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EFFECTS OF EXPERIMENTAL PROGRAMS FOR SECONDARY MATHEMATICS ON PUPIL INTEREST IN MATHEMATICS AS INDICATED BY AN OVERT PARTICIPATION INDEX OF INTEREST.

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AS PART OF A LARGER INVESTIGATION OF THE EFFECTS OF EXPERIMENTAL MATHEMATICS PROGRAMS ON THE ATTITUDES AND INTERESTS OF SECONDARY SCHOOL STUDENTS TOWARD MATHEMATICS, THIS STUDY WAS MADE TO DETERMINE THE DIFFERENTIAL EFFECT OF SEVERAL EXPERIMENTAL PROGRAMS UPON THE INTEREST OF STUDENTS WHO WERE COMPARED WITH STUDENTS IN MORE CONVENTIONAL PROGRAMS OF INSTRUCTION. PUPILS IN SIXTY 9TH-, 10TH-, AND 11TH-GRADE EXPERIMENTAL AND PAIRED CONVENTIONAL MATHEMATICS CLASSES WERE GIVEN THE OPPORTUNITY TO OBTAIN BY REQUEST COPIES OF A SERIES OF FOUR-PAGE, SPECIALLY PREPARED "MATHEMATICS ACTIVITY BULLETINS" FOLLOWING DISTRIBUTION OF THE FIRST ISSUE TO ALL PUPILS. REQUEST FOR LATER ISSUES, WHICH CONTAINED ANSWERS TO PREVIOUS PROBLEMS, PROVIDED A BEHAVIORAL INDEX OF INTEREST IN MATHEMATICS. COMPARISONS ON REQUEST FREQUENCIES AMONG THE EXPERIMENTAL AND CONVENTIONAL CLASSES WITHIN SEX, MATHEMATICS ABILITY, AND GRADE LEVELS PROVIDED SOME EVIDENCE THAT THE UNIVERSITY OF ILLINOIS COMMITTEE ON SCHOOL MATHEMATICS (UICSM) EXPERIMENTAL PROGRAM AT THE 9TH- AND 10TH-GRADE LEVEL MIGHT HAVE CONTRIBUTED TO A GREATER PUPIL INTEREST IN MATHEMATICS. A RELATED REPORT IS AA 000 059. (GD)

Effects of Experimental Programs for Secondary Mathematics on Pupil Interest in Mathematics as Indicated by an Overt Participation Index of Interest

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Effects of Experimental Programs for Secondary Mathematics on Pupil Interest in Mathematics as Indicated by an Overt Participation Index of Interest[1]

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This study was carried out to determine whether several recently developed secondary level experimental programs in mathematics have any differential effect upon pupil interest in mathematics when compared with more conventional programs of instruction. The study is part of a more extensive investigation of the effects of experimental mathematics programs on the attitudes and interests of secondary school pupils toward mathematics. In this study, an overt behavioral index of pupil interest representing different levels of activity with respect to extra-curricular mathematics materials was used to obtain a more objective measure of intrinsic interest than might be obtained by indices of expressed interest.

The experimental programs were those developed under the auspices of Ball State, Indiana; Teachers College (BSP); University of Illinois Committee on School Mathematics (UICSM); and School Mathematics Study Group (SMSG). These materials represent prototype programs for what is often labeled "modern mathematics".

With reference to the motivational basis for an individuals' participation in a certain area of activity, a distinction has often been made between intrinsic and extrinsic interest. Intrinsic interest in an activity is usually defined in terms of the extent the individual will choose to engage in the activity independent of whether such actions or participation have an implication or outcome beyond the satisfaction derived from so doing. In brief, an indication of preference for an activity because of the nature of the activity itself. In contrast, extrinsic interest refers to participation in an activity to the extent that such participation is expected to facilitate a separate objective or goal, i.e. the participation being a means to an end rather than an end in itself. In these terms intrinsic interest would seem to represent one of the main motivationally relevant objectives of an instructional program in that it refers to the pupils reaction to the instructional materials and subject matter content as such.

Applying this distinction to pupil interest in the content of various school subjects, a pupil could be considered to have stronger intrinsic interest in a given subject to the extent that he engages in activities involving the content or skills

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representative of that subject when doing so provides no tangible external rewards, e.g. higher grades, praise from teachers, etc.

In the present study, pupils were given the opportunity to obtain by request copies of a series of four-page mathematics activity "bulletins" comprised of materials about or involving mathematics. In addition to requests, pupils were also required to engage in bulletin relevant activities as a means of obtaining further issues. The extent to which pupils requested the bulletin and engaged in the relevant activities to obtain additional issues was considered an indication of their level of intrinsic interest in mathematics. Procedures were followed to minimize the possibility of the pupils' bulletin related activities providing obvious extrinsic rewards.

This index was used to determine whether there were any differences with respect to the interests pupils develop in mathematics between the conventional programs and each of the several experimental programs at the secondary level.

Two factors which on the basis of previous evidence were also considered likely to be relevent to pupil interests in mathematics are the pupils' sex and level of mathematics ability. In this study it seemed possible that these factors might either interact with the instructional variations being studied (i.e. that the effects observed for a given program may differ for males and females or for pupils of higher and lower ability) or might independently contribute to differences in observed interest. Consequently, to control for and separately examine their effects, these two pupil characteristics were taken into account.

I. Procedure

A. Sample

The sample consisted of pupils in a total of 60 pairs of ninth, tenth, and eleventh grade mathematics classes already participating in a field study concerned with the achievement effects of these experimental programs.

Each pair of classes was taught by the same teacher, at the same grade level, one class (E) being instructed with materials of one of the experimental programs, the other (C) with the conventional materials in use by the teacher for the same subject. Schools had been requested to assign pupils randomly to these alternate classes. Each pair of classes was in a different school and usually a different community. The schools were distributed geographically over a five state area (Minnesota, Wisconsin, Iowa, North Dakota, South Dakota).

Table 1 shows the number of E classes sampled by grade level and experimental program. As indicated above, each E class was paired with a conventional class.

Table 1

Number of experimental classes following each experimental program at each grade level which were included in the study.

	PROGRAM			
Grade	BSP	UICSM	SMSG	Total
9th	3	2	5	10
10th	5	2	17	24
11th	14	*	12	26
				60

*There is no 11th grade UICSM program

B. Method

A series of six four-page magazine format recreational or mathematics activity bulletins were prepared. The content of these bulletins included general information and articles about mathematics and topics in mathematics (e.g. topology, number systems, logic), activities which demonstrate mathematics principles and relationships, mathematics puzzles and games and in each issue a set of problems of the recreational rather than textbook type. The articles and materials were selected and prepared to cover topics of general interest and to avoid those specific to any particular instructional program. Similar considerations were given to the language and terminology used. A copy of one issue of the bulletin is included in the Appendex.

Sufficient copies of the first issue of the bulletin for each of the two classes were sent to teachers of ninth grade algebra, tenth grade geometry, and eleventh grade advanced algebra classes. The teachers were requested to distribute copies to all pupils in the two participating classes. The teachers were also requested to refrain from encouraging (or discouraging) reading or responding to the bulletin either directly or in relation to class assignments. The general purpose of the bulletin (i.e. assessment of pupil interests) was revealed to the teachers but no indication of any comparison between classes, teachers, etc., was suggested.

Instructions were provided in the first (and each subsequent) issue for obtaining the next issue of the bulletin. The procedure to obtain the second issue and in turn the third issue, consisted simply of filling out the addressed postcard enclosed with each copy with the pupils name, home address, grade and school and mailing it. Use of the pupils home address reduced the possibility that the teacher and other school related factors could influence the pupil's response.

Beginning with the third issue, however, the procedure for obtaining further issues was modified to require pupils to attempt but not necessarily solve, any of the three or four problems included in each issue. Instead of the postcard, a larger form with space for indicating attempted solutions in addition to the necessary pupil information was included for the pupil response with a stamped-addressed envelope. The attempted problem solution requirement was introduced because a request in and of itself for additional issues of the bulletin, although a probable indication of a certain level of interest in mathematics activities and materials, might represent only a passive level of interest or it might represent other motives such as a desire to obtain some personal mail or a free magazine with little actual interest in the content as such. Furthermore, motives at this level might not reflect the more specific interest in mathematics that could possibly be differentially developed by the instructional materials being compared. Consequently it was desirable to obtain an indication of a higher degree of interest and involvement in mathematics materials in terms of relevant effort and activity. So as not to restrict the future requests only to those who felt they had appropriate problem solving or mathematics ability, it was explicitly indicated that a correct solution was not necessary; only an attempt at a solution. Answers were provided in each subsequent issue.

This procedure was required for each issue after issue three up to and including issue number six. Pupils responding to issue number six, i.e. requesting a non-existant seventh issue, were sent a letter indicating no further issues were available, with an explanation of the purpose of the project and thanking them for their interest as well as providing answers to the problems in issue six.

The rate of response to the first issue (approximately 40%) indicated the possibility of a fairly rapid rate of attrition over the entire series of issues, since following the above procedure, if pupils stopped responding they received no further issues nor the opportunity to request further issues. Therefore, a "priming" procedure was instituted to elicit a more extensive response. Pupils who failed to respond further within a given period of time after making one or more requests were sent the next issue in the series with a note explaining that surplus copies of that issue were available but that to receive further issues required their response in the usual manner. No pupil was, however, "primed" on more than one occasion.

C. Analysis

1. Index of interest response

The number of separate issues of the bulletin requested by a pupil was considered an indication of his level of interest in the content of the bulletin. The total possible requests a pupil could make ranged from none through six. Table 2 shows the number of pupils in each grade at each request level with the request level representing the total number of separate issue requests made by a given pupil. Table 3 shows the number and percent of pupils making requests for each of the successive issues of the bulletin. Each request was contingent upon having made a previous request with the possible exception of receipt of one unsolicited priming issue. This contingency contributed, therefore, to the occurrence of a decreasing number of pupils at each successively higher total-request level (indicated in Table 2) with a relatively small number of pupils in the higher request level categories, i.e. pupils making four, five and six requests.

Because of the small number of pupils in the higher request level categories, it was necessary to combine categories to carry out the analysis. This was done in a way that would reflect not only the quantitative differences in number of responses but also the qualitative differences between the "non-participation requests" required for the initial issues and the "participation requests" required for the later issues.

Table 2

Number of pupils at each total request level for each grade level.

TOTAL REQUESTS MADE

Grade	0	1	2	3	4	5	6	Total
9	276	64	63	29	11	19	10	472
10	731	128	105	57	48	30	31	1130
11	669	124	100	42	28	33	16	1012

Table 3

Total Number and percent of pupils making requests for each successive issue of the bulletin by grade.

ISSUE NUMBER

Grade	2	3	4	5	6	7	No requests
9	196 (42)*	132 (28)	69 (15)	40 (9)	29 (6)	10 (2)	276 (58)
10	399 (35)	271 (24)	166 (15)	109 (10)	61 (5)	31 (3)	731 (65)
11	343 (34)	219 (22)	119 (12)	77 (8)	49 (5)	16 (2)	669 (66)
Total	938 (36)	622 (24)	354 (14)	226 (9)	139 (5)	57 (3)	1676 (64)

*Percent of each grade total shown in parentheses.

The request categories used for the analyses were as follows:

N-R: No requests - pupils who made no request following receipt of the initial issue.

NP-R: Non-participation requests - pupils who only made requests for issue two or issues two and three which did not require indication of activity relevant to the bulletin content (i.e. problem solving attempts). The maximum number of total requests possible for pupils in this category, was therefore, two.

P-R: Participation requests - pupils who requested one or more issues which required attempted problem solutions, i.e. one or more issues beyond issue 3. The minimum number of total requests for pupils in this category would be two, one straight request and one with an attempted problem solution with a priming issue intervening.

Underlying this response, classification is the assumption that pupils in the NP-R category had, on the average, a somewhat stronger interest in the bulletin materials and in mathematics in general than pupils in the N-R category and that pupils in the P-R category had, on the average, stronger interests and preferences for the bulletin content and for mathematics and related activities in general than those in the other two categories. Evidence bearing on this assumption will be presented below.

II. Analysis

The main question with which the analysis was concerned was whether there were any differences in response (i.e. requests) between pupils in classes instructed with each E program and those instructed by the same teachers with a conventional program. The analysis to determine the instructional differences was carried out separately for each E program within each grade. The responses of pupils in the E and C classes were pooled within the respective instructional categories for teachers following the same E program.

To observe and control for differences associated with sex or mathematics ability, the comparisons between E and C class pupils for each program were made within sex by ability level classifications, i.e. for each program the E - C comparisons were made for pupils classified jointly by sex and mathematics ability. The comparisons were made with respect to the proportions of E and of C pupils in each of the request categories using χ^2 to test the reliability of the request category differences. The null hypotheses being tested for each of the experimental program comparisons was that there was no difference between the proportions of E and C class pupils in each of the alternate request categories. For some comparisons the frequencies in the separate P-R and NP-R categories fell below the number necessary to make an appropriate statistical test. In such cases, the frequencies in these two request categories were combined and the comparisons made considering only two request categories, a "no-request" (N-R) and a "request" (NP-R and P-R) category. The results of such comparisons have to be interpreted differently than comparisons involving all three request categories.

Where statistically significant differences were obtained, considering all three request categories (that is, $p < .05$), further comparisons were made within the contingency tables. Procedures for partitioning χ^2 outlined by Castellan (2) were used to determine whether the result was attributable to differences for the NP-R or the P-R categories.

In addition to comparisons within sex and ability levels, E - C comparisons for each program were made with sexes combined within ability levels.

To examine sex differences independent of (i.e. across) instructional conditions, comparisons were also made between males and females with pupils combined across instructional conditions within levels of ability and grade levels.

To examine ability differences, comparisons were made for the request category proportions between all high and low ability pupils with pupils combined over sex and instructional conditions within grades.

With respect to mathematics ability, pupils were classified according to scores obtained on the mathematics section of Sequential Tests of Educational Progress, Level Two, (STEP) which had been administered at the beginning of the school year. A two level classification was made relative to the median of the distribution of scores for males and females separately at each grade level.

III. Results

A. Ninth grade

Table 4 shows the frequency in each request category for the ninth grade experimental program comparisons for pupils classified by instructional treatment (E or C), sex and level of mathematics ability. At this grade level only one of the sex by ability level comparisons for the three programs revealed a frequency difference that is reliable at the .05 level or less. This difference ($p < .05$) was observed for the UICSM program. A greater proportion of high ability girls in UICSM classes than in the conventional comparison classes made requests for the activity bulletin. For this statistical comparison it was necessary to combine both NP-R and P-R categories because of the small frequencies.

When the instructional treatment (E-C) comparisons are made for each program with males and females combined within levels of ability, a reliable difference ($p < .025$) was obtained for high ability pupils in the SMSG program comparison. A greater proportion of higher ability pupils in the conventional classes made requests than those in the SMSG program.

For this comparison, it was possible to partition the 2 x 3 contingency table to determine whether one or both request categories were contributing to the significant X^2. The difference was found to occur only for the NP-R category indicating that for the SMSG program comparison a significantly smaller proportion of E class pupils made participant-requests than C class pupils.

To examine sex differences, request frequencies for the respective sexes were combined across instructional conditions and comparisons made within levels of ability and within grade. Among lower ability pupils, a significant sex difference at the .05 level was observed. This difference was the result of a greater proportion of the lower ability girls making participant requests than the lower ability boys - there being no significant difference for the NP-R category. The fact that this difference occurs only at the lower ability level indicates that there is an interaction between sex and ability with respect to pupil request behavior in the ninth grade.

Comparisons to determine the association between request behavior and mathematics ability were made with pupils pooled across sex and instructional conditions. A reliably greater proportion of high ability pupils made requests in both the NP-R ($p < .05$) and the P-R ($p < .001$) categories. Since sex differences were observed for low ability pupils which could account for these ability differences, ability level comparisons were also made separately for boys and girls. For boys the ability differences were highly significant ($p < .01$) for both NP-R and P-R categories with the greatest proportion of requests from those having higher ability, but the differences for girls were nonsignificant. In brief, both the sex and ability differences appear to be due to the interaction between these factors with a smaller proportion of low ability boys making requests than were made by high ability boys or low ability girls.

Table 4

Number of E and C class pupils in each request category for ninth grade experimental program comparisons.

Higher Ability REQUEST CATEGORY		BALL STATE E	BALL STATE C	BALL STATE Total	UICSM E	UICSM C	UICSM Total	SMSG E	SMSG C	SMSG Total	TOTAL	
Males	N-R	7	5	12	9	6	15	12	8	20	47	
	NP-R	3	9	12	6	3	9	5	9	14	35	
	P-R	2	3	5	6	5	11	6	7	13	29	
		12	17	29	21	14	35	23	24	47	111	
Females	N-R	7	8	15	6	7	13 a	26	11	37	65	
	NP-R	5	5	10	(8	(1	12(9 a	2	7	9	28	
	P-R	5	1	6	11 (3	1 (0	(3	9	4	13	22	
		17	14	31	17	8	25	27	22	59	115	
Total	N-R	14	13	27	15	13	28	38	19	57 b	112	d
	NP-R	8	14	22	14	4	18	7	16	23 b	63	d
	P-R	7	4	11	9	5	14	15	11	26 b	51	d
		29	31	60	38	22	60	60	46	106	226	
Low Ability Males	N-R	11	17	28	8	9	17	21	23	44	89	c
	NP-R	1	7	8	2	4	6	3	12	15	29	c
	P-R	0	0	0	1	0	1	3	3	6	7	c
		12	24	36	11	13	24	27	38	65	125	
Females	N-R	11	15	26	4	6	10	19	20	39	75	c
	NP-R	4	2	6	3	6	9	6	7	13	28	c
	P-R	3	0	3	1	3	4	5	7	12	19	c
		18	17	35	8	15	23	30	34	64	122	
Total	N-R	22	32	54	12	15	27	40	43	83	164	d
	NP-R	5	9	14	5	10	15	9	19	28	57	d
	P-R	3	0	3	2	3	5	8	10	18	26	d
		30	41	71	19	28	47	52	72	129	247	

Significant differences:

a - E vs. C. $p < .05$ for N-R x NP-R + P-R

b - E vs. C (sexes combined), $p < .05$ for N-R x NP-R x P-R

c - M vs. F, (across instructional conditions) $p < .05$ for N-R x NP-R x P-R

d - H vs. L, (across sex and instructional conditions within grade), $p < .01$ for N-R x NP-R x P-R

B. Tenth grade

Table 5 shows the request category frequencies for each of the tenth grade experimental program comparisons with pupils classified by sex and ability. With respect to the instructional treatment comparisons within sex and ability levels for each experimental program, the only reliable difference was that observed for the UICSM program for high ability boys. For these pupils a significantly greater ($p < .02$) proportion of those in the UICSM program made requests for the bulletin than those in the conventional program taught by the same teacher. This result was obtained when P-R and NP-R categories were combined due to small frequencies in these categories.

When the experimental program comparisons were made combining responses for boys and girls within ability levels, a significant difference was also observed for the low ability pupils in the UICSM comparison. A reliably greater ($p < .01$) proportion of all low ability pupils in the UICSM classes made participant requests than their conventional class counterparts.

Comparisons to determine whether there were any differences in requests between sexes within levels of ability indicated no reliable differences at either ability level. Comparisons to determine whether there were any request differences associated with ability when pupils are combined across sex and instructional conditions indicated that although there were equal proportions of high and low ability pupils in the NP-R category, a much greater proportion of the high ability pupils made one or more participant requests. The difference for the P-R category was highly reliable, $p < .001$.

Table 5

Number of E and C class pupils in each request category for tenth grade experimental program comparisons.

REQUEST CATEGORY		BALL STATE E	BALL STATE C	BALL STATE	UICSM E	UICSM C	UICSM	SMSG E	SMSG C	SMSG	TOTAL	
Higher Ability												
Males	N-R	21	22	43	0	5	5	67	69	136	184	
	NP-R	8	3	11	8 (4	6(4	14(8	19	24	43	62	a
	P-R	6	2	8	(4	(2	(6	15	25	40	54	
		35	27	62	8	11	19	101	118	219	300	
Females	N-R	31	23	54	1	1	2	53	50	103	159	
	NP-R	8	1	9	2	4	6	19	11	30	45	
	P-R	3	4	7	2	2	4	23	21	44	55	
		42	28	70	5	7	12	95	82	177	259	
Total	N-R	52	45	97	1	6	7	120	119	239	343	
	NP-R	16	4	20	6	8	14	38	35	73	107	d
	P-R	9	6	15	6	4	10	38	46	84	109	
		77	55	132	13	18	31	196	200	396	559	
Lower Ability												
Males	N-R	18	15	33	8	13	21	65	99	164	218	
	NP-R	4	4	8	8	8	16	15	19	34	58	
	P-R	2	5	7	4	1	5	19	13	32	44	
		24	24	48	20	22	42	99	131	230	320	
Females	N-R	20	23	43	2	5	7	55	65	120	170	
	NP-R	3	2	5	4	2	6	20	19	39	50	
	P-R	1	0	1	4	1	5	8	7	15	21	
		24	25	49	10	8	18	83	91	174	241	
Total	N-R	38	38	76	10	18	28	120	164	284	388	
	NP-R	7	6	13	12	10	22 b	35	38	73	108	d
	P-R	3	5	8	8	2	10	27	20	47	65	
		48	49	97	30	30	60	182	222	404	561	

Significant differences:

a - E vs. C, $p < .05$ for N-R x NP-R + P-R

c - E vs. C (sexes combined), $p < .05$ for N-R x NP-R x P-R

d - H vs. L, (across sex and instructional conditions within grade), $p < .01$ for N-R x NP-R x P-R

C. Eleventh grade

Request category frequencies for pupils grouped by sex and ability levels in each of the eleventh grade experimental program comparison conditions are shown in Table 6. Chi-square tests for each of the E-C comparisons indicate that none of the differences for either of the experimental programs were reliable at the .05 probability level or less.

No significant sex differences were observed when comparisons were made between boys and girls combined across instructional conditions for each level of ability.

Comparisons between the request category proportions for pupils of higher and lower ability combining sexes and instructional conditions reveals a highly statistically significant difference for the P-R category. Although approximately equal proportions of high and low ability pupils made nonparticipant requests, a reliably greater ($p < .001$) proportion of the high ability pupils made participant requests.

D. Summary of Results

Considering all three grade levels only three of the eight experimental programs examined exhibited reliable differences between pupils in the E and C classes with respect to the proportions that made requests for the mathematics activity bulletin. These differences were found only for ninth and tenth grade programs. For none of the programs did the experimental - conventional program differences occur for all of the sex by ability classifications, which indicates that there were no overall instructional differences for any of the programs independent of sex and ability factors.

Table 6

Number of E and C class pupils in each request category for eleventh grade experimental program comparisons.

REQUEST CATEGORY		BALL STATE			SMSG			TOTAL	
		E	C		E	C			
Higher Ability									
Males	N-R	53	58	111	33	59	92	203	
	NP-R	21	14	35	12	18	30	65	
	P-R	19	14	33	12	9	21	54	
		93	86	179	57	86	143	322	
Females	N-R	37	31	68	24	40	64	132	
	NP-R	13	6	19	8	9	17	36	
	P-R	12	12	24	9	12	21	45	
		62	49	111	41	61	102	213	
Total	N-R	90	89	179	57	99	156	335	a
	NP-R	34	20	54	20	27	47	101	
	P-R	31	26	57	21	21	42	99	
		155	135	290	98	147	245	535	
Lower Ability									
Males	N-R	56	68	124	41	47	88	212	
	NP-R	13	24	37	10	18	28	65	
	P-R	8	8	16	5	4	9	25	
		77	100	177	56	69	125	302	
Females	N-R	30	40	70	20	32	52	122	
	NP-R	11	8	19	7	10	17	36	
	P-R	1	7	8	3	4	7	15	
		42	55	97	30	46	76	173	
Total	N-R	86	108	194	61	79	140	334	
	NP-R	24	32	56	17	28	45	101	
	P-R	9	15	24	8	8	16	40	a
		119	155	274	86	115	201	475	

Significant differences:

a - H vs. L (across sex and instructional conditions), $p < .01$ for N-R x NP-R x P-R

For two of the three programs for which reliable differences were observed (UICSM - 9th grade, higher ability girls; UICSM - 10th grade, higher ability boys and all lower ability pupils) the differences were in favor of the pupils in the respective experimental programs, i.e. the greater proportion of pupils making requests were in the E classes rather than the C classes. For one of these comparisons, UICSM - 10th grade, lower ability pupils, the differences occurred only in the P-R category, the category assumed to be indicative of greater interest, there being no difference in proportions in the NP-R category. For the other two comparisons, UICSM - 9th grade, higher ability girls and UICSM - 10th grade, higher ability boys, the differences were obtained only when proportions for both request categories were combined - the small frequencies precluding any more exact determination of the nature of the request differences.

The remaining instructional difference, SMSG 9th grade, high ability pupils, favored the conventional program in that there was a smaller proportion of experimental program pupils that made requests. However, this difference was observed only for the NP-R category, there being no difference in the proportion of pupils that made participant requests.

With respect to sex differences considered within each level of ability, the only difference was observed at the 9th grade level. Among lower ability 9th grade pupils a greater proportion of girls made participant requests than boys with no differences occurring for the NP-R category.

At each grade level considering all pupils independent of sex and instructional program, significant differences for both NP-R and P-R categories were obtained when comparisons were made between pupils of higher and lower mathematics ability. In every instance the greater proportion of pupils making requests were the higher ability pupils. However, at the ninth grade level the ability differences appears to be attributable to a strong difference in this respect for boys rather than girls, a factor that is reflected in the sex differences noted above at this grade level.

IV. Discussion

The fact that a rather limited number of instructional program differences were observed would seem to indicate that the instructional variations considered in this study do not have any strong effect on pupil interest at least for the behavioral index of interest that was used.

However, among the programs considered, the differences observed for the UICSM programs at the ninth and tenth grade levels indicate that the Illinois programs may be having some modest effect on pupil interests as measured in this study.

In this connection it is of interest to note one difference between the UICSM program and the other programs examined in the study. Each of the experimental programs recommends and includes instructional content and suggestions representing more recently emphasized pedagogical principles and techniques such as student involvement, discovery learning, developmental lessons, and the use of situational contexts with which the pupil can identify. However, the UICSM program appears to do so more consistently and extensively and ties together more closely the pupil exercises and teacher commentary reflecting these pedagogical principles and devices. In brief, the UICSM program appears to impliment the use of motivationally relevant instructional methods and techniques by building them into the instructional content whereas the other programs rely to a greater extent upon the teacher to do so independent of the program.

At the same time it needs to be recognized that among the number of separate instructional condition comparisons carried out in this study, a certain proportion are likely to reach the level of statistical significance on the basis of chance factors alone.

With respect to sex differences, this factor also did not appear to have any pronounced effect, occurring only in the ninth grade as an interaction with ability. The fact that there were no sex differences at the tenth or eleventh grade levels possibly reflects the operation of selection factors at each successive grade level.

In general, mathematics ability appears to be a factor associated to a greater extent with the index of pupil interest employed here than either sex or instructional program variations. One possible explanation of this may be that ability is correlated with interest in the material. Also it may be that pupils having, in addition to a certain level of interest, some degree of confidence in their problem-solving or mathematics skills tended to continue responding when a problem solving task was introduced while those with less confidence did not.

The latter explanation appears to be more in accord with the results that were obtained in that a greater ability difference was observed for those in the participant category than for those in the nonparticipant request category.

There is then, a question of whether ability or interest is more of a factor related to (or contributing to) the pupil request behavior that was observed herein. This question also bears on the underlying assumption that pupils in the alternate request categories differ, on the average, in their level of interest.

It was possible to examine these questions for the ninth grade pupils for most of whom end-of-year scores on an index of expressed interest in mathematics, developed by Aiken (1), and on a mathematics achievement test were available. This data was used to determine whether the pupils in each request category differed with respect to their mean scores for each of these variables and to determine the relative degree of association existing between these measures and the bulletin request index of interest.

For ninth grade males and females separately, means, standard deviations, and within-quartile frequencies for pupils in each of the three request categories were determined for these measures. This information is shown in Table 7. An analysis of variance and the Newman-Keuls procedure were used to test the differences between the request category means. The results of which are also shown in Table 7.

A statistic omega-squared (ω^2) suggested by Hays was computed from the variance estimates as an index of association. Omega-squared represents the proportion of the scale or test variance accounted for by the request index categories and Omega consequently is an estimate of the correlation between the bulletin request index and the interest or achievement test scores.

Table 7 Means, standard deviations and within quartile frequencies for pupils in each bulletin request category for scores on end-of-year measures of interest and achievement in mathematics.

Measure of expressed interest in mathematics - Aiken scale :

Request Category	Males Quartile 1	2	3	4	TOT	$\bar{X}$	s.d.	Females Quartile 1	2	3	4	TOT	$\bar{X}$	s.d.
N-R	42	36	34	19	131	3.24	0.84	38	41	32	29	140	2.91	0.92
NP-R	9	21	21	15	66	3.57	0.68	15	13	15	15	58	3.10	0.92
P-R	5	5	6	23	39	3.91	0.72	4	4	8	13	29	3.56	0.91
Totals	56	62	61	57	236	3.44	0.62	57	57	55	57	227	3.04	0.94

Males: $F = 12.3$, $p < .001$, $\omega^2 = .087$, $\omega = .30$
P-R > N-R, $p < .01$; P-R > NP-R, $p < .05$; NP-R > N-R, $p < .05$

Females: $F = 6.15$, $p < .005$, $\omega^2 = .043$, $\omega = .21$
P-R > N-R, $p < .01$; P-R > NP-R, $p < .05$

Measure of achievement in mathematics - STEP

Request Category	Males Quartile 1	2	3	4	TOT	$\bar{X}$	s.d.	Females Quartile 1	2	3	4	TOT	$\bar{X}$	s.d.
N-R	41	32	35	28	136	280.36	12.93	38	41	33	25	137	273.75	16.05
NP-R	12	25	16	12	65	281.68	11.56	11	13	13	20	57	279.09	11.22
P-R	3	9	8	17	37	287.62	8.56	8	2	5	11	26	280.69	14.65
Totals	56	66	59	57	238	281.85	12.20	57	56	51	56	220	275.95	15.00

Males: $F = 5.3$, $p < .01$, $\omega^2 = .035$, $\omega = .19$
P-R > NP-R, $p < .01$; P-R > N-R, $p < .01$

Females: $F = 4.1$, $p < .025$, $\omega^2 = .020$, $\omega = .17$
No significant differences between pairs of means

The results shown in Table 7 indicate that for the measure of expressed interest, the Aitken scale, the differences between category means are more reliable and there is a higher degree of association with the bulletin request index than is obtained for the measure of achievement. The differences between the interest and achievement measures are however much more apparent for males than females. This provides some evidence, from an independent measure of mathematics interest, that the request categories do represent different levels of interest in mathematics in general and that interest is at least as if not more strongly related to request behavior than is the pupils' level of achievement.

The within-quartile frequencies for pupils in each request category shown in Table 7 indicates that the overt behavioral bulletin request index of interest elicits responses indicative of high interest from some pupils who have relatively low expressed interests and/or ability in mathematics. This, of course, is also reflected in the relatively low degree of association found between the bulletin request index and the measures of expressed interest and achievement. This in turn suggests that the bulletin request index is tapping somewhat different individual characteristics than the other measures.

The lack of any strong association between the bulletin request index and the index of expressed interest may be due in part to certain limitations inherent in the bulletin request index as a measure of interest and/or the procedures used to obtain this measure.

One of these limitations concerns the request procedure itself. The procedure did not require an unequivocal reaction at any given point in time. Consequently, it is possible that a variety of interest irrelevant factors such as pupils' misplacing the initial request form or forgetting about the bulletin altogether could have occurred over time. These incidental events may have precluded, in some instances, an indication of even a moderate level of interest that possibly existed for some pupils. This means in effect that the "no request" category probably cannot be considered a very reliable indicator of low or negative interest at least not too the same extent that the requests indicate some level of positive interest. Another limitation (not unrelated to the above) is that the bulletin request procedure provided only for the manifestation of several degrees of <u>positive</u> interest but did provide for any differential indication of negative interest. That is, it does not distinguish among pupils having anything from neutral to strongly negative attitudes toward mathematics. Both of these limitations reflect the fact that the request procedure establishes a fairly high response threshold which tends to detect only those with relatively stronger overt response tendencies in addition to a certain degree of positive interest and consequently, tends to group together (in the "no request" category) pupils with interests ranging from moderately positive to strongly negative. In brief, it does not provide a sensitive differentiation over the entire continuum of interest that might exist, and also probably reflects an overt activity characteristic in addition to the interest factor.

In conclusion then, the experimental mathematics programs considered in this study did not, with the possible exception of the UICSM program, exhibit any consistent differential effects relative to conventional programs on pupil interest in mathematics as manifested by an overt participation index of interest. The limited occurrence of differential effects may have been due in part to the limited sensitivity of this index of interest. For the UICSM program there is some evidence suggesting that it may have contributed to a greater amount of pupil interest in mathematics than the conventional programs taught by the same teachers. However, evidence obtained from other and possibly more sensitive indices of interest and from a broader sample of teachers and classes would be necessary before any conclusive generalization is possible concerning the UICSM program.

Summary

Pupils in sixty ninth, tenth and eleventh grade experimental (Ball State, UICSM, and SMSG) and paired conventional mathematics classes were given the opportunity to obtain each in a series of specially prepared "mathematics activity journals" following distribution of the first issue to all pupils. Requests, requiring for later issues evidence of relevant respondent involvement (attempted solutions to "journal" problems), provided a behavioral index of interest in mathematics.

Comparison of request frequencies among the experimental and conventional classes within sex, mathematics ability, and grade levels, provided some modest evidence that the UICSM experimental program at the ninth and tenth grade might have contributed to a greater pupil interest in mathematics. A sex by ability interaction was observed at the ninth grade level with lower ability girls responding more frequently than lower ability boys. At all grade levels higher ability pupils were consistently observed to respond in significantly greater proportions than lower ability pupils.

Comparisons for ninth grade pupils between bulletin request categories and separate indices of interest and ability provided some evidence that interest rather than ability or achievement factors are associated with the observed request behavior.

References

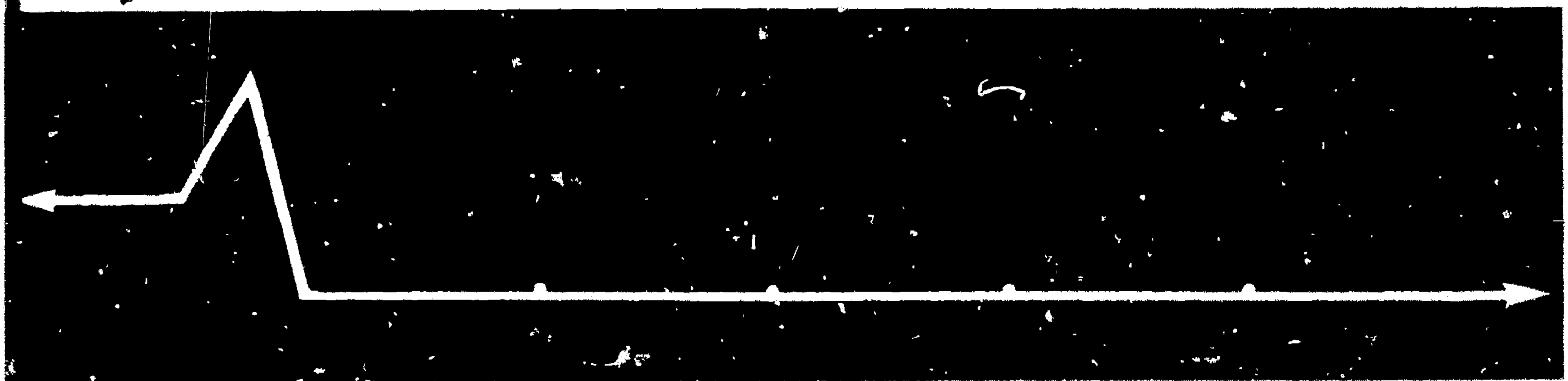
(1) Aiken, L. R., Personality correlates of attitude toward mathematics. J. Educ. psychol. 1963, 56 476-480.

(2) Castellan, N. J. Je., On partitioning of contingency tables. Psychol. Bull. 1965, 62, 330-338.

(3) Hays, W. L., Statistics for psychologists. Holt, Rinehart & winston, New York, 1963.

Appendix:

A. A copy of an issue of the mathematics activity bulletin, "Angles on Mathematics".



THE SEVEN BRIDGES OF KOENIGSBERG

The science of topology was founded when Euler, (pronounced oiler), one of the greatest mathematicians in all history, analyzed the problem of the seven bridges of Koenigsberg.

In the small German town of Koenigsberg, seven bridges crossed a river, as shown in Figure 1. It was a favorite pastime to try to plan a stroll so that each of the seven bridges would be crossed exactly once. Repeated trials seemed to indicate that this was impossible, but no one was able to prove that it could not be done.

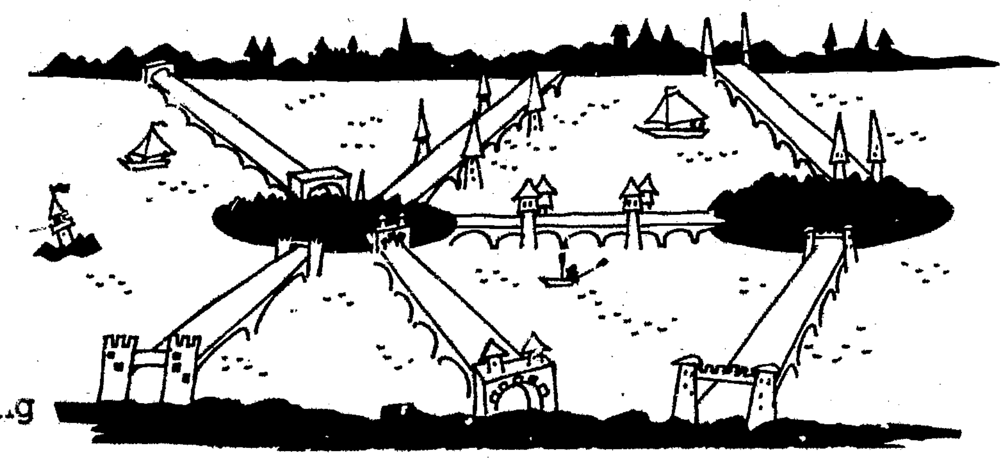


Figure 1

Euler simplified the problem by drawing a graphic diagram, replacing the land areas by points and the bridges by lines connecting these points. The problem of the bridges was now reduced to this: Is it possible to draw Figure 2 without lifting your pencil from the paper, and without going over any lines? The diagram of Figure 2 is often called a network. Lines of the network are called arcs, and the points where the arcs meet are called vertices. Each vertex is odd or even depending on the number of arcs leading to it. Thus, in Figure 2, vertices A, C, and D are odd: each is the meeting place of three arcs. Vertex B is odd also, since five arcs meet at that point.

Euler discovered and proved that a network can be traversed (or traced with a line) over each arc once and only once, if the graph contains only even vertices. In this case the tracing line may start at any vertex but will always finish at the same vertex. He further proved that if the network contains exactly two odd vertices it can be traced, but that it is not possible to return to the starting point. In this case the tracing line must start at one odd vertex and finish at the other. The third of his theorems gives the solution to the original problem: A network with more than two odd vertices is impossible to traverse.

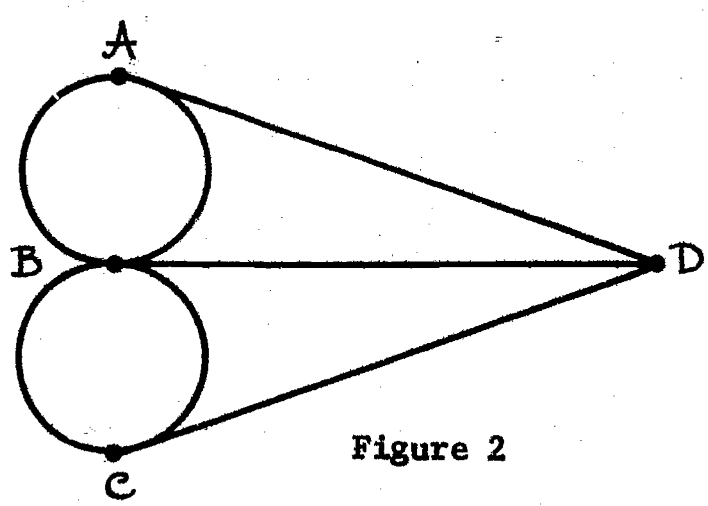
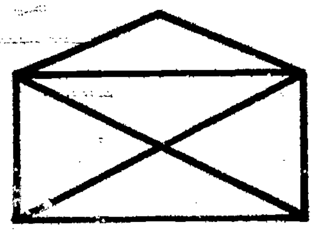


Figure 2

. . .TO GET THE NEXT ISSUE TURN TO PAGE THREE!

The Koenigsberg bridges? This system has four odd vertices. It is then impossible to take an evening stroll over all bridges without recrossing at least one bridge.

To understand these simple but basic topological theorems, you should try drawing figures to illustrate each type of network: All even vertices, two odd vertices, more than two odd vertices. Some of the following figures can be drawn without lifting your pencil or retracing a line, while others cannot. First see if you can determine, using Euler's laws, which can be traversed in only one journey. Then actually trace those that are possible to trace.

1.


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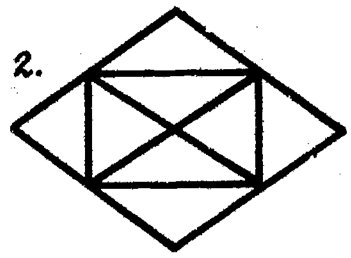

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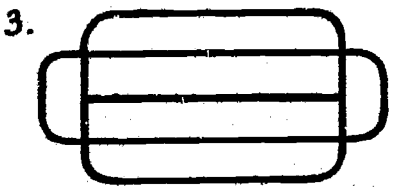

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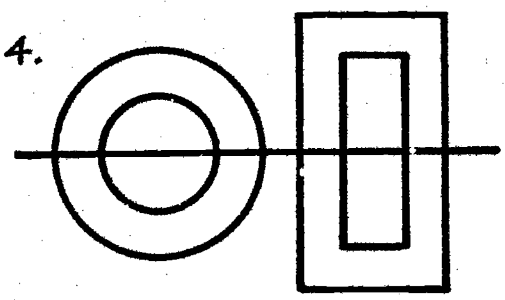

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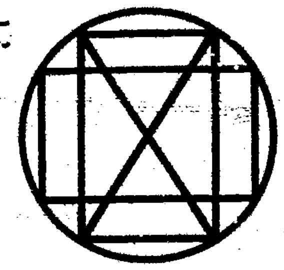


If you have mastered these ideas you may wish to examine and try to justify some further theorems about networks: (1) In any connected network there is always an even number of odd vertices. (For this theorem zero is an even number and connected means that you can always trace from one place on the network to all others.) (2) There is no network with just one odd vertex. (Even if you cannot prove (1), can you use it to prove (2)?)

TOPOLOGY, The "Rubber-Sheet" Geometry

Is a triangle equivalent to a rectangle or a circle? Is a cube equivalent to a sphere? According to topological theory, they are equivalents.

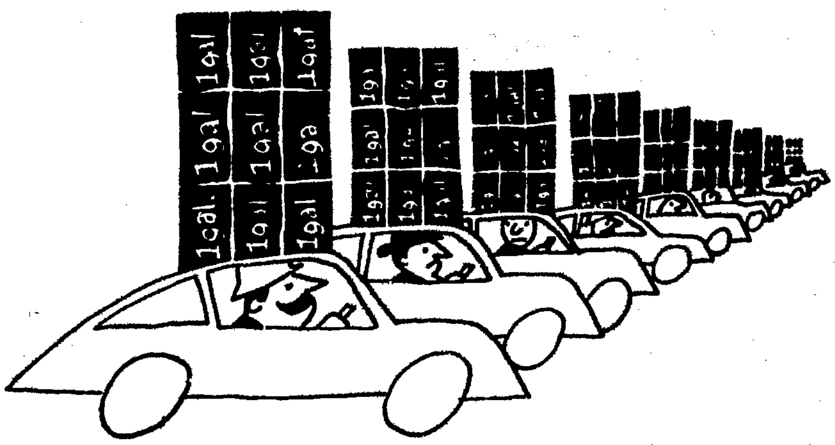
Topology is a kind of geometry, but it differs from conventional high school (or Euclidean) geometry in the following way: In conventional geometry, a figure may be moved through space without changing its size and shape. It is a quantitative geometry, one that deals with the sizes of things — lengths, areas, and volumes. Topology, on the other hand, deals with figures that may be distorted, changing their size and shape. Topology is a geometry which ignores sizes and concentrates on other types of questions, such as whether a certain point is inside, on, or outside a certain closed curve or surface.

In topology we are interested in those properties of geometric figures that do not change when the figures are deformed by bending, stretching, or molding. Thus closed plane figures — triangles, squares, circles, irregular polygons — are topologically equivalent to one another, since each can be deformed into the others. Similarly a cube is topologically equivalent to a sphere, since these can be deformed or molded into one another without tearing or breaking a surface. However, a sphere is not equivalent to a torus (doughnut shaped figure) since these cannot be deformed into one another. Because the definitions and theorems of topology consider a figure which can be bent, stretched, or molded, topology has been called the "rubber-sheet" geometry.

HOW TO GET THE NEXT ISSUE OF ANGLES ON MATHEMATICS

Print your name and home address on the back of the attached postcard, and mail the postcard. If you do this, within a short while you will receive a new issue of Angles on Mathematics at your home. Further issues will not be available from your school or teacher.

YOU MUST FILL OUT AND MAIL THE POSTCARD TO OBTAIN THE NEXT ISSUE.



1. Nine explorers, with as many cars, set out to explore a desert by proceeding due west from its eastern edge. Each car can travel 40 miles on the one gallon of gas its tank holds, and can also carry a maximum of nine extra gallon-cans of gas which may be transferred unopened from one car to another. No gas depots may be established in the desert and all the cars must be able to return to the eastern edge camp. What is the greatest distance one of the cars can penetrate into the desert?

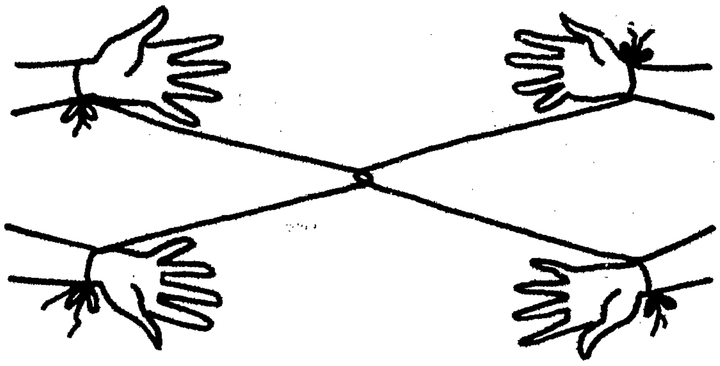
2. Every person who has lived on earth has made a certain number of handshakes. Can you explain how we can be positive that the number of people who have made an odd number of handshakes is even? (The solution to this problem is closely related to the Koenigsberg Bridge problem.)

TOPOLOGICAL PUZZLES:

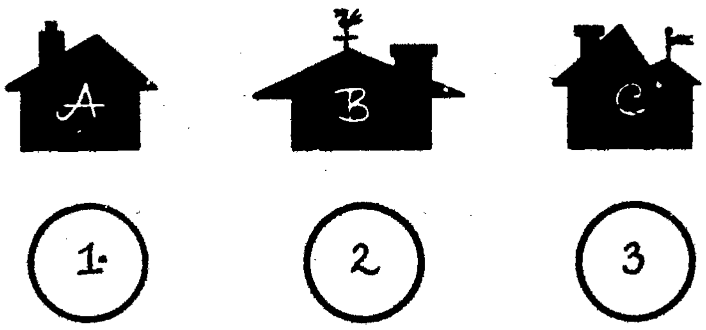
1) Lay a piece of rope or cord on a table. Challenge anyone (or try yourself) to seize one end in each hand and tie a knot without letting go.

2) Put on a vest and then a jacket. Now try removing your vest without removing your jacket. The jacket and vest may be unbuttoned, but at no point during the removal of the vest may your arms slip out of the coat sleeves.

3) To work on this puzzle you will need a partner. Tie each end of a piece of string to one of your wrists. Your partner should tie another piece of string to each of his wrists, first linking his piece of string with yours, as in the diagram. The problem is to unlink yourself from your partner without cutting, tearing, or untying the string. This <u>can be accomplished</u>.



4) There were three neighbors who lived in houses A, B, and C. Each wanted an electric line, a water line, and a gas line direct to the respective utility plants numbered 1, 2, and 3. But each neighbor refused to allow any line to cross any other line. Can the lines be laid to satisfy all three neighbors? Can you give a reason for your answer?

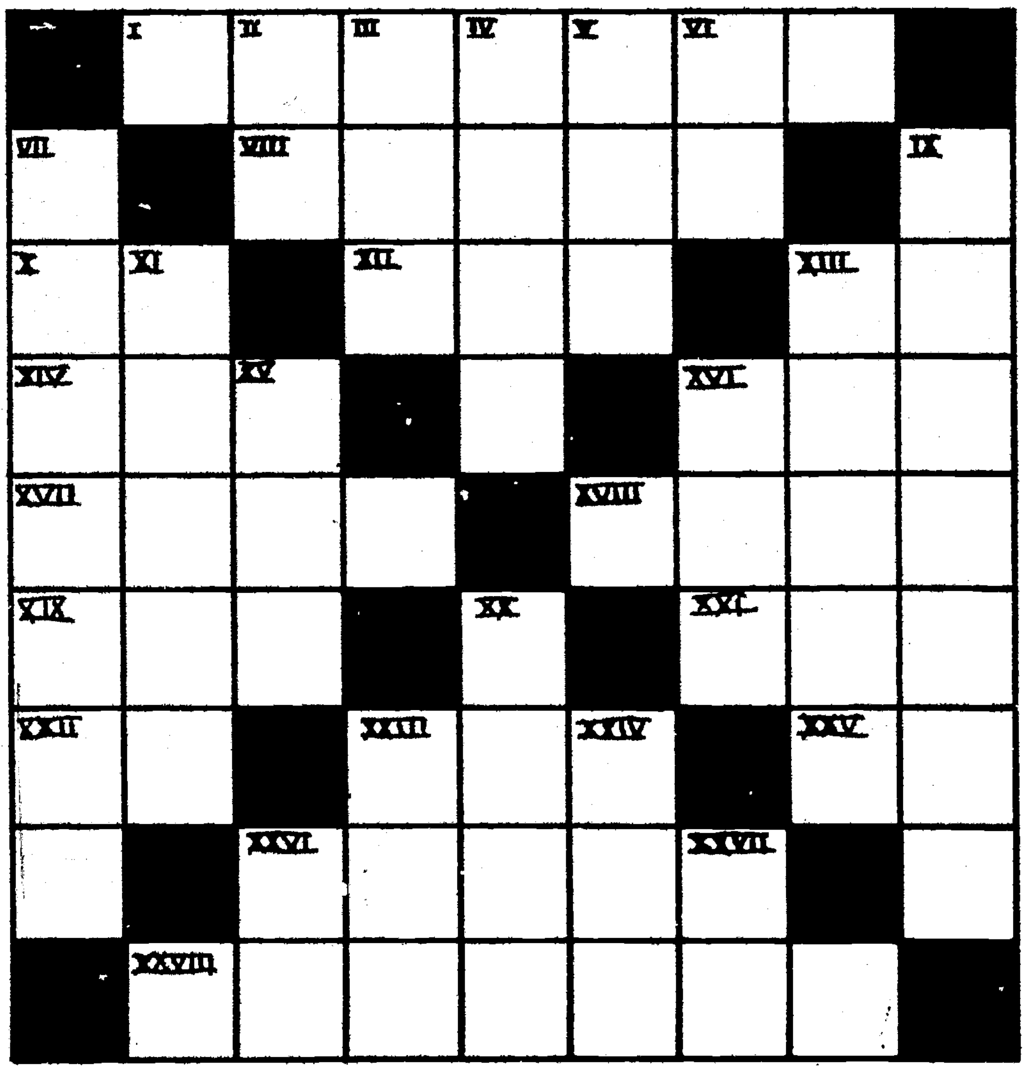


X Marks the Spot

Fill in the blank spaces with the <u>Roman numerals</u> corresponding to the definitions given.

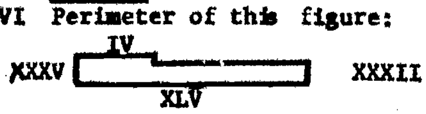
<u>ACROSS</u>

I Year of election: Johnson vs. Goldwater
VIII Song title: "_______ Trombones"
X A man bought a painting for $L and sold it for $CL. His profit was _______%.
XII The number of days in III weeks
XIII Solve for P: IV P + LXIX = DIX
XIV Washington _______ followed by I
XVI Multiply: I · II · III · IV · V
XVII A baker's dozen plus $\frac{III}{IV}$ dozen
XVIII (XXVIII Across) minus (XIX)
XIX C·a + X·b + c where a = b = c = I
XXI Square the number of sides a pentagon has
XXII Time is sometimes considered to be the ____th dimension
XXIII DCXCIX + I
XXV The smallest "perfect number"
XXVI Solve for G: G^2 = DXXIX
XXVIII $(XXXIII)^2$



<u>DOWN</u>

II $(XII)^2 + \frac{XII}{II}$
III Solve for A: $\frac{VIII}{III}A$ = MMDCCXX
IV Around the World in _____ Days
V Lincoln was the ____th president of the US
VI "_____ is company, three's a crowd"
VII The year Columbus discovered America
IX four-score and seven
XI $(XV)^2$
XIII Multiply the number of men on a baseball team by the square root of XI DOWN
XV _______ Blind Mice
XVI Perimeter of this figure:



XX One year less than a century
XXIII If you save $X a week, in a year you've saved $____.
XXIV (XXIII DOWN) - (CDXI)
XXVI Ali Baba and the _____ Thieves
XXVII One for the money, _____ for the show