Sex Differences in Mathematics Learning in a Canadian Setting*

Daiyo Sawada, Alton T. Olson, and Sol E. Sigurdson
University of Alberta

Sex differences in mathematics achievement were systematically examined at Grades 3, 6, 9, and 12 using test items written at three cognitive levels (Knowledge, Comprehension, and Application) over five areas of mathematical content (number, algebra, geometry, measurement, and statistics). A province-wide probability sample of 13,079 students was selected using a matrix sampling design. Significant differences in favor of males were found at each grade level, these differences varying directly with cognitive level and grade level. The results are discussed in terms of the current research scene and in terms of unequal opportunity for females in Canada.

Nous avons procédé à un examen systématique des differences de résultats en mathématiques entre garçons et filles des 3è, 6è, 9è, et 12è années. Nos tests comprenaient trois niveaux de cognition (connaissances, compréhension, et application) et portaient sur cinq parties de mathématiques (nombres, algèbre, géométrie, mesures, et statistiques). Nous avons choisi dans toute la province un échantillon probabiliste de 13,079 élèves au moyen d'un plan d'échantillonnage matriciel. Nous avons trouvé dans chacune des années des différences appréciables en faveur des garçons, différences qui varient en relation directe avec le niveau de cognition et l'année. Nous situons nos conclusions par rapport aux recherches actuelles et par rapport à l'inégalité des chances pour les femmes au Canada.

Research activity into sex-related differences as they impact upon mathematics learning, in concert with the recent increased concern for equal opportunity for women in all spheres of endeavor, has heightened in the 1970s (Ernest, 1976; Fennema, 1974, 1976; Glennon & Callahan, 1968; Sherman, 1977). Early studies focussed on the attempt to discover the existence and magnitude of sex differentials in mathematical performance either as a main objective, for purposes of controlling extraneous variance, or simply because it was usually done. These earlier studies, done primarily in the United States, have indicated that males tend to perform better than females, this difference growing larger as students progress through the grades, and showing stronger on items involving mathematical reasoning as opposed to computation alone (Glennon & Callahan, 1968; Suydum & Riedesel, 1969). Some of the studies done in the post-1970 period have offered data supportive of the position that, at least in

* This research was supported by a grant from the Minister's Advisory Committee on Student Achievement of Alberta Education.

part, male superiority in mathematics is due as much to variables of a socio-educational-cultural sort (attitude toward mathematics, differential course work, motivation, career orientation, perceived value of mathematics, and so on) as it is to native ability (Fennema & Sherman, 1977, 1978; Fox, 1976; Levenberg, 1976; Sells, 1976; Sherman, 1977).

In Canada, only two studies have appeared in the literature (Robitaille, 1977; Robitaille & Sherrill, 1979). The dearth of research activity in Canada on sex-related differences in mathematics achievement suggested to the authors that a systematic look at sex differences in mathematics performance across the elementary and high school grades would be in order. One such study found that sex-related differences in mathematics achievement in Canada are similar to those found in the United States (Robitaille & Sherrill, 1979). If the picture of dominant superiority of one sex over the other is found consistently, a mandate for further research into the etiology of such differences would be appropriate so that constructive change might be introduced to ensure equal opportunity for both sexes in mathematics instruction.

The study reported here was done in conjunction with a province-wide mathematics assessment done in Alberta at the Grade 3, 6, 9, and 12 levels (Sawada, Olson, & Sigurdson, 1978). Three basic questions were addressed:

1. Do boys do better than girls in mathematics over the Grades 3, 6, 9, and 12?

2. Do boys do better than girls in mathematics at all cognitive levels (Knowledge, Comprehension, Application)?

3. Are the effects addressed in questions 1 and 2 related to differences in mathematics content?

METHOD

Sample

The present study was conducted as part of a province-wide assessment of achievement in school mathematics done at Grades 3, 6, 9, and 12. At each grade level a list of all schools in the province offering that grade was obtained and stratified according to enrolment in that grade. For Grades 3, 6, and 9, 10% of the schools were randomly selected for each stratum. For Grade 12, 20% of the schools were selected. This procedure resulted in 102 Grade 3 schools, 101 Grade 6 schools, 56 Grade 9 schools, and 50 Grade 12 schools. In each of these schools students at the given grade levels were tested resulting in responses from 3,373 Grade 3 students, 3,068 Grade 6 students, 3,194 Grade 9 students, and 3,444 Grade 12 students.

Tests

The tests used to assess mathematics achievement were based on the Province of Alberta Curriculum of Studies. No standardized commercial instrument was suitable. Instead, a large bank of test items was collected from various national, international, and state mathematics assessment reports including those produced by National Assessment of Educational Progress (NAEP). From this large collection of over 6,000 items appropriate items were selected by matching with objectives in the Alberta Curriculum. If suitable items were not available, they were constructed so that important objectives would not go untested.

This set of appropriate items underwent three rounds of further evaluation, one round by mathematics educators at a university level, and two rounds by practising teachers at the Grade 3, 6, 9, and 12 levels from an urban and from a rural setting. This resulted in the final selection of 120 items at each grade level. Since some items were given at more than one grade level (so-called "common" items) only 275 different items were required to produce the four 120-item test batteries for each grade level. Although many of the items were used at more than one grade level, each of the items was assigned ("targeted") at a given grade level according to the Province of Alberta Curriculum of Studies. Of the 48 items, 132 were of the constructed response type (27.5%) while the remaining 348 (72.5%) were multiple-choice.

Each test item was classified in three ways: (a) grade level (3, 6, 9, and 12); (b) cognitive level (Knowledge, Comprehension, Application); and (c) content (number, algebra, geometry, measurement, statistics). As defined, the three cognitive levels were a modification of Bloom's Taxonomy (Bloom, 1956). The Knowledge and Comprehension levels were taken directly from Bloom. The Application level included Bloom's definition for Application plus all of the higher levels in his taxonomy. The content for all four grades was classified by the topics in (c) above except for a minor exception in Grade 12 where a content strand related to consumer problems was added. In preparation for the matrix sampling scheme that was used, each 120-item battery was partitioned into six booklets of 20 items each at Grades 3, 6, and 9, and four booklets of 30 items each at Grade 12. This meant that no one student had to write for more than 30-40 minutes.

The test booklets underwent two rounds of pilot testing with students. Appropriate modifications were made and a teachers' test manual was produced and pilot tested once. These pilot testing sessions resulted in an easily administered test package for the sample classrooms.

Data Collection

Test packages were prepared for each classroom and sets of these were mailed to the principals of the sample schools. On May 17, 1978, the tests were administered by the teachers across the province. Returns were received from 100% of the schools in the sample. However, not all students were present on the day of testing.

For Grades 3, 6, and 9 the return rates from students were 95%, 90%, and 93% respectively while at Grade 12 the rate was 73%. The lower rate at Grade 12 can in part be attributed to the fact that many of the larger high schools are timetabled much like universities — if a student doesn't have a class at a particular time he is not required to be present at the school. Apparently at 0900 to 1000 on May 17, 1978, only 73% of the sample Grade 12 students were attending classes. The number of students writing each test booklet is shown in Table 1. Each test booklet, and thus each test item, had a minimum of 500 responses in each grade where it was administered.

At the Grade 6, 9, and 12 levels separate machine scored answer sheets were used. At the Grade 3 level, all work was done directly in the test booklets.

RESULTS

Two sets of analyses were done. The first focussed on grade level and attempted to trace sex differences as reflected in mathematics achievement over grade. The second analysis focussed on cognitive level as the reference variable. For each analysis the results for each mathematics content area are presented. Because the consumer related items were given only at Grade 12 they were deleted from the analysis. In passing it was noted that differences in performance on these items favoring boys was more pronounced than on any other content area at Grade 12.

Grade Level Results

As shown earlier in Table 1 each booklet (and therefore each test item) was written by at least 500 students. For each test items the statistic of interest was the percentage of students giving the correct response. Thus, for each test item it can be asked whether the proportion of boys giving the correct response is significantly different from the proportion of girls giving the correct answer. On the basis of the binomial distribution it can be easily calculated that for each grade level, differences in percentage of correct response of from 5 to 10 percentage points anywhere along the scale are significant at approximately the 0.05 level. Likewise differences of from 10 to 15 percentage points are significant at approximately the 0.01 level. The details of these calculations are provided in Sawada, Olson, and Sigurdson (1978). A simple yet valid analysis can be done by doing a tally of all the items that show a significant difference between sexes and then comparing these tallies for each grade level, cognitive level, and mathematics content area.

TABLE 1

Sample Breakdown According to Booklet and Sex

Grade	*Booklet*	*n*	*Girls*	*Boys*
3	A	563	282	281
	B	569	299	270
	C	559	294	265
	D	563	281	282
	E	547	300	247
	F	548	270	278
6	A	520	284	236
	B	517	258	259
	C	500	252	248
	D	509	258	251
	E	511	267	244
	F	507	258	249
9	A	541	270	271
	B	543	271	272
	C	518	271	247
	D	529	261	268
	E	520	251	269
	F	527	276	251
12	A	846	424	422
	B	855	406	449
	C	855	405	450
	D	850	411	439

The first tally, done according to grade level and mathematics content, is shown in Table 2. At each grade level boys scored (significantly) higher on more test items than did girls.

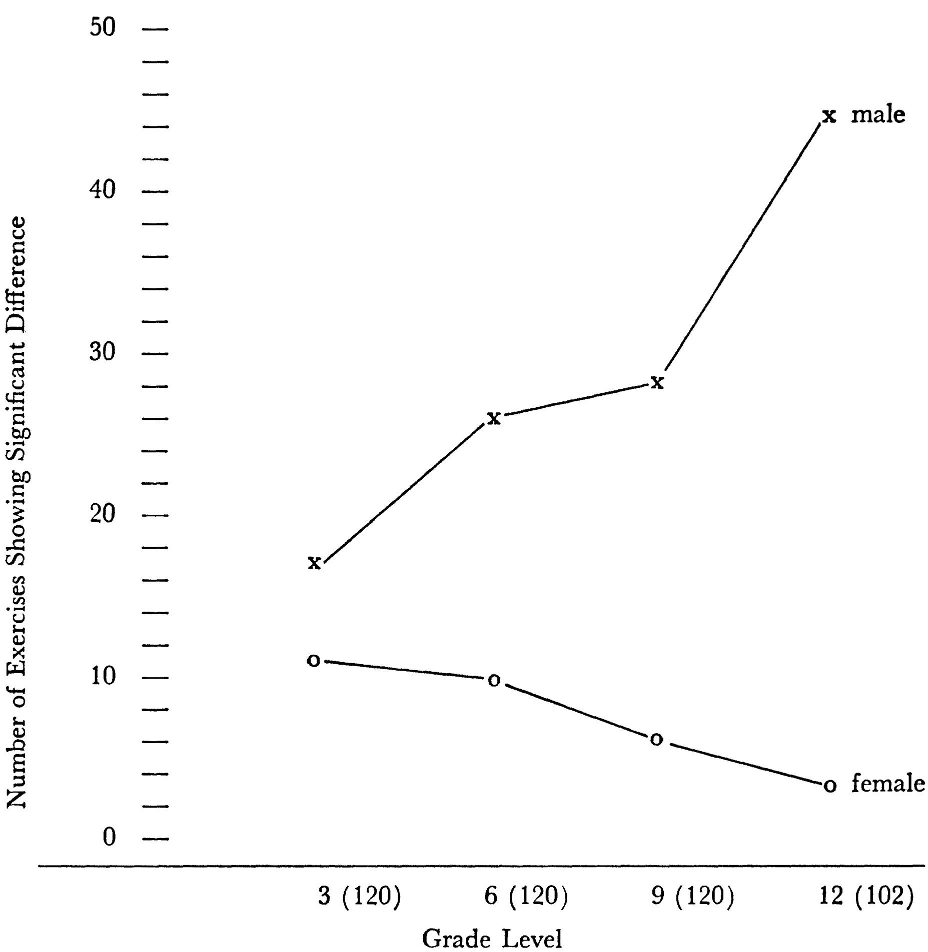
At Grades 3, 6, 9, and 12 boys outperformed girls 17 to 11, 26 to 10, 28 to 6, and 45 to 3 respectively. Over all grade levels, boys outperformed girls 116 to 30. Thus, out of 462 instances of comparison, 146 gave rise to significant differences and of these 146 significant differences, 116 were in favor of boys. These results are rather clear cut. The pattern of differences over the grade levels is of particular interest and is graphically portrayed in Figure 1. It shows that the superior performance of males over females is noticeable at all grade levels and is a monotonic increasing function of grade level. On the other hand the graph of female superiority is always lower than the male graph but more importantly is a monotonic decreasing function of grade level.

TABLE 2

Frequency Count of the Number of Times One Sex Significantly Outperforms the Other per Topic and Grade Level

Grade	Topic	Amount of Difference in Percentage Points							
		5 - 9.9[a]		10 - 14.9[b]		15+		Totals	
		B>G[c]	G>B	B>G	G>B	B>G	G>B	B>G	G>B
3	Number	4	4	3	5	1	0	8	9
	Algebra	0	0	0	0	0	0	0	0
	Geometry	2	1	1	0	1	0	4	1
	Measurement	4	1	0	0	0	0	4	1
	Statistics	1	0	0	0	0	0	1	0
	Totals	11	6	4	5	2	0	17	11
6	Number	8	2	2	2	0	1	10	5
	Algebra	3	0	0	0	0	0	3	0
	Geometry	3	4	2	0	0	0	5	4
	Measurement	2	0	4	0	0	0	6	0
	Statistics	1	1	1	0	0	0	2	1
	Totals	17	7	9	2	0	1	26	10
9	Number	5	2	3	0	0	0	8	2
	Algebra	4	3	2	0	0	0	6	3
	Geometry	7	1	1	0	1	0	9	1
	Measurement	1	0	3	0	0	0	4	0
	Statistics	0	0	1	0	0	0	1	0
	Totals	17	6	10	0	1	0	28	6
12	Number	5	1	2	0	1	0	8	1
	Algebra	13	2	4	0	2	0	19	2
	Geometry	7	0	1	0	2	0	10	0
	Measurement	5	0	3	0	0	0	8	0
	Statistics	0	0	0	0	0	0	0	0
	Totals	30	3	10	0	5	0	45	3
Overall Totals		75	22	33	7	8	1	116	30

[a]Significant at the 0.05 level.
[b]Significant at the 0.01 level.
[c]B>G means boys outperformed girls.



(n) — refers to the total number of items at each grade level

FIGURE 1

Graph of Number of Times Each Sex Significantly Outperforms the Other over Grade Level

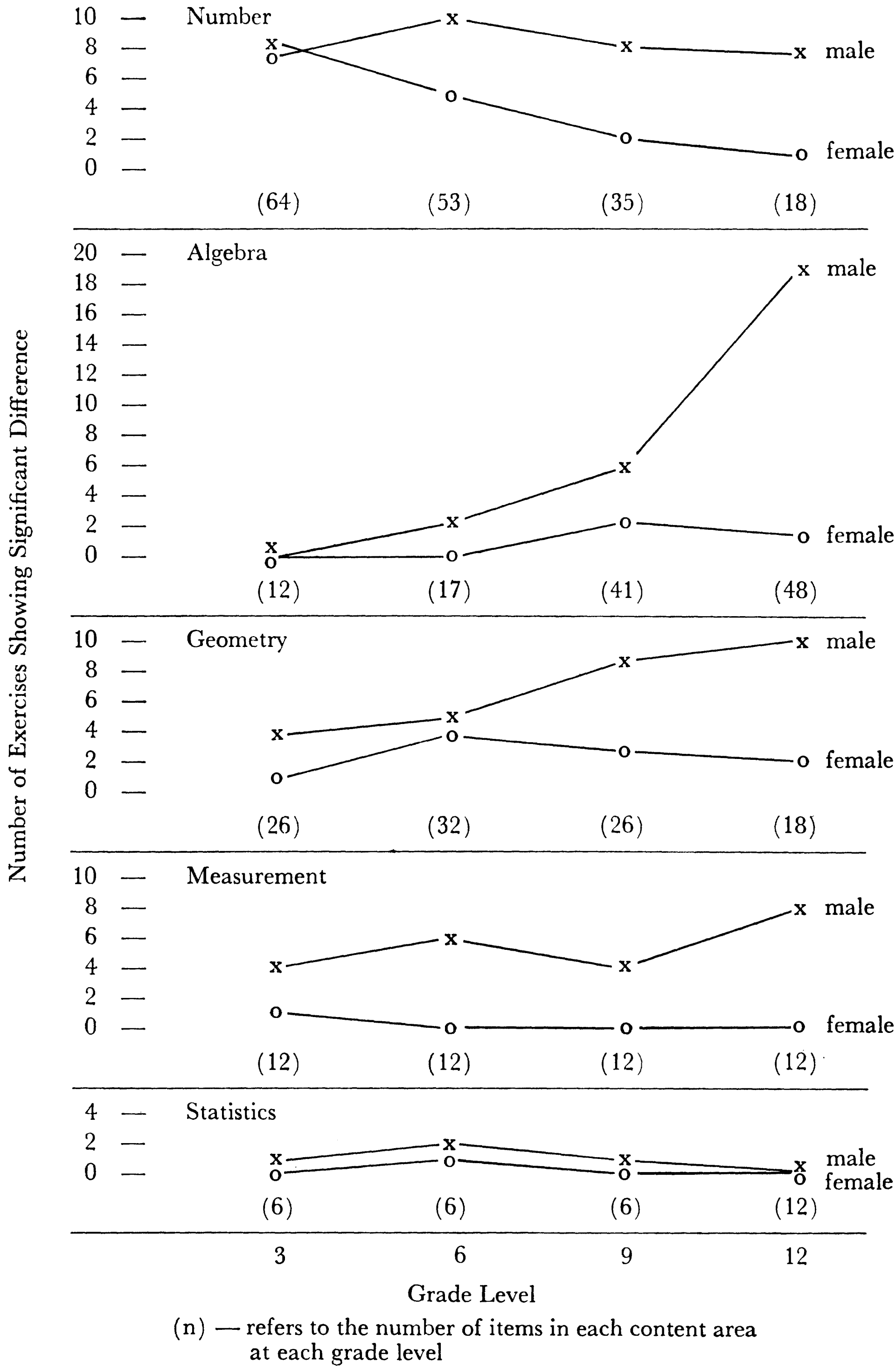


FIGURE 2

Graphs of Number of Times Each Sex Significantly Outperforms the Other for Each Mathematics Content Area

When mathematics content is taken into account (number, algebra, geometry, measurement, statistics), as shown in Figure 2, male superiority remains dominant. Only on the topic of number and only at the Grade 3 level did girls perform better than boys.

Cognitive Level Results

Each of the 257 test items was classified at one of three cognitive levels: (a) Knowledge; (b) Comprehension; and (c) Application. The classification of a particular item was done with reference to the target grade level even though that test item may have been used at another grade level. Therefore, only responses from students at the target grade level for a given item were considered for the cognitive level analysis. Using these performances, a tally was prepared exactly as for the previous analysis but with cognitive level considered as well. The tally is shown in Table 3.

At each cognitive level boys did better than girls: 15 to 9 at the Knowledge level; 30 to 6 at the Comprehension level; and 33 to 2 at the Application level. Graphing these results shows the same type of relationship as was obtained over grade. The graph of male superiority is a monotonic increasing function with cognitive level, whereas for girls it is a monotonic decreasing function (see Figure 3).

When this same relationship is examined in the context of grade level a slightly more refined picture is produced. Figure 4 shows that at the Knowledge level girls actually outperformed boys, but this superiority diminishes and by Grade 9 boys outperform girls at all cognitive levels.

When the factor of mathematics content is considered an even more refined view is obtained. As shown in Figure 5, the success of girls on the Knowledge items at Grades 3 and 6 is due primarily to their performance in the number area. For all other topics and for all cognitive levels boys continue to show superiority.

CONCLUSIONS AND DISCUSSION

Some rather strong results were obtained with respect to sex differences as reflected in mathematics achievement in the Alberta schools.

Conclusions

1. The number of exercises on which boys did significantly better than girls was greater than the number on which girls did significantly better than boys (116 to 30). This was true at each grade level. More specifically, the graph of male superiority over females was a monotonic increasing function with grade; for girls it was a monotonic decreasing function. Thus at Grade 3, boys outperformed girls, and more importantly they steadily increased the difference through to Grade 12.

TABLE 3

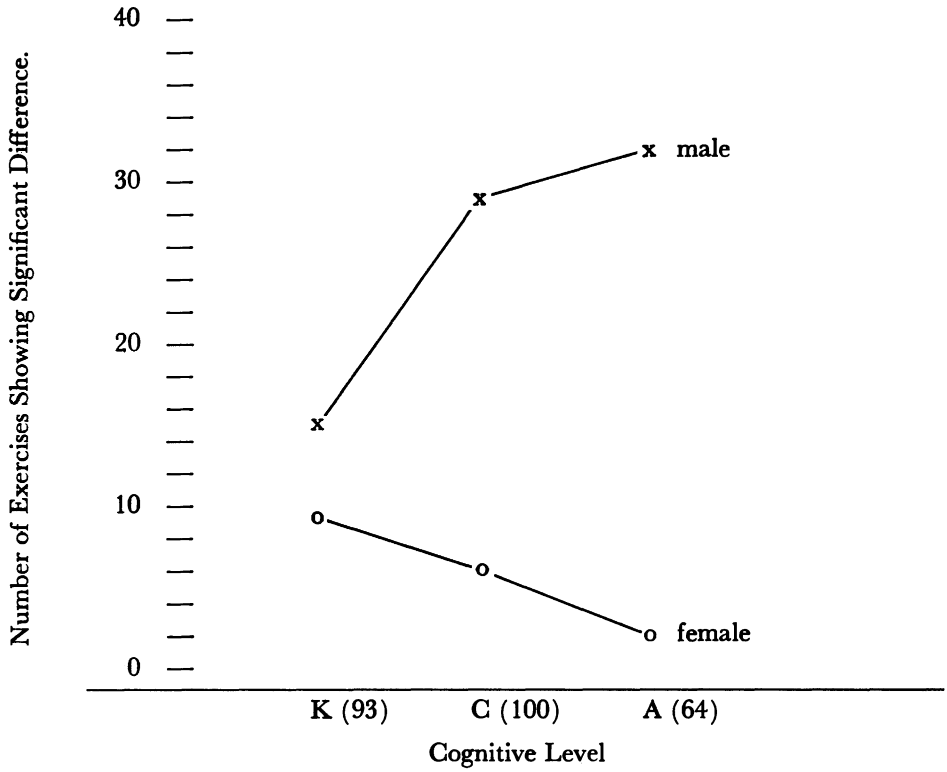
Frequency Count of the Number of Times One Sex Significantly Outperforms the Other at Different Levels of Cognitive Complexity

		Amount of Difference in Percentage Points																	
		5 - 9.9[a]						*10 +*[b]						*Totals*					
Grade	*Topic*	*B>G*			*G>B*			*B>G*			*G>B*			*B>G*			*G>B*		
		K	*C*	*A*[c]	*K*	*C*	*A*	*K*	*C*	*A*	*K*	*C*	*A*	*K*	*C*	*A*	*K*	*C*	*A*
	Number	0	2	0	3	1	0	0	4	0	1	1	0	0	6	0	4	2	0
	Algebra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Geometry	0	1	1	0	2	0	0	0	2	0	0	0	0	1	3	0	2	0
	Measurement	3	0	1	0	0	0	0	0	1	0	0	0	3	0	2	0	0	0
	Statistics	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	Totals	3	4	2	3	3	0	0	4	3	1	1	0	3	8	5	4	4	0
	Number	0	4	2	1	0	0	0	0	0	1	0	0	0	4	2	2	0	0
	Algebra	0	0	3	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
6	Geometry	1	0	1	2	0	0	0	0	1	0	0	0	1	0	2	2	0	0
	Measurement	0	0	1	0	0	0	1	0	1	0	0	0	1	0	2	0	0	0
	Statistics	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
	Totals	1	4	7	3	1	0	1	0	2	1	0	0	2	4	9	4	1	0
	Number	0	2	1	1	1	0	0	3	0	0	0	0	0	5	1	1	1	0
	Algebra	0	1	1	0	0	0	1	1	0	0	0	0	1	2	1	0	0	0
9	Geometry	1	2	1	0	0	0	0	1	1	0	0	0	1	3	2	0	0	0
	Measurement	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
	Statistics	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
	Totals	1	5	3	1	1	0	1	5	3	0	0	0	2	10	6	1	1	0
	Number	2	1	0	0	0	1	0	0	1	0	0	0	2	1	1	0	0	1
	Algebra	3	4	4	0	0	1	1	1	1	0	0	0	4	5	5	0	0	1
12	Geometry	0	1	1	0	0	0	1	0	1	0	0	0	1	1	2	0	0	0
	Measurement	0	0	5	0	0	0	1	1	0	0	0	0	1	1	5	0	0	0
	Statistics	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Totals	5	6	10	0	0	2	3	2	3	0	0	0	8	8	13	0	0	2
	Totals	10	19	22	7	5	2	5	11	11	2	1	0	15	30	33	9	6	2

[a]Significant at the 0.05 level.

[b]Significant at the 0.01 level.

[c]K: Knowledge level; C: Comprehension level; A: Application.



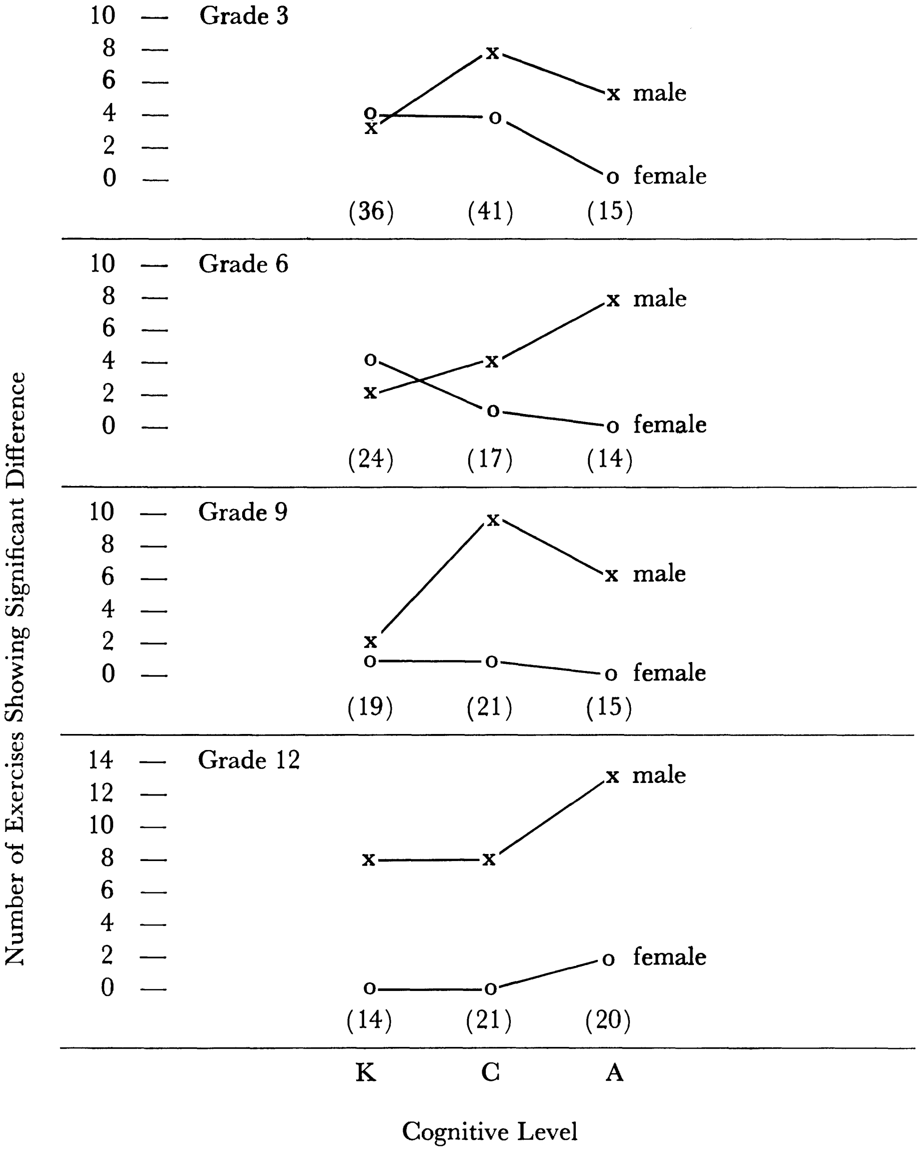
(n) — refers to the total number of items at each cognitive level

FIGURE 3

Graph of the Number of Times Each Sex Significantly Outperforms the Other at Each Cognitive Level

2. With regard to cognitive level, the number of exercises on which boys did significantly better than girls was greater than the counterpart figure for girls at each cognitive level. More interestingly, the graph of male superiority over females was a monotonic decreasing function.

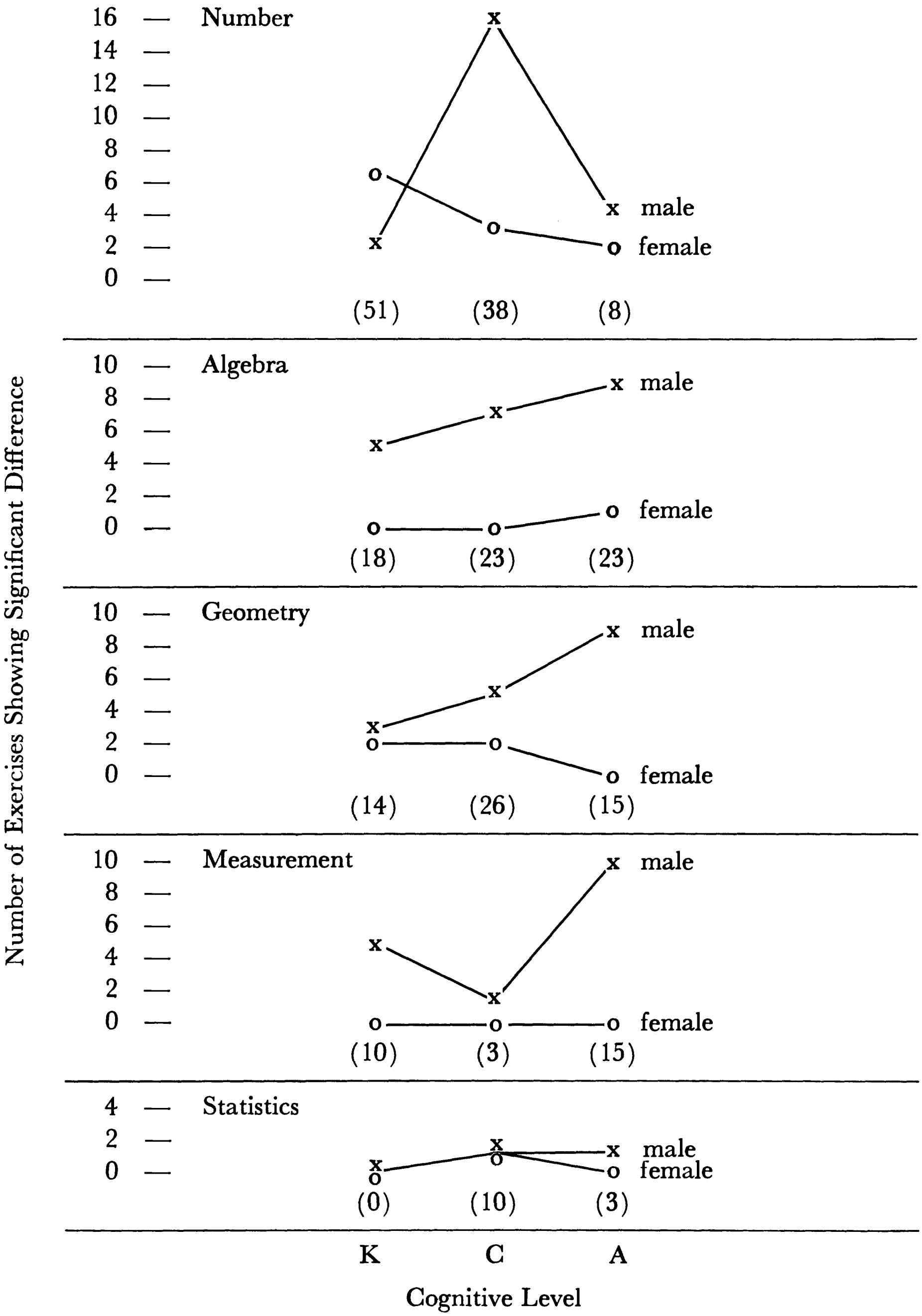
3. In considering all three factors of grade, cognitive level, and mathematics content area, only in the area of number, and only at the Grade 3 level, and only at the Knowledge level did girls do better than boys. It might be noted that results of the assessment in British Columbia (Robitaille & Sherrill, 1979) agree with the above conclusion in finding that girls outperform boys only at the Knowledge level (Computation and Knowledge Domain in the B.C. study). However, their statement that "females outperform males on mathematical objectives which require cognitive behaviors from the lower end of the scale" (p. 51), according to



(n) — refers to the total number of items at each cognitive level for each grade

FIGURE 4

Graphs of Number of Times Each Sex Significantly Outperforms the Other at Each Cognitive Level for Each Grade



(n) — refers to the total number of items at each cognitive level
for each content area

FIGURE 5

Graphs of Number of Times Each Sex Significantly Outperforms the Other at Each Cognitive Level for Different Mathematics Content Areas the present study, is true only for Grades 3 and 6 and only for number content and not for algebra, geometry, measurement, or statistics.

Discussion

It appears that on the basis of a province-wide probability sample, boys in Alberta are better at mathematics than girls. Since current research suggests that much of the differential performance in mathematics is due to socio-educational-cultural variables (e.g., Fennema & Sherman, 1977, 1978) it would appear appropriate to investigate in Canada what sort of socio-educational-cultural variables give rise to male superiority in mathematics. By understanding the factors which produce male superiority, changes may be introduced to ensure that girls will have a fair opportunity to acquire the competence (excellence) in mathematics so essential in many areas of human endeavor.

NOTE

Copies of the *Alberta Assessment of School Mathematics* are available from Planning and Research Branch, Alberta Education, 11160 Jasper Avenue, Edmonton, Alberta T5K 0L2, free of charge.

REFERENCES

Bloom, B. S. (Ed.). *Taxonomy of educational objectives: The classification of educational goals.* New York: Longmans, Green & Co., Inc., 1956.

Ernest, J. Mathematics and sex. *American Mathematical Monthly*, 1976, *83*, 595-614.

Fennema, E. Mathematics learning and sexes: A review. *Journal for Research in Mathematics Education*, 1974, *5*, 126-139.

Fennema, E. *Influences of selected cognitive, affective and educational variables on sex-related differences in mathematics learning and studying.* Paper presented at the meeting of the Educational Research Association, San Francisco, 1976.

Fennema, E., & Sherman, J. Sex-related differences in mathematics achievement, spatial visualization and sociocultural factors. *American Educational Research Journal*, 1977, *14*, 51-71.

Fennema, E., & Sherman, J. Sex-related differences in mathematics achievement and related factors: A further study. *Journal for Research in Mathematics Education*, 1978, *9*, 189-203.

Fox, L. H. Women and the career relevance of mathematics and science. *School Science and Mathematics*, 1976, *26*, 347-353.

Glennon, V. J., & Callahan, L. G. *A Guide to current research: Elementary school mathematics.* Washington, D.C.: Association for Supervision and Curriculum Development, 1968.

Levenberg, L. H. Accuracy of academic self assessment and its relation to age, sex, achievement, I.Q., and self esteem (Doctoral dissertation, Indiana University, 1975). *Dissertation Abstracts International*, 1976, 36A 7299. (University Microfilms No. 76-11, 462).

Robitaille, D. F. A comparison of boys' and girls' feelings of self-confidence in arithmetic computation. *Canadian Journal of Education*, 1977, *2*, 15-22.

Robitaille, D. F., & Sherrill, J. M. Achievement results in the B.C. mathematics assessment. *Canadian Journal of Education*, 1979, *4*, 39-53.

Sawada, D., Olson, A. T., & Sigurdson, S. E. *Alberta assessment of school mathematics: Technical report.* A report submitted to the Minister's Advisory Committee on Student Achievement, Alberta Education, Edmonton, Canada, 1978.

Sells, L. W. *The mathematics filter and the education of women and minorities.* Paper presented at the meeting of the American Association for the Advancement of Science, Boston, February 1976.

Sherman, J. *Summary of effects of biological factors on sex-related differences in mathematics achievement.* Paper presented at the meeting of the American Educational Research Association, New York, 1977.

Suydam, M. N., & Riedesel, C. A. *An interpretive study of research and development in elementary school mathematics. Vol. 1. Introduction and summary: What research says* (Final Report, Project No. 8-0586). Washington, D.C.: Department of Health, Education, and Welfare, 1969.

Daiyo Sawada is a Professor, Alton T. Olson is an Associate Professor, and Sol E. Sigurdson is a Professor, all in the Faculty of Education at the University of Alberta, Edmonton, Alberta T6G 2G5.