The Women and Mathematics Program: A Preliminary Statistical Evaluation

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This paper describes preliminary analyses of a pilot study designed to evaluate the effectiveness of the Women and Mathematics program. WAM, an acronym for Women and Mathematics, is a secondary school lectureship program sponsored by the Mathematical Association of America under a grant from IBM. Since math is a "critical filter" to many careers, the purpose of WAM is to interest high school 10th graders, women in particular, in studying more math by providing role models, and to acquaint counselors and teachers with career opportunities open to students with good math backgrounds (MAA, 1976 and Ernest, 1976).

The evaluation that will be described is a first attempt at determining if WAM lectures had any short-term effect on attitudes toward math and sex roles in math-related fields.

The study was conducted in two New Jersey cities, chosen not only because of their different demographic characteristics but also because of our own connections within the school systems. The first city is a large urban center with 260,000 people according to the 1970 census and has five public high schools. The other, a suburban city, has 24,000 people with only one public high school. The urban city has a median income of $9,000; the suburban city's median income is $18,000. The median education level of an adult in the urban city is 10th grade — less than a high school degree. In the suburban city the median is "some college."

The 10th graders (males and females) in each public high school were divided into two groups. One group heard a WAM lecture; the other did not. This division had to be done within the confines of the school schedule, so as to cause minimal disruption to the existing classes. An attempt was made to get the same range of math ability and background in both groups.

A questionnaire was given to all 10th graders about two weeks after the experimental group heard the lecture. The student questionnaire contained three sections:

(1) Demographics: This included what courses each student had taken, the student's grade point average, parents' occupations and schooling, and the student's future plans.

(2) Career awareness questions: The students evaluated the usefulness of math to eight careers. The following depicts a part of the questionnaire exemplifying these questions:

Career	How useful are advanced math skills?
economist	nu |___|___|___|___| eu
lawyer	nu |___|___|___|___| eu

where nu = not useful
eu = extremely useful

(3) 24 attitude statements: The student indicated his/her agreement-disagreement to statements concerning confidence towards math, usefulness of math, teachers'-parents' influence, and perception of math as a male domain. These statements were extracted mainly from a study by Fennema and Sherman (1976). The following are two examples:

	sa	a	u	d	sd
Taking math is a waste of time.	|	|	|	|	|
Most girls I know are not very good in math.	|	|	|	|	|

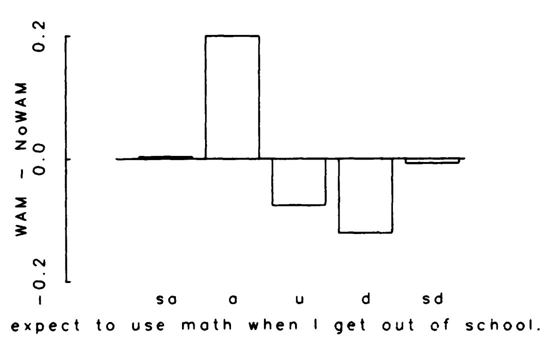
where sa = strongly agree
a = agree
u = uncertain
d = disagree
sd = strongly disagree

Also, a representative of the school was asked to fill out a form about the make-up and characteristics of the school population, the history of enrollment by sex in each of the upper level math courses for the current and previous three years, and the standardized testing that is given to the students and the availability of these scores for our use.

The analyses that are reported here are preliminary because only two of the tested schools have been analyzed and because of the pilot nature of the study. Results are from two of the schools — one from each city. The sample sizes were 236 in the urban school and 339 in the suburban school. The urban school is larger but absenteeism was a problem there.

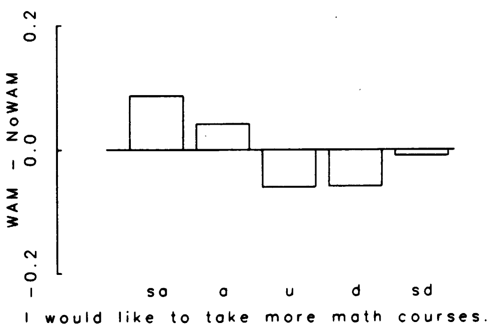
The first step of the analysis involved looking at each of the attitude and career awareness responses individually at each school to see if there was any effect from hearing a WAM lecture. For each statement the χ^2 statistic to test for independence in two-way tables was calculated to check if there was a statistically significant difference between WAM and no-WAM responses. In this case we have a 2×5 table: WAM or no-WAM vs. five possible responses to each statement or question.

Figure 1
Urban School



For example, consider the statement: "I expect to use math when I get out of school." For the urban school there is a significant difference between WAM and no-WAM response at the 2% level. Figure 1 gives a way of looking at the responses to see how the WAM answers differ from the no-WAM answers. The figure depicts a bar graph of the difference between the proportion of WAM and the proportion of no-WAM students giving a certain response. Each bar represents one of the five possible responses — sa, a, u, d, sd. For example, seven-tenths of the WAM group responded "agree" to the statement. Only one-half of the no-WAM group responded "agree." The difference between the two proportions is .2 as seen in Figure 1. This shift towards agreement and away from disagreement (the negative bars at "u" and "d") suggests that the WAM talks may be adjusting student attitude in the urban school towards usefulness of math. Interpretation of this effect requires the raw bar charts of the no-WAM responses, which measures the attitude of the students before a WAM visit, in conjunction with Figure 1.

Figure 2
Urban School



For the statement, "I would like to take more math courses," the χ^2 test says that the two groups at the urban school are not significantly different. However, Figure 2 shows a shift which is systematic — proportionately more WAM respondents agree or strongly agree with this statement. Unfortunately the χ^2 test ignores the order of the categories which is important here; hence these difference bar graphs are necessary. After inspecting these χ^2 results, it is evident that in future analyses a test which looks for systematic trends would be more appropriate.

Figure 3
Suburban School

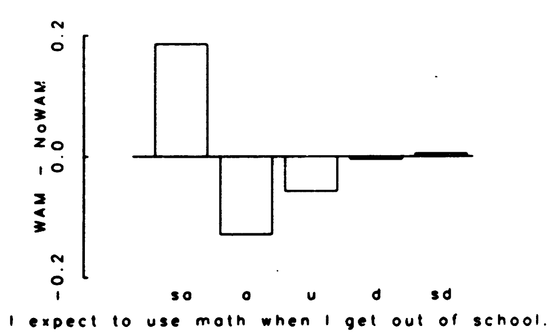
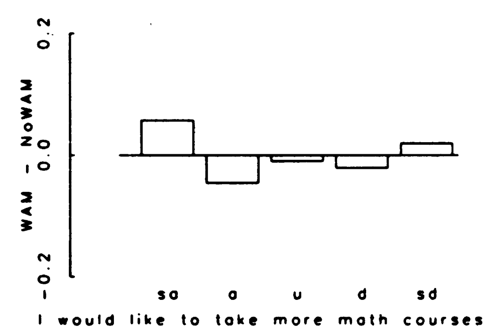


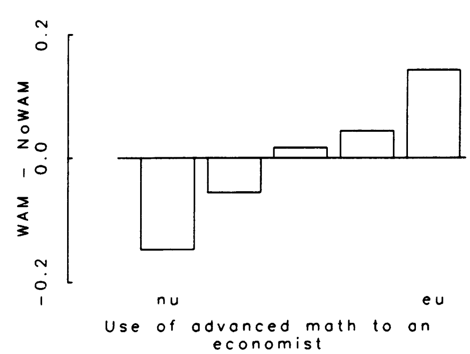
Figure 4
Suburban School



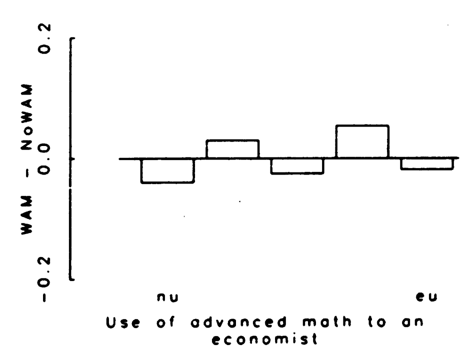
Inspecting the same questions for the suburban, more affluent school district, we find a significant WAM effect at the 1% level for the first statement (Figure 3). Here the shift is more from "uncertain" and "agree" for the no-WAM group to strongly agree for WAM. Looking at the second statement (Figure 4), not only is there no significant difference but also there is no distinct pattern seen. It could be that no WAM effect is evident because most of the suburban students already had intended to take more math. However, this was not the case. 54% of the no-WAM group responded uncertain to strongly disagree.

Summarizing the results of all 24 attitude statements, a WAM effect was found for about one-half of the statements in the urban city school. This was not true in the suburban school where little WAM effect was seen.

Figure 5
Urban School



Suburban School



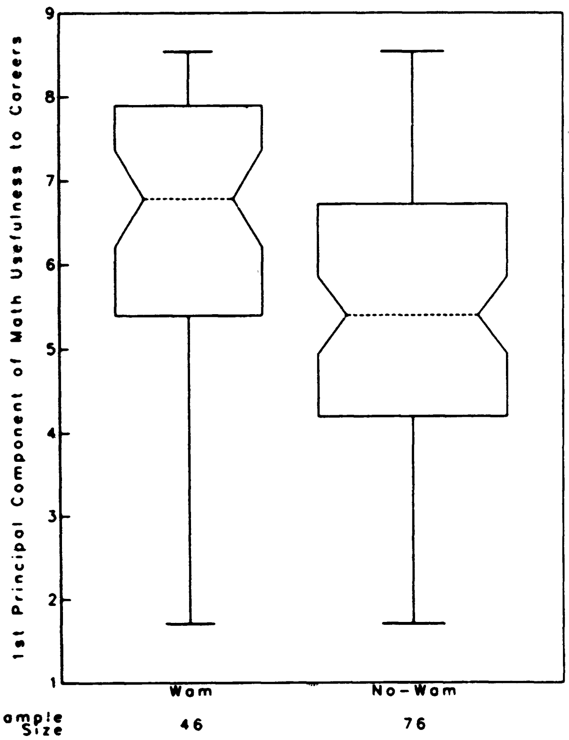
The second section of the questionnaire contained a list of eight careers. The students were asked to evaluate the usefulness of math to each career. Figure 5 exemplifies the responses at both schools regarding usefulness of math to an economist — the scale now ranges from not useful to extremely useful. In both schools the χ^2 test shows a significant WAM effect at an

11% level. After eliminating the nonrespondents, the suburban school had a much larger sample answering this statement; hence, smaller differences were judged significant. However, inspection of the difference bar graph shows that the suburban school's large χ^2 value is due to randomly ordered differences and thus is not impressive for our purposes. However, the top difference bar graph (the urban school) does show a distinctive pattern — a larger proportion of those hearing the WAM lecture thought that math was useful to an economist. For the urban school, patterns somewhat similar to this one were seen for all eight careers with varying levels of significance. In the suburban school only two careers showed a pattern in favor of a positive WAM effect.

We have just described some of the univariate methods used to inspect this data. It is very voluminous to summarize results in this fashion and these methods do not take account of interresponse correlations. Perhaps it might be better to summarize each student's impression of the importance of mathematics to various careers as a linear combination of their responses to the eight careers. The advantage of such a measure is that it is more continuous and thus more types of analyses are applicable. Also, it focuses more generally on career awareness than on a specific career.

To detect a WAM effect the choice of linear combination should be that which best discriminates between the WAM and no-WAM mean vectors — the discriminant axis. However, in doing some general exploratory analysis of the urban school data, the direction accounting for the greatest variability of all eight career responses — the 1st principal axis — was used to inspect for WAM and the many other possible differences (e.g., sex, attitude towards math, parents' occupations, etc.) simultaneously. It proved to be of interest from the WAM and no-WAM viewpoint. The data for students in one particular school who answered all eight questions are projected onto this axis. Next, the students were grouped first by WAM and no-WAM, and then boxplots were used to compare how the distribution of the measures varied between WAM and no-WAM.

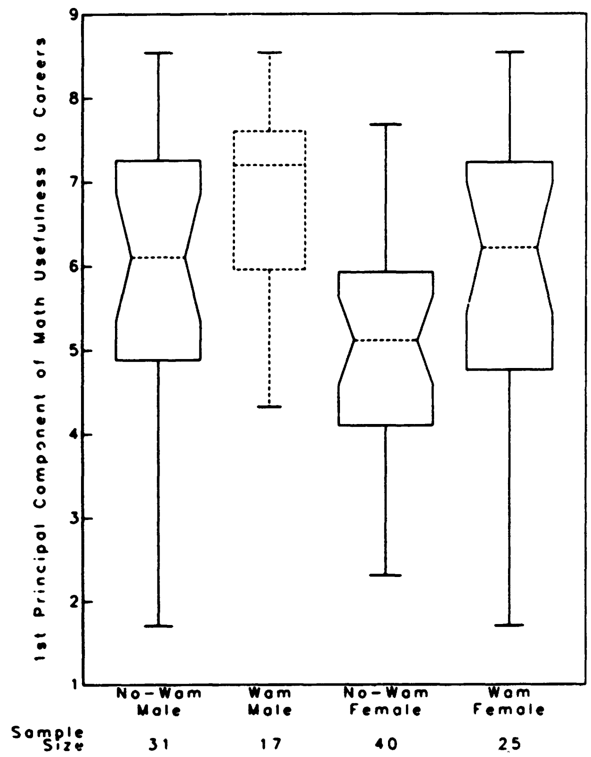
Figure 6
Urban School



A boxplot (McGill et al., 1977) is a summary of the distribution of a sample displayed graphically as seen in Figure 6. The quartiles define the upper and lower edges of the box. The lines out of the box extend to the upper and lower extremes of the data set. The dashed line through the middle of the box indicates the median. The width of the box is proportional to the square root of the sample size of the data set. When comparing two or more independent data sets, upper and lower notches are added to each box which are defined so that if the notches of two boxes overlap, the medians are insignificantly different at approximately the 5% level.

Figure 6 depicts the boxplots for the urban students' usefulness responses to the eight careers projected onto the first principal axis. Note that the WAM median is above the no-WAM median and the notches do not overlap. This suggests that the two groups are different. Since the direction is data determined from the combined groups, the notches may be too small for a test of significance at the 5% level. The coefficients of the eigenvector which defines the linear combination are all positive supporting that the WAM group generally perceives math as more useful.

Figure 7
Urban School

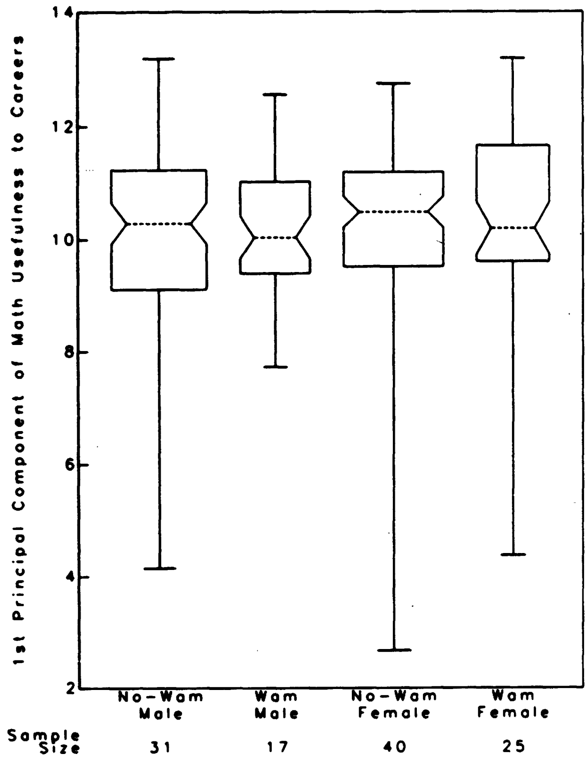


The WAM audience was composed of both sexes. So perhaps this significant difference was due solely to effects on the male respondents, with no effect on the females. Hence the students were regrouped, separating males and females. Students who did not indicate their sex were eliminated. Now there are four sample distributions — corresponding to no-WAM males, WAM males, no-WAM females, and WAM females — as shown in Figure 7.

The WAM female median is higher than the no-WAM female median. The sample sizes, which are indicated on the figure, are quite small and the enlarged notches now overlap slightly.

The same conclusion can be drawn from the two male groups. The dashed box indicates that the notches for the WAM males are so wide, due to the small sample size, that they extend beyond at least one quartile.

Figure 8
Suburban School

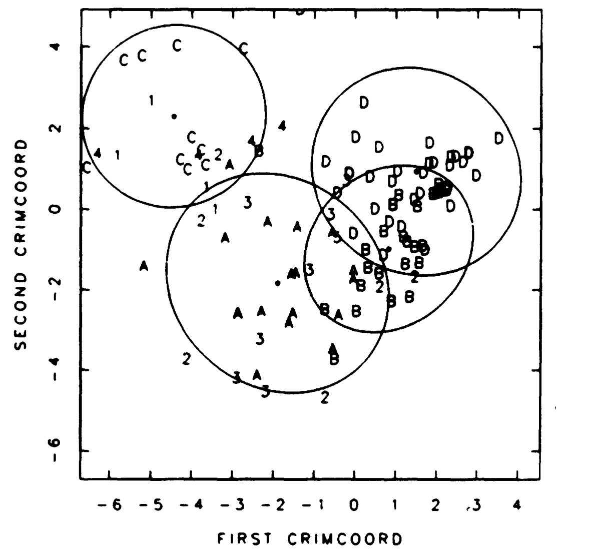


Figures 6 and 7 suggest that a WAM talk increases awareness of the importance of math to careers for both sexes in the urban school. However, Figure 8 shows that when using the same procedure in the suburban school no such effect was found. All four medians are about the same. Since the coefficients of the suburban school's principal axis differ from those of the urban school, direct comparison between Figures 7 and 8 cannot be made. Though no WAM effect is seen here, projection along the first discriminant axis did uncover an effect.

Finally, we demonstrate another multivariate approach for analyzing this data. Perhaps there is a natural grouping of students suggested by their responses which may have some interesting interpretation. Again, focus is on the eight responses regarding the importance of math to careers using the urban school as it has proved to show the greatest WAM effect thus far. To find this natural grouping hierarchical clustering (Johnson, 1967) was used on all urban students in the eight dimensional space without regard to WAM or sex. The focus of the discussion will be on the display and interpretation of the clusters.

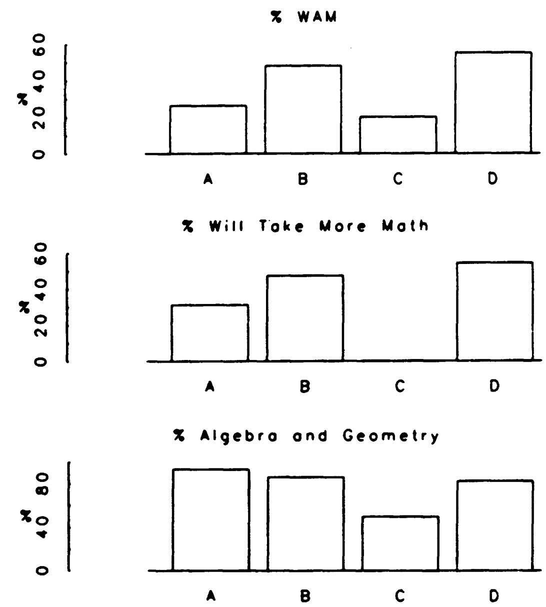
Four main clusters (A,B,C,D) and five smaller clusters (1,2,3,4,5) with fewer than eight students in each were found. In order to display and evaluate how well separated the four larger clusters are, a graphical technique suggested by Fowlkes and McRae (1977) was used. Figure 9 shows a scatter plot of all the students responding to all eight careers as plotted in the two-dimensional space which best shows the separation between the clusters — the first two discriminant coordinates. That is, the X-axis is the direction which most greatly separates the mean vectors of the clusters relative to the within group separation. The Y-axis is the direction which gives the next greatest separation of cluster means relative to the within group separation such that the projected data on the two axes are uncorrelated. The cluster sizes and individual cluster covariance structures are used to determine these directions. The ellipses, which correspond to the four large clusters, are centered at the cluster means and are scaled so that about 90% of the corresponding cluster is expected to be inside the ellipse.

Figure 9
1st Two Discriminant Coordinants
for Math Usefulness Perceptions



In this two dimensional space clusters B and D do not seem very different, whereas A and especially C are separated from the others and from each other.

Figure 10
Urban School



Next we attempted to see if there was a relationship between these clusters and any of the demographic variables. Figure 10 indicates the three demographic variables which did seem to discriminate among clusters. In Figure 10a each bar represents the percentage of WAM respondents in the corresponding cluster. Clusters B and D have a high WAM percentage — 1/2 are WAM where only 1/3 of the total population is WAM. The other two clusters, A and C, have fewer WAM respondents than the average. Figure 10b shows that the two high WAM clusters (B and D) also have a higher percentage of students who want to take more math than in the high no-WAM clusters. This is very encouraging, though not conclusive. Finally, from Figure 10c, it is seen that cluster C, which is located at the top of Figure 9, can be differentiated from the other three clusters in that fewer of its members were taking algebra and geometry. There is no noticeable difference between clusters in terms of any other demographic variables.

Summarizing Figure 9, clusters B and D are predominantly WAM and also contain more students who want to take more math. It is encouraging that this interest in math is confounded with the WAM effect. Clusters A, B and D have a larger percentage of algebra and geometry students than cluster C.

In summary,

(1) Indications of a WAM effect were seen in the urban school.

(2) Only slight evidence of a WAM effect was found in the suburban school. In analyses not discussed above, male and female responses to the math-as-a-male-domain statements were significantly different. Further study is warranted to determine if this is masking a slight WAM effect.

(3) Only two of the schools visited have been analyzed. Consequently caution must be exercised in considering these preliminary results.

Clearly, as many questions have been raised as answered by this analysis. Additional work is in progress.

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