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ABSTRACT

Research findings that indicate the need for greater integration in the development of verbal and mathematical skills for college technical majors are presented in this paper. Although the project discussed was originally designed to isolate language-related difficulties that affect mathematical skills among bilingual Hispanic students, some problems shared by mainstream students were also uncovered. The tests used were designed to demonstrate the effect of verbal skills on logical ability and algebraic problem-solving ability. Patterns of thought manifested in the results of the written exams were then pursued further through clinical interviews. It is stressed that extant programs aimed at the preparation of minorities for technical education at college fall short by not including language skills as an integral part of the program. Such an integrated program, it is suggested, would enhance students' problem-solving performances. The tabulated results of the exams are appended. (RDN)

Technical Education Today: The Need for a Greater Emphasis on Verbal Skills and Their Relation to Successful Problem Solving *

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Technical Education Today:
The Need for a Greater Emphasis on Verbal Skills and Their Relation to Successful Problem Solving

INTRODUCTION

For the past two and one-half years, we have been attempting to identify any specifically language-related difficulties which might hinder the academic progress of bilingual Hispanic technical students at the college level. Our research effort was one of the first funded as a result of the change in emphasis from the recruitment to the retention of minority students in college programs. Although current statistics indicate that the percentage of minorities enrolled in higher education programs[1] are approximately equal to minority representation in the country as a whole,[2] the percentages of minorities receiving baccalaureate degrees in science-related disciplines, or enrolled in graduate programs in science-related professional fields, remain well below their national representation.[3] By addressing the particular problems of Hispanic minority students we hope to be able to influence the design of programs aimed at helping these students and decreasing this degree of underrepresentation.

In our research, we have discovered a variety of learning difficulties encountered by bilingual Hispanic students. In our effort to isolate problems unique to Hispanics, however, we find that, in some cases, mainstream students suffer from similar learning difficulties, albeit to a lesser extent. The purpose of this paper is to present those findings which we believe clearly indicate the need for greater integration in the development of verbal and mathematical skills for all college technical majors. Evidence for this point of view was not one of our original objectives. Nevertheless, many of our investigation results strongly support the conclusion that language skills play a crucial role in various problem solving settings.

We will discuss how verbal skills affect two important mathematical skills, namely, logical ability and algebraic problem-solving ability. In general, we find that language factors strongly influence the overall performance of both Hispanic and non-minority students, although certain semantic constructions appear to pose particular difficulties for Hispanic bilingual students. When asked to solve logic problems involving two or more negations, all of our sampled bilingual and monolingual students exhibited certain interesting but erroneous logic patterns. Another result common to both groups is the dependence of algebraic problem-solving ability upon verbal context. However, Hispanic students exhibited errors in reasoning not found among their non-minority peers.

RESEARCH PROCEDURE

In order to determine the interplay between verbal and mathematical skills, a number of written testing instruments were developed. Some of the details regarding these exams, including the motivation and rationale behind them, are provided below. Bilingual students were given parallel English and Spanish versions, while the monolingual students took only the English version. Interesting patterns of thought manifested in the results of the written exams were then pursued further through clinical interviews. During these interviews, selected students were asked to verbalize their approaches and solutions to selected problems.

Logic Exam

The logical structure of the Spanish language allows for certain doubly-negated statements to retain the negative interpretation instead of reverting to the positive interpretation, as would be the case in the English language.

For example, the only grammatically correct way of translating the statement, "I do not want any money" into Spanish would be "yo no quiero ningun dinero," which, if translated literally into English, becomes "I do not want no money." A question that immediately comes to mind is whether Hispanics are more likely to misinterpret doubly-negated statements when solving problems because of this logical inequivalence between the two languages. If true, this would have adverse ramifications for Hispanic students, since the usage of double negatives in the English language is not infrequent.

To study this difference in language structure, an exam was designed in which students were asked to read a statement with various negations, and then select an answer among multiple choices for an equivalent statement. Equivalent exams were constructed in English and Spanish (not merely translations of one another) to study any possible differences across language. We also thought it would be informative to investigate the effect of students' preconceptions in solving these types of logic problems. The question of interest was whether students who were asked to interpret a subtle sentence containing various negations were biased in their selection of an answer due to their preconceived notions as to what was the actual situation in the "real world." Our hypothesis was that, on problems where no strong preconceptions existed, students would attempt to reason out the problem, thereby obtaining the correct answer more often than in a similar problem where they might be tempted to choose an answer reflecting the real world situation.

The English version of the exam is included in the Appendix to facilitate further discussion. The questions used in testing our hypothesis of student bias due to preconceptions are 3, 5, 6, and 8. It is evident that questions 3 and 6 are completely structurally equivalent. However, in question 3, most students (and in particular, technical students) have a preconceived notion

that college graduates generally earn more than $10,000 per year, whereas in question 6, students would be less likely to have any strong preconceptions concerning the yearly growth of fig trees. Similarly, questions 5 and 8 are also equivalent in structure; question 5 should be the more "biased" question of the two, since most people think of basketball players as being over six feet tall, whereas for question 8 most people would realize that not all oranges will necessarily have the same number of seeds. Thus, by constructing questions 3 and 5 so that their answers are counter-intuitive ("all college graduates earn less than $10,000 a year" for #3 and "all basketball players are less than six feet tall for #5), we were then able to test our hypothesis by observing the differences in the responses to problem pairs 3 and 6, and 5 and 8.

Other aspects to note are that there were two negations at most in any problem. There were two problems, numbers 4 and 7, which asked students to interpret a pictorial diagram. Finally, in problem 9, students were asked to determine whether the statement, "I do not want no money" meant that money was, or was not, wanted. Although it could be argued that the aforementioned quoted statement is of questionable grammatical construction, it does carry the same meaning as "I do want money," albeit in a less forceful fashion. This problem should illustrate most clearly of all whether Hispanics are confused by statements containing double negations, due to the structure of the Spanish language discussed earlier.

Algebra Exams

There is a general consensus among math and science educators that word problems are a nemesis for most students. Proficiency in solving word problems demands that the solver not only have a command of the subject matter (e.g., algebra, physics, biology, etc.), but also a command of the language used in the problems. No amount of expertise in the subject matter will yield a correct

solution if the problem is initially misunderstood, or misinterpreted at the semantic level. Thus, minority students who are often underprepared in language skills are more likely to have difficulties in solving word problems at the semantic translation stage than are non-minority students. The difficulties may be more acute for Hispanic students who are not native speakers of the English language.

In an attempt to examine how performance in solving algebra word problems is influenced by the amount of semantic processing required by the problem, four exams were designed. The four exams, Terse Word Problems, Verbose Word Problems, each in both Spanish and English, are constructed so that each of the two Terse-Verbose pairs are completely equivalent in mathematical content. However, in the Terse exams the questions are brief and simply stated, while in the Verbose exams questions are embellished with irrelevant technical jargon. The Spanish versions were given only to the Hispanic group, while both groups took the English version. The Terse and Verbose exams were not administered contiguously, since students would be likely to detect the similarity in content between the pair. The problems in all four exams required only elementary algebra, since the purpose was not to test for mathematical sophistication but to study the degree to which semantic processing could affect performance. The level of difficulty and the type of problems are illustrated by the following pair of equivalent problems from the English version of the Terse and Verbose exams.

Terse	Verbose
A number divided by a second number gives 2. The first number minus the second number also results in 2. What are the numbers?	The Gartenhaus-Schmidt stress quotient is defined to be the loss of sleep factor divided by the coefficient of fear. The quantity obtained by subtracting the coefficient of fear from the loss of sleep factor is given the name Breakpoint Indicator. What are an individual's loss of sleep factor and coefficient of fear given that his Gartenhaus-Schmidt stress quotient is 2 and that his Breakpoint Indicator is also 2?

Sample

All of the students tested were majoring in technical areas with the majority coming from engineering programs. The 60 bilingual Hispanic students were mostly composed of Freshmen and Sophomores. Although almost all of these students would have to be judged as balanced bilinguals based upon their performance on English and Spanish language proficiency exams, many received their early mathematics training in Spanish. The 74 participating monolingual students were recruited from an introductory Physics course for engineers and consequently were exclusively freshmen and sophomores. The results of other written tests, and the distribution of grade point averages, would indicate that both groups were "typical" of the University, although the median grade point average for the bilinguals was slightly less than that of the monolingual sample.[4]

RESULTS

The results of the written exams on logic and algebra are shown in Tables 1 and 2 respectively. All exams were graded on the basis of the total number correct. For the Hispanic students we have shown the results of both the English and Spanish versions of the exams. Also shown in Table 1 is a breakdown by question of the English version of the logic exam, showing the percentage of the group responding correctly. The entry in the column labeled χ^2 is the result of a 2 x 2 chi-square analysis between the bilinguals and monolinguals, taking into account the number correct versus the number wrong for each question.

Examination of the mean and standard deviation on the exams makes two conclusions readily apparent. First, it is clear that the performance of the bilingual group is very similar across language. Although the differences are not significant, these students appear to perform slightly better in English.

This is probably because most of their recent technical training has been in English. The mean scores also indicate that the monolingual group has a decided advantage over the bilingual group. Some, but by no means all, of this difference can be attributed to the fact that, as a sample, the monolingual volunteers were slightly better prepared academically than the bilingual group.[4] This is also evidenced by the smaller standard deviations of mean score for the monolinguals, implying that they form a more homogenous academic group.

Discussion of Results for the Logic Exams

Analysis of the logic exam results by question shows several interesting differences between the bilingual and monolingual groups. Significant differences occur for questions 1, 4, 7, 8, and 9, and the differences in questions 5 and 6 approach significance. These large differences in performance may be due to the logical inconsistency in the meaning of double negations between English and Spanish, as evidenced by question 9. In this question, the percentage of Hispanic students who interpreted two negations as an overall single negation was 40%, compared to only 8% for the non-minority group. The results in this question alone illustrate that Hispanics are more likely to interpret double negations in English as they would have interpreted the double negation in Spanish.

It was somewhat surprising to discover how poorly both groups performed on questions 3, 5, 6, and 8. Not only did these problems cause inordinate difficulties, but there is strong evidence in support of our hypothesis that the students' preconceptions influence their choice of an answer chosen. In both pairs of equivalent questions, 3 and 6 as well as 5 and 8, the number of students who obtained the correct answer in both the bilingual and non-minority groups doubled in going from the "biased" questions to the "unbiased" questions. A detailed breakdown of the performance in these four questions is shown in Table 3, where the upper and lower entries correspond to Hispanic and non-minority students, respectively. As Table 2 shows, if a student obtained the correct

response in the "biased" question of each pair, then there was a very good probability that the student would also answer the "unbiased" question correctly, whereas the converse is not true. This pattern appeared to hold for both groups. Thus indications are that in logic problems such as those in this study, the percentage of correct responses is much lower in problems where the correct answer is counter-intuitive (that is, the answer is in conflict with "reality") than in problems where students have little intuition concerning what is the actual case in "reality."

We have not shown the breakdown of the Spanish version of the logic exam for the Hispanics. This is because, with two notable exceptions, the results are very similar across language. The two exceptions were questions 7 and 9. The performance on question 7 was significantly better in English. However, it is not appropriate to compare this question across language, since the only similarity between the English and Spanish versions was that both problems involved the interpretation of a pictorial diagram; in content, the two versions were not equivalent. Question 9 in Spanish asked the students to interpret the statement "en una fiesta, no hay ninguno que no le gusta tomar cerveza," which translated properly becomes "at a party, there is not anyone who does not like beer" but if translated literally becomes "at a party, there is not no one who does not like beer." In this problem, the bilingual group did significantly better in Spanish with 83.3% obtaining the correct answer.

Discussion of Algebra Exam Results

As the means and standard deviations given in Table 2 indicate, the performance by both groups was poorer on the Verbose exam. The non-minority group is the least affected by increasing the verbal processing necessary for solving a problem, as evidenced by the smaller difference-mean between the Terse and Verbose exams, $\bar{D} = 9.26 - 8.56 = .70$, compared to difference means of 1.37 and 2.47 for the bilingual group in English and Spanish, respectively. The question

that remains is whether the difference-means are large enough to imply a genuinely larger adverse effect in problem solving for Hispanic students than for non-minority students as a function of increasing verbal material. Tests of significance on the differences in performance between the Terse and Verbose exams revealed that all three difference-means are statistically significant beyond the 1% level. Another result, which is not surprising in view of the additional difficulties that bilinguals encounter due to the language barrier, is that a statistical test between the difference-means of bilinguals (in English) and the non-minority group revealed that the difference-mean between the two groups was also statistically significant beyond the 1% level.

A somewhat unexpected result is the large disparity in performance of the bilingual group across language. This would not be surprising if the bilingual group were English dominant. However, an evaluation of these students' language skills revealed that there is very little disparity between the English and Spanish proficiencies of the bilingual group as measured by performance on language proficiency exams.[4] A possible explanation for the disparity encountered here is that the vast majority of students in the bilingual group have received their mathematics and science instruction during high school and college in English. These students are therefore not accustomed to solving word problems in Spanish, and may commit more errors as a result.

INSIGHTS FROM CLINICAL INTERVIEWS

To more fully understand the nature of the difficulties encountered by the students on the written exams we randomly selected a number of students from each group and interviewed them extensively. During videotaped interviews the students were asked to "think aloud" while they tried to solve problems. This procedure has proven to be extremely effective in illuminating strategies employed by students confronted by logical problems similar to those used in this study. In our research with Hispanic students, we have found that such

interviews are a very effective means of determining to what degree difficulties are language-related. Beyond the difficulties deriving from the logical inequivalence of double negatives in Spanish and English as mentioned earlier, logical error patterns were similar for both groups. Interview results on algebra problems, however, do seem to indicate that certain misinterpretations of verbal problems are quite common among the bilingual students.

Logical Rules Employed by Students

Interviews using questions from the logic exam were conducted with a total of 17 students, 8 from the Hispanic group and 9 from the non-minority group. The interviews revealed that students preferred to employ "rules" in a mechanical fashion to solve these problems, rather than attempt to rephrase and understand the meaning of each problem in order to select a suitable answer.

Only one of the procedures employed by students consistently yielded the correct answer. This procedure can be summarized as follows: *Break the sentence into components. Next analyze each part, starting with the innermost, and take into account each negation in turn until the statement of the problem is paraphrased into the correct answer.* This procedure is best illustrated with an example. In problem 3 it would work as follows: *Not all college graduates earn less than $10,000 per year means there must be some that earn more than, or equal to $10,000 per year. But if this is false, then all college graduates must earn less than $10,000 a year.* In problem 5 the procedure would be: *Some basketball players are not less than 6 feet tall implies that some basketball players are more than, or equal to 6 feet tall. But if this is not true, then all must be less than 6 feet tall.* Only two of the students interviewed, both from the monolingual group, consistently applied this procedure successfully.

Far more frequently used than the above procedure were rules which were efficacious in obtaining the correct answer in some of the problems, but which resulted in specious logic when applied blindly to all problems. Five rules were clearly identified which students used either singly or in "packages" of two or more at a time. These rules are described below, along with verbatim quotes from the students' protocols illustrating their usage.

Rule 1: The phrase "not all" can be replaced with the word "some".

- "We're saying 'not all college graduates,' so we're saying some."
- "When you see the word 'not all' substitute 'some'."
- "You have to sort of be logical. But I guess you can always put in 'some' for 'not all.' "

Rule 2: Questions beginning with 'not all' or 'some' must have answers beginning with 'some.' "

- "The key to this question is the 'not all,' that's how you know 'some' should be in the answer."
- "Without looking at the answers, I know that the answer will have 'some' in it because the question says 'some'. "

Rule 3: In questions where the world is dichotomized into two complementary and exhaustive categories (e.g., those earning less than $10,000, and those earning more than or equal to $10,000 per year), stating that some of the group is in one of the categories implies that there must be some in the complementary category.

- " 'not all' means some are going to be included and some aren't."
- "I would go with 'some' because if 'not all' earn less than $10,000, then some must earn less and some must earn more."

Rule 4: Negations can always be cancelled in pairs.

- "I cover up the first part of the question, and only cancel 'nots' within the statement that's being decided on."

- "Two negative signs make a positive, so I pick 'a'. "

Rule 5: If all else fails, resort to either intuition or experience in finding a suitable answer.

- "I know people that like to eat steak and also like corn, but not all people that like to eat steak like to eat corn, just because I do."
- "You can't say that 'all college graduates earn less than $10,000' because that goes against statistics; you can't pick C, even though that's what the answer seems like. I eliminate the answers that are very general, like d, because it's not true that all college graduates earn more than $10,000 in the real world. So I picked 'a'. "

A few examples would serve to illustrate how students applied some of the rules above. In problem 3, an application of rules 1 and 2 would immediately yield the answer with "some" in it, namely a). There is a much more convoluted method by which some students arrive at answer a). This entails an application of rule 1 resulting in "it is false that *some* college graduates earn less than $10,000 a year," followed by a liberal application of rule 4; that is, rule 4 allows "it is false" to convert "less than" into "more than," making the final answer "some college graduates earn more than $10,000 a year."

It happens to be true that an application of rule 4 to this problem results in the correct answer. If the "false" and the "not" are cancelled, we are left with "all college graduates earn less than $10,000 a year." However, students who applied this rule blindly got into trouble in problem 5. Here they were inclined to cancel the two "nots," and thus obtained "some basketball players are less than 6 feet tall." But since this answer did not appear among the choices, these students then applied rule 3, resulting in answer b). "Some basketball players are more than 6 feet fall."

It should be pointed out that neither group differed appreciably in which of the five rules were used and in how they were applied. Although each group used these rules with approximately the same frequency, the percentage of correct responses exhibited during the interviews reflected the percentage of correct responses for each group as a whole, as shown in Table 1.

Misinterpretation of Problems by Hispanic Students

One of the clearest indications that mathematics performance is largely mediated by language proficiency for Hispanic students was found in the results of interviews where students were asked to translate from a linguistic to a mathematical representation. Students were asked to read a sentence describing a mathematical relationship, and then to write an equation expressing that relationship. Detailed results of this study have been presented elsewhere,[5] so we will only summarize some of the salient findings here.

We discovered that certain errors were common among the Hispanic group, and that these errors derived from misinterpreting the problem statement. Other errors believed to be of a more conceptual nature were manifested by both bilingual and monolingual groups alike. No evidence, however, was found among the monolingual group for the kind of misinterpretation error displayed by the bilinguals. For example, in the problem,

> Write an equation using the variables S and P to represent the following statement: "There are six times as many students as professors at this University." Use S for the number of students and P for the number of professors,

some Hispanic students wrote $6S = 6P$. These students explained that the phrase "as many students as professors" meant an equal number of each, that is, $S = P$. The "six times" in front of the statement was taken to imply that each side of $S = P$ should be multiplied by 6. Other students wrote $6S + P = T$. These students explained that this equation related the number of students, professors, and the total student-professor population, T, in the appropriate proportion. In the problem,

> "Write an equation to represent the following statement: "A certain council has 9 more men than women on it." Use M for the number of men and W for the number of women,

five out of the nine Hispanics interviewed wrote 9M = W. There appear to be two main factors contributing to this error. First, this problem was preceded in the interview by two other problems, such as the students and professors problem above, which asked for a multiplicative relationship between two variables rather than an additive relationship. These students may therefore have become functionally fixed after working out two previous problems involving multiplicative relationships. The fact that three out of the five students who erred in this fashion could be subsequently prompted to write an additive but incorrect relationship, M + 9 = W, is evidence that they had been somewhat uncritical in their interpretation of this problem. The second contributing factor to this error appears to be interpretational. This was evidenced by the remaining two students, who couldn't be prompted into discovering that the problem asked for an additive relationship. These two students were adamant in interpreting the phrase "9 more men than women" to mean "9 times more men than women."

DISCUSSION

The results we have presented indicate that language skills and problem solving skills are not decoupled; in fact, indications are that problem solving is largely mediated by language skills. Only recently have investigations focused on the interdependence of language and problem solving skills. Thus far, results show strong correlations between these skills,[6] particularly for bilingual students such as Asian Americans[7] and Hispanic Americans.[4, 8]

The large number of programs servicing minority students to come into existence during the last decade in Universities throughout the country is testimony to the fact that many minority students are underprepared in verbal,

quantitative, and problem solving skills when they enter universities. Needless to say, many of these students would have a much more difficult time coping with the many pressures of college study, were it not for the services provided by these programs.

We feel, however, that extant programs[9-13] aimed at the preparation of minorities for college level work fall short by not including language skills as an integral part of the program. Even though McDermott, Piternick and Rosenquist[9] list "weakness in mathematical and verbal skills" as one of several limitations of minority students enrolled in science programs, verbal skills are, in the majority of cases, taught independently of, rather than integrated with, cognitive skills. For the most part, these programs address the technical deficiencies and leave the job of remedying the students' verbal skills to English Departments or English as a Second Language programs. It is clear from the data presented in this paper that it is often difficult to separate quantitative, verbal, and problem solving skills, and that it therefore may prove more efficacious to treat all three in an integrated manner.

The virtues of such a method are numerous. First, students could be taught to glean important information from complex word problems and how to appropriately translate this information into mathematical terminology, while allowing the instructor to discuss misinterpretations as they arise. Instructors could also emphasize the importance of language precision in communicating technical information, and illustrate how sloppiness can result in ill-defined problems. Since students seem to have a proclivity to draw from their preconceptions or intuitions in solving problems, one could warn students against selecting an answer only because it "makes sense," and encourage them to play by the "rules of the game;" in other words, to teach them that in the problem-solving game adhering to rules may demand that one choose counterintuitive answers.

One essential tool in problem solving is the use of diagrams. A program such as the one we advocate could not only develop the students' skills at using diagrams to solve technical problems, but would also teach students to use diagrammatic techniques to understand problems at the linguistic level. In problems requiring the comprehension of subtleties in the language, teaching students something as simple as diagramming sentences may prove helpful to students with language deficiencies. It is disturbing how little students use diagrams to solve problems, as evidenced by the fact that, of the 17 students interviewed on questions from the logic exam, not one attempted to write or draw anything to help them solve the problems, although a marker and pad were made available to them at the start of the interview. We found this surprising in view of the straightforward and powerful diagrammatic techniques which could have been used to solve these problems. For example, in problem 3, a very easy procedure that would yield the correct answer is to dichotomize the world into two categories - those earning less than $10,000, and those earning equal to or more than $10,000 a year. The statement that not all college graduates earn less than $10,000 a year demands that there be some college graduates in the $\geq$ $10,000 region, as depicted by Figure 1b. From Figure 1b, the answer is obvious.

Perhaps the most important function that a coherent language, quantitative, and problem-solving teaching method could serve would be to convince students that all of learning is related, and that there is fundamentally little difference in the "logic" behind an elaborate mathematical proof and a well-written essay. Increasingly, technical education demands that more and more knowledge be compressed into four years of college, and students are being asked to fulfill their technical requirements at the expense of nontechnical courses, where such language skills may be developed. This may be a dangerous trend in view of the fact that many students who enter a technical field do so because they were "good" in math and "not-so-good" in verbal skills. It may be time to examine how technical programs could incorporate language skills as an integral part

of the program. This would not only improve the students' verbal abilities, but results from our research indicate that problem-solving performance would improve as well.

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Table 1

Results of Logical Double Negative Exams

Maximum Score on Each is 9

	Hispanic N = 60		Non-Minority N = 74
	Spanish	English	English
MEAN	3.85	4.10	5.59
STA. DEV.	1.68	2.18	1.73

PERCENTAGE CORRECT

English Version

Question Number	Hispanic	Non-Minority	x^2
1	55.0	79.7	9.4*
2	60.0	60.8	0
3	13.3	17.6	.4
4	53.3	86.5	17.9*
5	13.3	27.0	3.8
6	33.3	48.6	3.2
7	78.3	91.9	5.0*
8	28.3	54.0	9.6*
9	60.0	91.9	19.4*

*Significant beyond .05 level

Table 2

Results of Terse and Verbose Exams

Maximum Score on Each is 10

	HISPANIC N = 60				NON-MINORITY N = 73	
	Spanish		English		English	
	Mean	Sta. Dev.	Mean	Sta. Dev.	Mean	Sta. Dev.
TERSE	6.87	2.01	7.82	1.99	9.26	.94
VERBOSE	4.40	2.39	6.45	2.51	8.56	1.30
D = TERSE-VERBOSE	2.47*	1.72	1.37*	1.44	.70*	1.28

*Difference is significant beyond .01 level.

Table 3

Breakdown of Questions 3, 5, 6, and 8

of Logic Exam

Question 3 ("biased")

Question 6 ("unbiased")	correct	incorrect
correct	5 10	15 26
incorrect	3 3	37 35

Question 5 ("biased")

Question 8 ("unbiased")	correct	incorrect
correct	7 15	10 25
incorrect	1 5	42 29

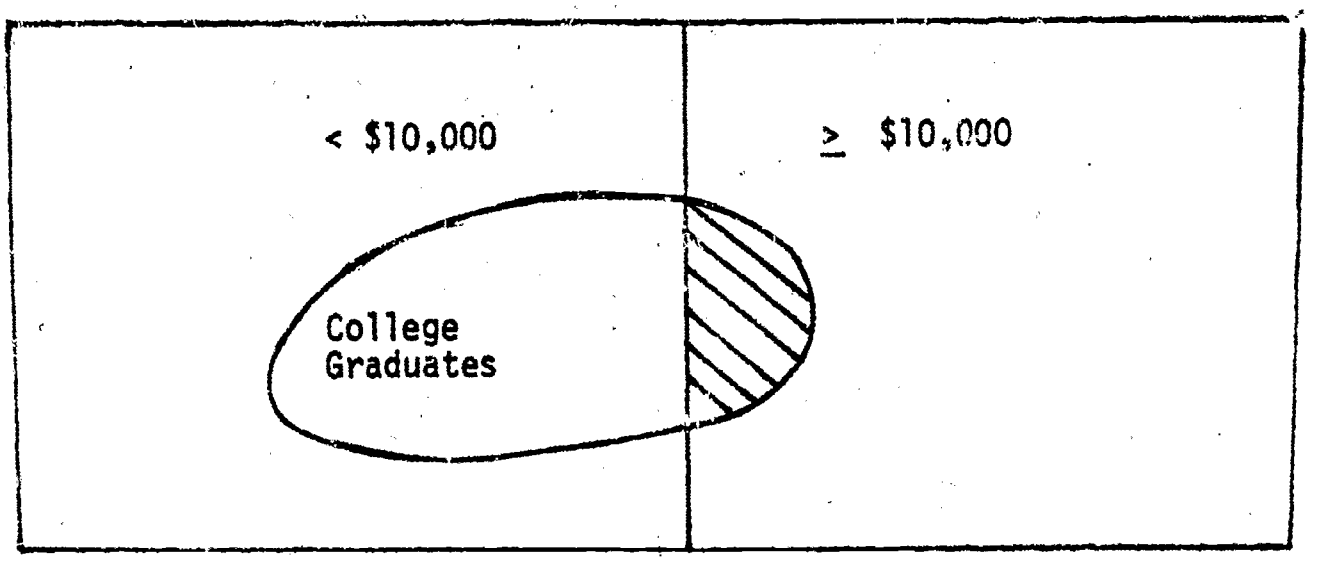
Note: Entries represent number of students. The top and bottom entries correspond to bilingual and non-minority students, respectively.

Figure 1

Diagrammatic Analysis of

Question 3 from Logic Exam

(a)



The statement "not all college graduates earn less than $10,000 a year" dictates shaded region above. Negating this statement dictates the situation below.

(b)