Math ACT and Composite ACT scores, high school rank, math course currently enrolled in, and accurate placement in math course (students may elect not to follow advisor's recommendation). At the end of the semester when grades were available, grade received was added to the data and other academic information was verified from available student records.

Math (beginning algebra, intermediate algebra, advanced algebra, trigonometry, calculus), science (biology, chemistry, physics), and computer science classes taken in high school were also requested. This information was self-reported and not verified by existing student records.

In addition to the descriptive data, part two of the questionnaire was designed to measure attitude and anxiety factors primarily toward math. The attitude factors measured were confidence (A'ITCONF), usefulness of math (A'ITUSE), attitude of mother (ATTMOTH), attitude of father (ATTFATH), effectance motivation (A'ITEFFM), attitude of teachers (ATTTEAC), attitude of math as a male domain (ATTDOM), and attitude toward success (A'ITSUCC). The anxiety factors were all grouped under one category (ANXIETY). The items comprising each factor are shown on the sample questionnaire (see Appendix—Math Questionnaire). The questionnaire used was formulated by combining ideas gained from reviewing the Fennema-Sherman Mathematics Attitude Scale (Fennema and Sherman, 1976), Dutton's Attitude Scale (Dutton, 1954), and MARS, Math Anxiety Rating Scale (Richardson & Suinn, 1972), and the anxiety scale used by Betz (1978) of Ohio State University. In order to address the issue of content validity, the items were reviewed for reasonableness and accuracy by a panel of faculty.

DATA ANALYSIS

The SPSSX, Statistical Package for the Social Sciences, was used to analyze the data. The SPSSX Reliability program (Cronbach's coefficient alpha) was used to calculate the reliability of the factors measuring attitude and anxiety. When a factor has high reliability, it is assumed that all of the statements in the questionnaire relating to that factor are measuring the same characteristic. Frequencies were calculated for each variable. The t-tests for statistical significance were calculated for each variable (academic achievement data and anxiety and attitude factors) for males vs. females.

RESULTS

Academic Achievement of Students

Male and female engineering students in two separate data sets were compared in terms of high school rank, number of math courses taken in high school, number of science courses taken in high school, ACT scores, grade in first college math course, and cumulative grade points. High school rank (percentile) for the women engineering students was significantly higher than the rank of the male students for both sets of data. The mean rank for male students entering fall of 1981 was 18.15 and the mean rank for women was 11.05, t (281) = 5.11, $p \leq .000$. For fall of 1983, the means were 17.88 and 7.76, respectively, t (105) = 8.05, $p \leq .000$.

In terms of ACT, comparisons were made for two data sets. One included a breakdown of all ACT scores (fall 1981 data), while the other (fall 1983 data) included only the math and composite ACT score (see Table 1). In neither data set did men and women differ on composite score (1981: t (263) = 1.67; 1983: t (64) = 1.11) or on the Math subtest (1981: t(249) = 1.71; 1983: t(367) = .25). However, the men and women represented in the 1981 data set did differ on Social Studies, t(263) = 2.21, $p \leq 0.28$, and English, t(262) = 5.54, $p \leq .000$. No difference was noted in the subtest score for Natural Science, t (263) = .39.

TABLE 1. Comparisons of ACT Scores for Men and Women Engineering Students (1981 and 1983 data sets)

Variable	Statistic	Men	Women
ACT Composite (1981 Data)	Mean	25.10	25.90
	Std. Dev.	3.79	4.05
	n	135.	130.
ACT Composite (1983 Data)	Mean	25.43	26.
	Std. Dev.	3.96	3.06
	n	326.	44.
Math ACT (1981 Data)	Mean	27.56	26.56
	Std. Dev.	4.27	5.14
	n	135.	129.
Math ACT (1983 Data)	Mean	27.65	27.45
	Std. Dev.	4.47	3.86
	n	325.	44.
Social Studies ACT (1981 Data)	Mean	23.16	24.75*
	Std. Dev.	6.	5.77
	n	135.	130.
English ACT (1981 Data)	Mean	20.90	23.63**
	Std. Dev.	4.14	3.86
	n	135.	129.
Natural Science ACT (1981 Data)	Mean	28.21	28.
	Std. Dev.	4.64	4.
	n	135.	130.

** $p \leq .01$.
* $p \leq .05$.

Thus, while the composite scores indicated no differences, individual scores indicated that women appeared to fit the societal expectation of performing better in Social Studies and English than the males. Even though high school ranks were higher for the women on both of these samples, this difference in ability levels was not reflected in higher ACT math or composite scores. This particular performance measure (ACT) indicated the men and women were generally at the same achievement level on entering the engineering college.

The number of math and science courses taken in high school was obtained from the students entering fall 1983. Students were asked to check courses they had taken from a list of available math and science classes (see Appendix—Math Questionnaire). The women had taken more science classes ($M = 3.38$) than the men ($M = 3.12$), $t(75) = 2.37$, $p \leq .021$. The women also had taken more math classes ($M = 5.16$) than the men ($M = 4.76$), $t(77) = 3.14$, $p \leq .002$. However, when analyzing performance measures at the college level, no significant differences were observed. Men ($M = 2.06$) and women ($M = 2.25$) were not significantly

different in grade in their first college math course as measured on the traditional four-point grading scale, t (407) = 1.03. Cumulative grade point average after four semesters also indicated no significant differences for the men (M = 2.63) and women (M = 2.56), t (217) = .97. The fact that women had more math and science courses in high school appeared to have no relationship to certain performance measures at the college level.

Another performance measure available on entering students was the scores on the math placement tests (see Table 2). Students take two of five exams based on high school math courses completed. The five exams include 20 problems and are of increasing difficulty levels as follows: Algebra A, Algebra B, Algebra C, Trigonometry, and Calculus. No significant differences were noted between the men and women on any of the five tests given (AA: t (11) = .77, AB: t (115) = 1.03, AC: t (236)) = .36, TRIG: t (175) = .57, CA: t (44) = .26). Thus, the men and women were performing at the same level on these exams even though other measures of high school background such as high school rank and number of math courses completed in high school indicated that the high school preparation of the women exceeded that of the men.

TABLE 2. Comparison of Average Scores of Men and Women on Math Placement Test Scores. (Total number items = 20)

Variable	Statistic	Men	Women
Algebra A	Mean	9.44	7.0
	Std. Dev.	5.41	4.90
	n	9.	4.
Algebra B	Mean	11.38	12.07
	Std. Dev.	3.73	3.51
	n	63.	54.
Algebra C	Mean	8.03	8.21
	Std. Dev.	3.86	3.67
	n	123.	115.
Trigonometry	Mean	8.30	8.61
	Std. Dev.	3.44	3.78
	n	88.	89.
Calculus	Mean	10.00	9.65
	Std. Dev.	5.26	3.91
	n	20.	26.

Attitude and Anxiety Factors

In addition to achievement data, this experiment was designed to measure attitude and anxiety factors towards math. Students participating in this study were asked to respond to a set of statements relating to math confidence and anxiety, using a five-point scale (5 = strongly agree, 4 = agree, 3 = uncertain/undecided, 2 = disagree, 1 = strongly disagree). Some of the items were phrased negatively (see Appendix—Math Questionnaire) but these items were recoded to agree with the others.

Attitude toward math was addressed by making statements regarding attitude in eight different areas: confidence in one's ability to perform in math (ATTCONF), encouragement and confidence in the student by the father (ATTFATH), the attitude of the student toward success in math (ATTSUCC), the encouragement and opinion of the student's teachers (ATTTEAC), the attitude of the students toward math as a male dominant area (ATTMDOM), the perceived usefulness of math (ATTUSE), and the motivation of the student to work on math problems (ATTEFFM). In each of the eight areas, several statements were made. These statements were then grouped for analysis purposes. Cronbach's alpha coefficient was utilized to estimate the reliability of each cluster of statements. The reliabilities were found to be .70, .75, .79, .41, .60, .75, .51, and .64 respectively for the eight areas. Since the attitude toward success cluster was not reliable, analyses were performed on individual items.

As can be seen on Table 3, all of the average attitude responses were at or above 3.65. Both means of the responses to the anxiety statements were above 3.5. Based on these positive responses, it appears that the students generally possessed positive attitudes and perhaps some anxiety regarding math.

Significant differences were found for three of the eight clusters measuring attitude. Attitude toward success indicated a more positive response by the women, $t(391) = 3.33$, $p \leq .001$. A breakdown of the attitude toward success items was made due to the low reliability of the items when clustered (see Table 4). Variables included the following: 1. happy to be regarded as an excellent math student, $t(428) = 1.53$, 2. being regarded as smart would be great, $t(58) = .68$, 3. would think I was some kind of a grind if I got A's, $t(401) = 2.74$ (recoded), 4. would like me less if I were really a good math student, $t(83) = 3.89$ (recoded). On the items that showed significant differences (3 and 4), the women believed more strongly than the men that getting A's would not make people think of them as grinds and that people would not think less of them if they were good students.

The attitude of the teachers as perceived by the students was also significantly different for men and women, $t(397) = 2.57$, $p \leq .010$. Women felt they were encouraged by their teachers more than were the males. The third area, the attitude of the students toward math as a male dominant area, also revealed a significant difference, $t(406) = 5.99$, $p \leq .000$. Although neither male nor female students agreed with statements representing math as a male dominant field, females were more strong in their disagreement than were the males. Attitude toward success, attitude of teachers, and attitude of students toward math as a male dominant field were the three attitude areas that indicated highly significant differences with the more positive response being given by the women in each of the three areas as indicated in Table 3.

On five of the eight attitude factors measured, no significant differences were found for males and females. Both the males and females indicated a high level of encouragement from their mother, $t(401) = .73$, and father, $t(399) = .81$. Confidence levels, $t(411) = .72$ and attitude about the usefulness of math, $t(410) = 1.78$ were also high for both groups. Effectance motivation to view a math problem as a challenge and to enjoy working on a problem until a solution was reached. There was no difference between the sexes on this variable,

TABLE 3. Average Scores for Men and Women on Attitude and Anxiety Towards Math Item Clusters

Variable[a]	Statistic	Men	Women
Confidence	Mean	4.10	4.03
	Std. Dev.	.59	.59
	n	364.	49.
Attitude of Mother	Mean	4.03	4.10
	Std. Dev.	.61	.64
	n	354.	49.
Attitude of Father	Mean	4.10	4.18
	Std. Dev.	.66	.61
	n	352.	49.
Attitude toward Success	Mean	4.17	4.43**
	Std. Dev.	.51	.49
	n	344.	49.
Attitude of Teacher	Mean	3.87	4.09**
	Std. Dev.	.55	.58
	n	350.	49.
Male Dominant Field	Mean	4.12	4.72**
	Std. Dev.	.68	.43
	n	359.	49.
Usefulness	Mean	4.49	4.61
	Std. Dev.	.47	.40
	n	363.	49.
Effectance Motivation	Mean	3.65	3.70
	Std. Dev.	.66	.58
	n	359.	49.
Anxiety	Mean	3.62	3.58
	Std. Dev.	.63	.62
	n	357.	49.

[a] **Variables Described in Appendix on Math Questionnaire.**

** $p \leq .01$.

TABLE 4. Average Scores for Men and Women on Attitude Toward Success Variables

Variable[a]	Statistic	Men	Women
	Mean	4.42	4.58
	Std. Dev.	.66	.64
	n	380.	50.
2	Mean	4.21	4.30
	Std. Dev.	.75	.93
	n	377.	50.
3**	Mean	3.64	4.10
	Std. Dev.	1.10	1.23
	n	354.	49.
4**	Mean	4.37	4.71
	Std. Dev.	.82	.54
	n	352.	49.

[a] Variables include the following: 1. It would make me happy to he recognized as an excellent student in mathematics. 2. Being regarded as smart in math would be a great thing. 3. People would think I was some kind of a grind if I got A's in math. (recoded) 4. It would make people like me less if I were a really good math student. (recoded) See Math Questionnaire in Appendix.

** $p \leq .01$.

$t(406) = .50$. Many attitude factors were similar when comparing males to this select group of women who have chosen engineering.

Anxiety was measured by a series of eight statements (see Appendix—Math Questionnaire). These statements referred to feelings of anxiety the students possess regarding taking major math tests, taking smaller math quizzes, asking questions in class, doing homework, and walking into a college math class for the first time. These statements were grouped for analysis purposes and indicated a reliability coefficient of .78 using Cronbach's alpha reliability coefficient.

As predicted, anxiety factors showed no differences by sex, $t(404) .42$, but the average score for this factor was noticeably lower than any of the attitude factors measured (see Table 3). These statements had an average score just beyond the uncertain/undecided range for both sexes. While frequency distributions indicated a spread of scores over the possible range of one to five, a small percentage (5.4) were definitely anxious (mean scores of 2.5 or less) and approximately half of the students (55.7%) reported not possessing feelings of anxiety (mean scores of more than 3.5) when asked to express feelings toward math. However, 38.9% of the average anxiety scores were in the uncertain/undecided range (2.51 to 3.50). Thus, anxiety toward math may be a problem experienced by many students.

Some additional questions were included to help clarify the high school experience. High school background items measured characteristics of the high school experience regarding math homework, courses, and teachers. Women showed a more positive response toward their high

school experience with mean scores of 4.21 and 4.39 for the men and women, respectively, $t(405) = 1.98$, $p \leq .049$. Statements regarding competency of high school math teachers, having math homework in high school, and taking advanced math classes in high school, showed that women in engineering may have experienced a more favorable high school experience than the males.

CONCLUSIONS AND RECOMMENDATIONS

In all the data analyzed for academic achievement, the women either ranked higher or were not statistically different. Academically, women were higher in high school rank, number of math courses taken in high school, number of science courses taken in high school, English ACT score, and Social Studies ACT score. There were no differences on performance measures on entering college or during the first semester. Neither were there differences on math placement test scores, grades in the first college math class, and cumulative grade-point average. While one might expect these performance measures to be higher due to the superior academic achievement prior to entering college, this expectation was not realized. Perhaps, the transition from high school to college was more difficult for women in this study. This appears to mark a point at which their academic achievement is no longer superior to their male peers. The transition point between high school and college in the academic career of women may be a time when special help is needed.

In regard to attitude toward math, some significant differences existed, with the women indicating a more positive attitude than the men. Women reported they were encouraged more by their teachers and women also had a more positive attitude toward success than men in the study. This supports the literature that indicates significant others have a very positive influence on choosing a nontraditional career such as engineering (Becker, 1981; Aiken, 1970; Ernest, 1976; Dutton, 1965; House, 1975; Casserly, 1980; Haven, 1972; Fox, 1977; Solano, 1977). Women engineering students also did not view math as a male domain area. The role of their high school teachers in instilling a positive attitude may be connected to this viewpoint. The finding that males more than females view math as a male domain suggests that subtle social pressures may exist at the college level that did not exist for these women at the high school level. Women may start to doubt their choice for the first time when they encounter males with these attitudes at the collegiate level. Moreover, the females who were subjected to this attitude at the high school level may have decided against a math-oriented curriculum while in high school. Thus, for many women, the attitude that math is a male domain may be encountered for the first time in college. Women in engineering also showed a more positive response to their high school experiences in general. This positive high school math experience may be the reason these women were in engineering. High school experiences, academic achievement, and attitude development appear to be important factors in selection of a nontraditional field for this select group of women.

Anxiety factors appear to be similar for men and women in engineering and the average scores for both groups were just beyond the uncertain/undecided range. Although the majority reported no anxiety toward math, many definitely considered themselves anxious or were uncertain about their feelings. Thus anxiety may be an academic problem for them. Additional help may be needed for many students, male and female, to reduce anxiety feelings toward math.

Appendix—Math Questionnaire

PART 1 DESCRIPTIVE DATA

NAME _____ SOC. SEC.# _____ AGE ON 9/1/83 ____ MALE OR FEMALE ___ WHITE OR NONWHITE ____
MATH ACT _____ COMPOSITE ACT ____ HIGH SCHOOL RANK _____ MATH COURSE OR COURSES CURRENTLY ENROLLED IN _____
GRADE RECEIVED ___ MATH PLACEMENT SCORE: AA _____ AB _____ AC _____ TRIG ___ CALC —ACCURATE PLACEMENT _____
Indicate- whether you took the following courses in secondary school. Mark yes or no. Beginning algebra _____
Intermediate Algebra _____ Geometry Trigonometry _____ Analytic Geometry ___ Calculus _____ Biology _____
Chemistry _____ Physics _____ Computer Science _____

PART 2 READ THE FOLLOWING STATEMENTS. THERE ARE NO RIGHT OR WRONG ANSWERS. MARK EACH STATEMENT AS FOLMWS:

Strongly Agree - Mark 5 Agree - 4 Uncertain/Undecided - 3 Disagree - 2 Strongly Disagree - 1

ATTCONE	1. I am sure I could do advanced work in mathematics.
ATTMOTH	2. My mother thinks I'm the kind of person who could do well in mathematics.
ATI'FATH	3. My father has strongly encouraged me to do well in mathematics.
ATTSUCC	4. It would make me happy to be recognized as an excellent student in mathematics.
ATTTEACH	5. My teachers have encouraged me to study more mathematics.
ATTMDOM	6. Females are as good as males in mathematics.
ATTUSE	7. I'll need mathematics for my future work.
ANXIETY	8. Math doesn't scare me at all.
ATTEFFM	9. When a math problem arises that 1 can't immediately solve, I stick with it until I have the solution
ATTCONF	10. 1 can get good grades in mathematics.
ATI'MOTH	11. My mother has strongly encouraged me to do well in mathematics.
ATI'FATH	12. My father thinks 1'11 need mathematics for what I want to do after I graduate from high school.
ATI'SUCC	13. Being regarded as smart in mathematics would be a great thing.
ATTTEAC	14. Math teachers have made me feel I have the ability to go on in mathematics.
ATTMDOM	15. Studying mathematics is just as appropriate for women as for men.
ATTUSE	16. 1 study mathemalics because I know how useful it is.
ANXIETY	17. 1 haven't usually worried about being able to solve math problems.
ATTEFFM	18. I am challenged by math problems I can't understand immediately.
ATI'CONF	19. I'm no good in math.
ATTMOTH	20. My mother thinks I'll need mathematics for what I want to do after I graduate from high school.
ATI'FATH	21. My father thinks I'm the kind of person who could do well in mathematics.
ATTSUCC	22. People would think I was some kind of a grind if I got A's in math.
ATTTEAC	23. My guidance counselor would encourage me to take all the math I can.
ATTDOM	24. I would have more faith in the answer for a math problem solved by a man than a woman.
ATTUSE	25. I see mathematics as a subject I will rarely use in my daily life as an adult.
ANXIETY	26. I almost never have gotten shook up during a major math test.
A'ITEFFM	27. I would rather have someone give me the solution to a difficult math problem than to have to work it out for myself.
ATTCONF	28. For some reason even though I study, math seems unusually hard for me.
A'ITMOTH	29. My mother wouldn't encourage me to plan a career which involves math.
ATTFATH	30. My father wouldn't encourage me to plan a career which involves math.
ATTSUCC	31. It would make people like me less if I were a really good math student.
ATTTEAC	32. I have found it hard to win the respect of math teachers.
ATTMDOM	33. Girls who enjoy studying math are a bit peculiar.
ATI'USE	34. In terms of my adult life it is not important for me to do well in mathematics in college.
ANXIETY	35. I usually have been at ease during small weekly math quizzes.
ATTEFFM	36. I think mathematics is the most enjoyable subject I have taken.
ATTTEAC	37. My teachers would think I wasn't serious if I told them I was interested in a career in science and mathematics.
ANXIETY	38. Mathematics homework usually makes me feel uncomfortable and nervous.
H.S. BACK	39. Overall, I had good math teachers in high school.

ANXIETY 40. I get a sinking feeling when I think of asking questions in math class.
H.S. BACK 41. I usually had homework in math in high school.
ANXIETY 42. My mind goes blank and I am unable to think clearly when working mathematics.
H.S. BACK 43. I avoided taking some advanced math classes in high school because I didn't want to lower my grade point average.
ANXIETY 44. Walking into a college math class the first time would scare me.

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