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ABSTRACT

This study examined computerized scheduling in 16 Vancouver secondary schools by analyzing (1) the results of a questionnaire to the principals of the schools, (2) class size balancing by computer, and (3) the effect of additional simulate runs on the number of student conflicts and the "date of smooth operation." A simulate run is defined as being the same as a scheduling run except that the operation is stopped after students have been placed in courses of their choice for purposes of predicting possible conflicts in the final run. Results indicated that computerized scheduling saved both secretarial and teacher time, the majority of schools had smoothly operating timetables within the first two weeks of school, and class lists and textbook rental receipts were the most widely used extensions of the computer scheduling system. Analysis of the course masters confirmed that the class size balancing was good. While no significant relationship between the number of simulate runs and the conflict rate could be found, it appeared that additional simulate runs were advantageous. Schools with extra simulate runs were, in general, operating smoothly earlier. (Author/WM)

RESEARCH REPORT

COMPUTERIZED SCHEDULING IN VANCOUVER SCHOOLS

April, 1973

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Research Report 73-05

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Abstract

The purpose of this study was to examine computerized scheduling in sixteen Vancouver secondary schools, fifteen of which use the Honeywell Scheduling Program and one which is served by Columbia Computing Services Limited. This was accomplished by analyzing:

a) the results of a questionnaire to the Principals of the sixteen schools,
b) class size balancing by computer, and
c) the effect of additional simulate runs on the number of student conflicts and the "date of smooth operation".

The principal findings of the questionnaire were:

1. Scheduling students by computer saves both secretarial and teacher time. It was not determined how much time was saved for administrators.

2. Under the computerized system, the majority of schools had smoothly operating timetables within the first two weeks of school.

3. For the schools using the Honeywell Scheduling Program the median conflict rate (the percentage of students per school with conflicts) after the final scheduling run in August was 4.7%. The remaining school, on a flexible modular system of scheduling, had a 62% conflict rate. Conflict rates varied proportionately with the complexity of the timetable system.

4. Class lists and textbook rental receipts were the most widely used extensions of the computer scheduling system.

5. The three main advantages of having computer scheduling were cited as the saving of secretarial time, more complete and accurate student lists, and better balancing of class size.

6. The two main criticisms of the system were that the turn-around time for simulate runs was too long and that the run dates were too early and inflexible.

7. All sixteen Principals wished to continue to have computer scheduling.

The analysis of the course masters confirmed the opinions of the Principals that the class size balancing was good.

While no significant relationship between the number of simulate runs and the conflict rate could be found, it appeared that additional simulate runs were advantageous: schools with extra simulate runs were, in general, operating smoothly earlier.

It was noted that many of the difficulties of the present system could be eliminated through improvement of the present hardware.

COMPUTERIZED SCHEDULING IN VANCOUVER SECONDARY SCHOOLS

A. INTRODUCTION

Computers are a fact of life in Vancouver schools: grade 6 and 7 students are using a computer terminal to improve their arithmetic skills; high school students are learning the fundamentals of programming in computer science classes; and students in eight secondary schools are bringing home computer-produced report cards.[1] This report is concerned with yet another computer application in Vancouver schools: computer scheduling.[2]

Traditionally, the task of scheduling students has been done entirely by hand. However, in recent years the increased number of students, the broader offerings of courses, and the additional flexibility of programs and timetables have put a strain on manual methods of scheduling. Computers have been introduced to alleviate that strain.

The Scheduling Process

The over-all object of student scheduling is to produce a conflict-free timetable (the "master timetable") which allocates students to courses in accordance with their indicated choices. Clearly this must be accomplished within a set of constraints: the availability of teachers, room capacities, student course requests, time pattern of the school day, and so on. The number of sections of each course is another contributing factor: it is theoretically easier to build a timetable for a large school, where a course may have several sections open to students to fit into their schedules, than for a small school which has only one section for a given course. The task of a timetabling committee is to construct a master timetable which takes all such factors into consideration. The resulting timetable has aptly been described as "...the principal, if not the only, bulwark standing between the administrator and chaos."[3] Once this master timetable has been built, students are assigned to class sections within it.

Under a computer scheduling system, the master timetable is likely still to be constructed manually, but computer-produced information may speed its preparation considerably. The tally and the pairing matrix, (see Appendices A and B) listed in step 5 of Figure 1, are two such aids. The tally gives an accurate count of the total number of students requesting each course by course number, sex and grade. The pairing matrix lists the potential student conflicts between

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[1] Studies on these computer applications are now in progress.

[2] A glossary of computer scheduling terms is included at the end of this report (page 27).

[3] Murphy, J. and R. Sutter, School Scheduling by Computer - The Story of GASP, New York: Educational Facilities Laboratories Inc., 1964.

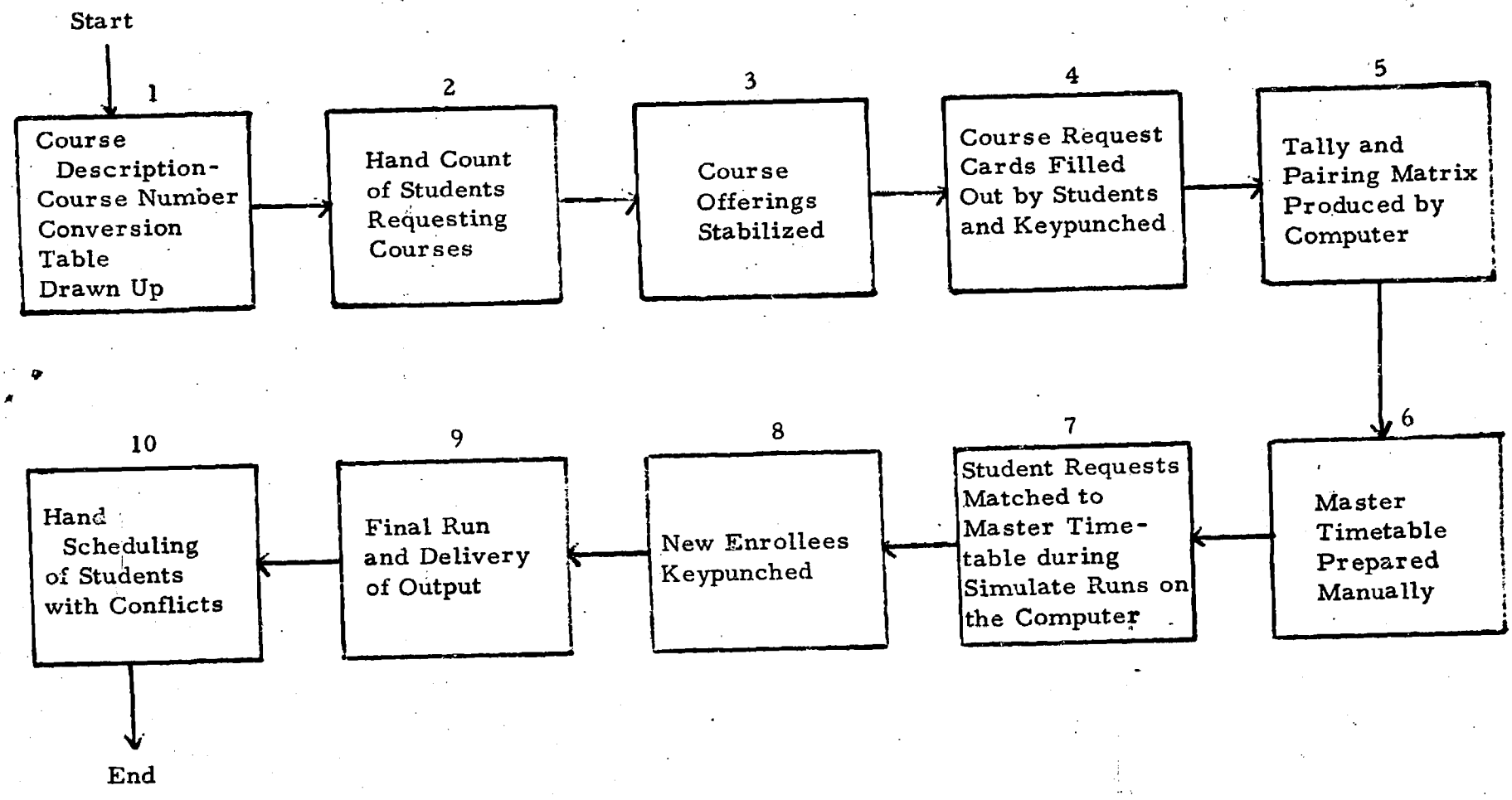

FIGURE 1. Flowchart of the Steps in the Computer-Scheduling of Students in Vancouver Secondary Schools

any two courses (i.e., the number of students that have chosen any two courses). A selective listing of students requesting any one course may also be produced. These statistics provide invaluable assistance to the timetabling committee in their attempt to build a conflict-free master timetable. Simulate runs (step 7 of Figure 1) enable the committee to test and improve the timetable.

The Advantages of Computer Scheduling

The possible advantages of computer scheduling are many, but Richardson and Clark, in their article, "Understanding the Process of Computer Scheduling" cite what they consider to be the "real" advantages:

> In the first place, computers will usually do a better job of scheduling than is done by hand when measured in terms of class balance and the successful scheduling of pupils. This is true for two reasons: First, with computer scheduling, it is possible for the Principal repeatedly to revise his master schedule and try additional scheduling passes (simulate runs). With hand scheduling, the time involved in scheduling the pupils is so great that it is not feasible to revise the master schedule and re-schedule pupils once a large number of them have been scheduled.
>
> Second, the computer does not tire and quit after several trials at scheduling a pupil. Instead, it continues to try different possible schedules for each pupil until it finds the schedule which is best for the pupil and which results in the best possible class balance. In the UPDATE program, the computer may make as many as 100,000 tries for one pupil before settling on a schedule. This results in better class balance than is the case with hand scheduling.[4]

The output from the final computer run has also been cited as an appreciated "extra" of computer scheduling. Most of the resulting lists would not be produced under manual methods, simply because of lack of time and clerical help. The output for each of the fifteen Vancouver secondary schools using the Honeywell Scheduling Program, for example, may include any or all of the following, according to the individual needs of the school:[5]

1. Updated course masters--give the number of seats used (students scheduled) per course section.

2. Conflict pattern for students not scheduled indicates--
   (a) all the courses a student has chosen,
   (b) all the time blocks in which those courses are available,
   (c) the particular time block selected for each scheduled course, and
   (d) the course that conflicts and which has not been scheduled.

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[4] Richardson, D. and J. Clark, "Understanding the Process of Computer Scheduling", School Progress, February, 1969, p. 55.

[5] Source: Dodds, W. "How to Use V.S.B. Computerized Scheduling", Vancouver School Board, March, 1973.

3. Multiple copies of student schedules

4. Alphabetical homeroom lists

5. "Subject Section/Marks Gathering" Form -- used by subject teachers to record students' marks

6. Teacher timetables

7. Program-specialty report--presents a count of the number of students by specialty

8. Alphabetical school lists

9. Textbook rental and fee receipts

10. Master revision cards--contain a copy of the information on the student file (only for schools using the computer grade reporting system)

11. Quick reference copy of school timetable.

The availability of multiple copies of such printed records helps distribute the workload. With additional copies of the master timetable, for example, more teachers and counsellors may assist in the final hand-scheduling of students with conflicts.

Actual research evidence on the merits of the computerized versus the manual approach to scheduling, however, is scarce. A study by Jacobson involving seven high schools which were scheduled by computer and five comparable schools using the manual method did not reveal consistent advantages for either approach.[6] One of the purposes of this study was to determine the viewpoint of Vancouver secondary school principals in regard to this question.

Flexible Modular Scheduling

As mentioned previously, fifteen Vancouver secondary schools are using the Honeywell Scheduling Program on the Honeywell 200 Computer at the Vancouver City College Computing Centre. One school, King George Secondary, is being served by Columbia Computing Services Limited, 1336 West Pender Street, Vancouver 5, B. C.

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[6]Jacobson, M. E., "A Study of Scheduling Problems and Practices in High Schools which Employ and do not Employ Data Processing". Ann Arbor: University of Michigan, unpublished doctoral dissertation, 1966.

King George is involved in what has been described[7] as a "bold departure from traditional scheduling plans": it has adopted a flexible modular system of scheduling. M. Clemens Johnson, in his book Educational Uses of the Computer: An Introduction, describes it thus:

> Modular scheduling represents an attempt to achieve more individualized student programs through changes in the school day and the organization of classes. In modular scheduling the school day is divided into modules as small as fifteen minutes with different courses meeting for varying lengths of time, for instance, two modules for one course, five for another. The key characteristic is flexibility in the organization of the master schedule of classes.[7]

The complexities of a flexible modular system of scheduling are such that in most cases it would be unfeasible to schedule by hand.

B. OUTLINE OF THE STUDY

The purpose of the study was to examine the use of computer scheduling in Vancouver secondary schools. The evaluation consisted of three parts:

1. Questionnaire to Principals - The Principals of eighteen Vancouver secondary schools were asked to complete a questionnaire in an attempt to determine their views on computer scheduling (See Appendix C). They were invited to comment on such aspects of computerized scheduling as the amount of teacher and clerical time required as compared to the time spent under manual methods, the length of time needed to get the timetable running smoothly, the number of residual student conflicts, the use of the optional extensions and innovations of the scheduling system, and what they saw to be the advantages and/or the limitations of computer scheduling. A summary of the responses to the questionnaire appears in section C of this report.

2. Class Size Balancing by computer - The updated course masters were obtained from four schools chosen to represent different school setups (different timetable systems, school size, etc.) A summary of the class size balancing of the four schools was made on the basis of these data. The results appear in section D of this report.

3. Number of Simulate Runs - The number of simulate runs used to produce the final timetable was obtained from each school. A summary of the number of simulate runs and its relation to the conflict rate and the "date of smooth operation" is presented in section E of this report.

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[7] M. Clemens Johnson, Educational Uses of the Computer: An Introduction, Chicago: Rand McNally & Company, 1971, p. 64.

C. QUESTIONNAIRE TO PRINCIPALS RE COMPUTER SCHEDULING

Principals of all sixteen schools using computer scheduling responded to the questionnaire. The questionnaire was not applicable for two secondary schools still using manual methods of scheduling.

Table I presents a summary by school of the responses to items 1 - 6 and 10 of the questionnaire. The number of simulate runs, the timetable system and the population size of each school are also included in the table.

An analysis of the questionnaire responses by item follows.

Question 1 - By what date in September 1972 was the timetable operating smoothly in your school?

The "date of smooth operation" ranged from September 5 to November 9. Table II presents a breakdown of the smooth operating dates of the 16 schools with regard to the timetable system and the school population.

The majority of the schools (62.5%) reported smoothly operating timetables within the first two weeks of school. School number 15 (refer to Table I), with a smooth operating date of November 9, attributed the delay to an unexpected influx of 100 students which necessitated an extensive reshuffling of the timetable. School number 14, with a smooth operating date of October 1, cited the loss of the master tape as the delaying factor.

It appears that those schools on the semester system had fewest problems in obtaining a smoothly operating timetable (all five were operating smoothly within the first two weeks). The dates for the schools on a partial semester system, on the other hand, ranged from the first to the tenth week. With regard to school size, the four smallest schools (as might have been expected) were operating smoothly within the first two weeks.

TABLE I: SUMMARY OF THE RESPONSES OF PRINCIPALS IN SIXTEEN SECONDARY SCHOOLS OF VANCOUVER TO A QUESTIONNAIRE ON COMPUTER SCHEDULING PRACTICES AND THEIR EFFECTS ON THE SCHOOL

School Number	Smooth Operating Date	Time Compared to Hand Timetabling*	Reduces Teacher Timetabling Time?	Saves Secretarial Time?	% of Students with Conflicts	Operating Innovations and Extensions																Total Number Innovations and Ext.	Continue Computer Scheduling?	Number of Simulate Runs	Timetable System**	School Population***
						Partial Semestering	Semestering	Modular Scheduling	Grade Reporting	Attendance Accounting	Marks Analysis	Textbook Rental	Record Keeping	PRC Labelling	Class Lists	Library Loans & Acquisitions	Double Lunch Hour	Extended School Day	Special Needs Identification	Pupil Personnel Data	Data from Guidance Testing Program					
1	Sept. 5	-	Yes	Yes	1.1%		X					X			X					X		4	Yes	2	S	B
2	Sept. 5	-	Yes	No	9.9%	X			X		X	X		X	X				X	X		8	Yes	4	PS	C
3	Sept. 6	Same	Yes	Yes	0.5%		X			X		X			X		X	X		X		7	Yes	3	S	C
4	Sept. 8	Better	Yes	Yes	10.0%	X			X		X	X		X	X					X		7	Yes	3	PS	A
5	Sept. 8	Same	Yes	Yes	1.2%		X					X			X							3	Yes	2	S	A
6	Sept. 12	C. C.	Yes	Yes	1.3%							X			X							2	Yes	2	FY	B
7	Sept. 12	Same	Yes	Yes	4.4%	X	X		X		X			X	X				X	X		8	Yes	1	S	B
8	Sept. 15	Better	Yes	Yes	7.8%		X		X		X	X		X	X				X	X		8	Yes	2	S	A
9	Sept. 15	Same	Yes	Yes	0.7%				X		X	X		X	X				X			6	Yes	2	FY	B
10	Sept. 17	Better	Yes	Yes	4.1%							X			X				X			3	Yes	2	FY	C
11	Sept. 20	C. C.	Yes	No	6.6%	X			X		X			X								4	Yes	3	PS	B
12	Sept. 22	Same	Yes	Yes	5.0%										X					X		2	Yes	2	FY	B
13	Sept. 27	Slower	No	Yes	10.7%				X		X	X		X	X							5	Yes	2	FY	C
14	Oct. 1	Slower	No	Yes	3.7%	X						X			X							3	Yes	2	PS	B
15	Nov. 9	N.A.	Yes	Yes	9.5%	X	X		X		X	X		X	X				X			8	Yes	2	PS	C
16	Sept. 15	C. C.	C. C.	Yes	62.0			X							X		X	X				4	Yes	2	FM	A

* C. C. = can't compare--never done by hand
N. A. = not applicable

** FM = flexible modular
S = semester
PS = partial semester
FY = full year

*** A = < 1500
B = 1500 - 2000
C = > 2000

TABLE II: ANALYSIS OF SMOOTH OPERATING DATES OF TIMETABLES FOR SECONDARY SCHOOLS IN VANCOUVER CLASSIFIED BY TIMETABLING SYSTEM AND SCHOOL ENROLMENT

Week Number	Dates	Number of Schools with Smooth Operation	Timetable System*				School Enrolment		
			S	PS	FY	FM	A (< 1500)	B (1500-2000)	C (> 2000)
1	Sept. 5-8	5	3	2	-	-	2	1	2
2	Sept. 9-15	5	2	-	2	1	2	3	-
3	Sept. 16-22	3	-	1	2	-	-	2	1
4	Sept. 23-29	1	-	-	1	-	-	-	1
5	Sept. 30-Oct. 6	1	-	1	-	-	-	1	-
10	Nov. 4-10	1	-	1	-	-	-	-	1
	Totals	16	5	5	5	1	4	7	5

* S - semester system
PS - partial semester system
FY - full year system
FM - flexible modular system

2. How does your response to item 1 above compare with the time taken when timetabling was done entirely by hand?

TABLE III: SUMMARY OF RESPONSES TO ITEM 2

Response	Number
"Better"	3
"Slower"	2
"Same"	5
"Can't Compare"	3
No Answer	3
Total	16

Two schools reported that it took longer to get a smoothly operating timetable using the computer, one of these being the school whose master tape was lost; on the other hand, two schools on a partial semester system noted that they could not have handled the timetable complexity without the computer.

3. Has the use of computers reduced the amount of time that teachers spend in timetabling activities?

"Yes" - 13 (81.25%)
"No" - 2 (12.50%)
No comparison available - 1 (6.25%)

One school principal commented that using the computer had reduced work for most teachers, but had increased the work for those involved in computer scheduling; another that the work load of counsellors was heavier with the computer system.

4. Does the use of computers in scheduling save secretarial time that can be devoted to other tasks?

"Yes" - 14 (87.50%)
"No" - 2 (12.50%)

One of the schools that answered "no" noted that secretaries have never been used in timetabling work.

5. During the final computer run in August for how many students did the computer print out a conflict sheet?

For each of the schools, a conflict rate was produced by converting the number of students with conflicts to a percentage of the total number of students. A frequency distribution of these conflict rates is presented in Table IV.

TABLE IV: FREQUENCY DISTRIBUTION OF CONFLICT RATES

Conflict Rate	Number of Schools
0.0 - 0.9%	2
1.0 - 1.9%	3
2.0 - 2.9%	0
3.0 - 3.9%	1
4.0 - 4.9%	2
5.0 - 5.9%	1
6.0 - 6.9%	1
7.0 - 7.9%	1
8.0 - 8.9%	0
9.0 - 9.9%	2
10.0 -10.9%	2
11.0% and above (62%)*	1
Total	16

*See explanation in subsequent paragraph.

As mentioned in the introduction, several factors (teachers available, rooms available, time pattern of the school day, etc.) affect the building of the master timetable and consequently the conflict rate. Table V examines the relation between one such factor - the timetable system - and the conflict rate.

TABLE V: THE AVERAGE CONFLICT RATES OF SCHOOLS UNDER FOUR TIMETABLE SYSTEMS

Timetable System	No. of Schools	Average Conflict Rate
Semester	5	3.0%
Full Year	5	4.4%
Partial Semester	5	7.9%
Flexible Modular	1	62.0%

The partial-semester schools (i.e. those which offered both year-length and semester length courses) had a high average conflict rate (7.9%) in comparison with those on the full year (4.4%) and with those on the semester system (3.0%).

The median conflict rate for all the schools was 4.7%.

The exceptionally high conflict rate (62.0%) of the school with a flexible modular scheduling system is misleading. Most of these conflicts were resolved by "backscheduling modules": teachers agreed to hold classes during their free modules (20 minute blocks) to accommodate students who, for example,

might be missing one module in a five-module course because of a conflict on one day. The success of this backscheduling procedure was evidenced by the fact that the timetable was operating smoothly by September 15.

6. The following innovations and extensions may be accomplished with computer scheduling. Check those that are operating in your school.

Table VI summarizes the responses of the principals in regard to innovations and extensions.

TABLE VI: SUMMARY OF INNOVATIONS AND EXTENSIONS USED BY SCHOOLS WITH COMPUTER SCHEDULING

Innovation or Extension	Number of Schools Reporting Use	% of Schools
Class Lists	15	93.75
Textbook Rental	12	75.00
Grade Reporting by Computer	8	50.00
Marks Analysis	8	50.00
Permanent Record Card Labelling	8	50.00
Pupil Personnel Data	7	43.75
Partial Semestering	6	37.50
Semestering	6	37.50
Identification to Subject Teachers of Students with Special Needs	6	37.50
Double Lunch Hour	2	12.50
Extended School Day	2	12.50
Modular Scheduling	1	6.25
Attendance Accounting	1	6.25
Record Keeping	0	0.00
Library Loans and Acquisitions	0	0.00
Data from Guidance Testing Program	0	0.00

It is evident that the class lists and textbook rental receipts produced by the computer are the two extensions most widely used. The mark reporting system, an outgrowth of the scheduling system, is now being used in eight Vancouver Secondary Schools.

7. What do you consider to be the advantages of having computer scheduling? (i. e., what are its strengths and benefits for your school?)

Some of the more frequently cited advantages were:

"Saves secretarial time"	(7)
"More complete and accurate student lists"	(6)
"Better class size balancing"	(5)
"Informative conflict matrix"	(4)
"More information produced for teachers"	(4)
"Better master timetable produced through use of simulates for testing"	(4)
"Greater complexity and flexibility in timetable format"	(3)
"Individualized student timetables"	(3)
"Multiple copies"	(3)
"Timetabling committee time saved"	(2)
"Saves student 'sign up' and resultant chaos"	(1)
"The school is ready for 100% operation on opening day"	(1)

8. What do you consider to be the limitations (if any) of computer scheduling? What constraints does it impose on the operation of your school?

Comments cited regarding limitations and constraints included:

"No constraints"	(6)
"No limitations"	(3)
"Turn-around time for simulate runs too long--slowness of feedback"	(4)
"Early, inflexible run dates--inadequate time allotment"	(4)
"Program itself needs refining--not flexible enough"	(3)
"In spite of continuing improvement of soft-ware, the output to the school continues to be less accurate"	(1)
"Program errors negate advantages if extra work is needed"	(1)
"Procedure for hand timetabling difficult conflicts, late registrants, etc. is very demanding of counsellor time"	(1)

9. What are your expectations from computer scheduling in the years ahead?

Listed below are some of the expectations noted:

"More extensive use of the innovations and extensions listed in item 6"	(7)
"Generation of master timetables"	(4)
"Few conflicts"	(2)
"More flexibility in the final run time"	(2)
"An updating facility"	(2)
"Improved advice, consulting, reference material, etc."	(2)
"Better balancing of classes"	(1)

10. Do you want to continue to have computer scheduling?

Fifteen principals responded with an unqualified 'yes'. One answered "absolutely--but with reservations" and noted a need for greater accuracy and better coordination.

D. CLASS SIZE BALANCING BY COMPUTER

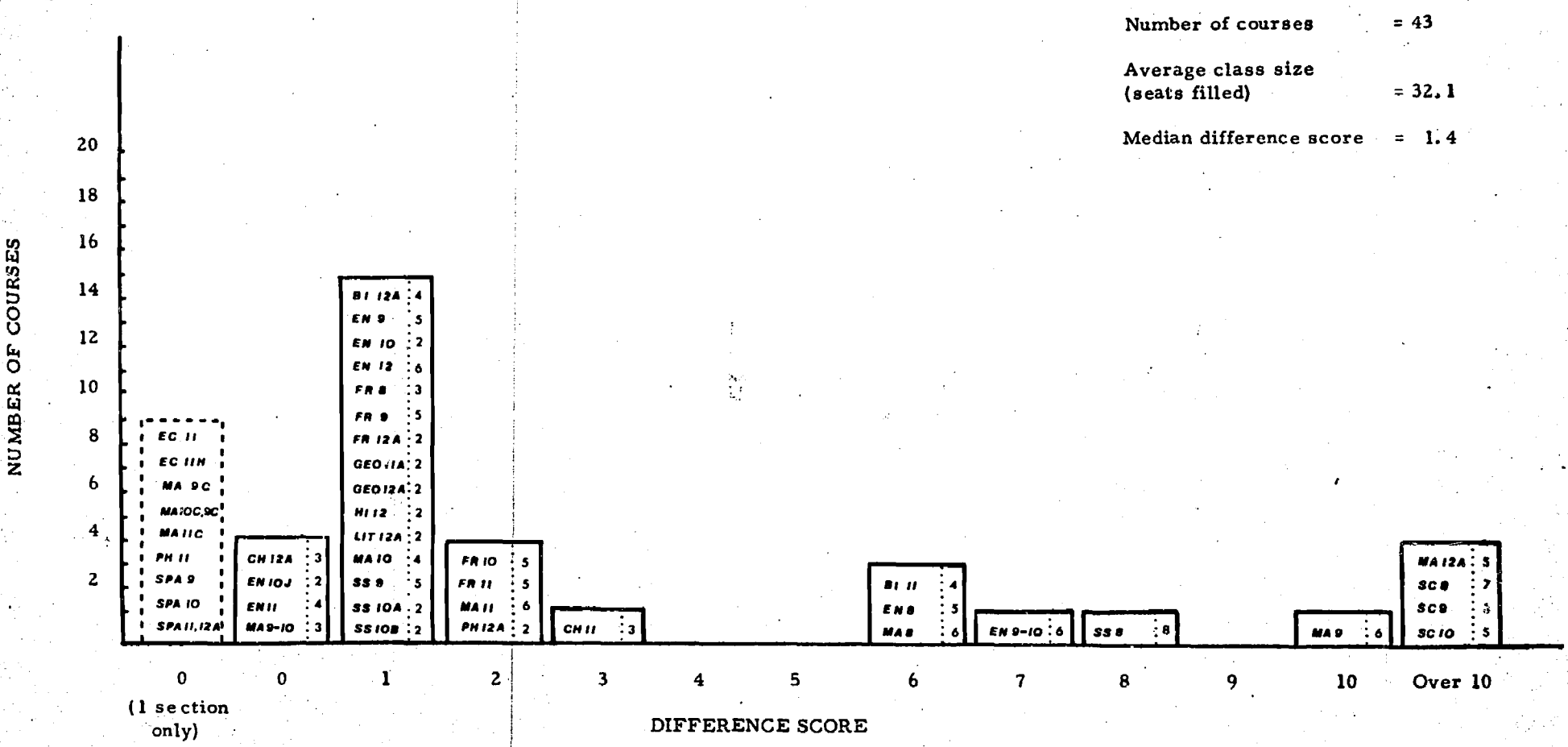
In order to examine the class size balancing by computer, updated course masters (see Appendix D) were obtained from four of the secondary schools, (school numbers 1, 5, 9 and 11 in Table I). The printouts covered first term only courses for schools 1 and 5, full year courses for school 9, and both first term and full year courses for school 11 (on a partial semester system). Schools 1, 9 and 11 had populations between 1500 and 2000 students; school 5 had fewer than 1500 students.

Five subject areas were considered: English, social studies, mathematics, science and languages. It was felt that additional courses, which varied considerably from school to school and which, in general, were small in size, did not provide a valid basis for inter-school comparisons.

Within each subject area, the range of section sizes for each course was determined. A difference score (calculated by subtracting the number of seats in the smallest section of a course from that of the largest section) was determined for all the pertinent courses within each school and the results were represented by means of a bar graph (see Figures 2 - 5). The names of the courses and the number of sections per course are included on the graphs. A large number of courses with low difference scores indicate a "good" class size balancing.

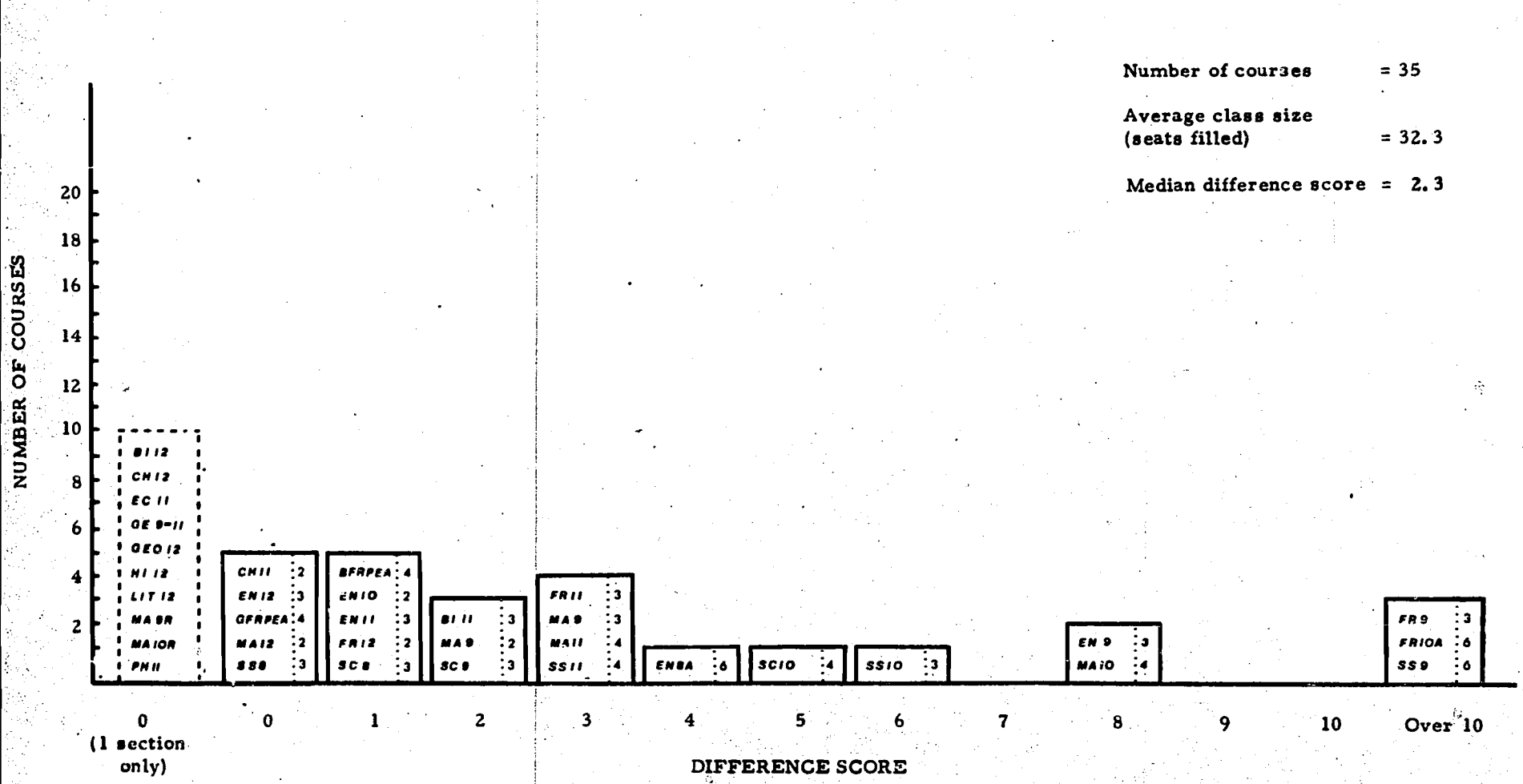
For all schools, there was a marked clustering of courses at the lower end of the distribution of difference scores, with a difference score of "1" being the most prevalent. Note also that courses with high difference scores generally had a large number of sections.

Table VII presents a summary of the class size balancing of the four sample schools.



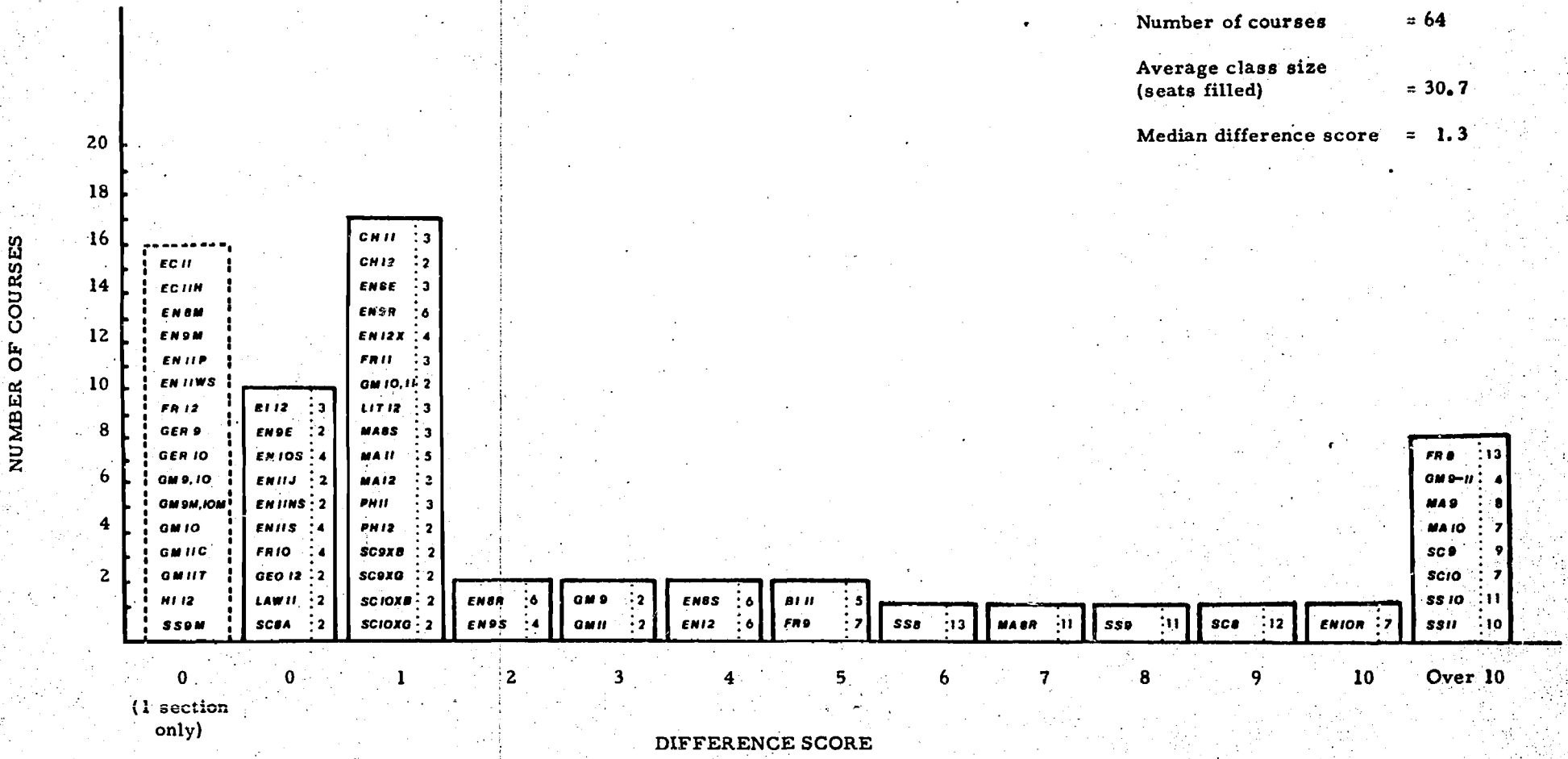
(Difference between the number of seats in the largest section of a course and the number of seats in the smallest section of the course.)

FIGURE 2: CLASS SIZE BALANCING BY COMPUTER FOR SCHOOL 1. (THE NUMBER OF COURSE SECTIONS IS INCLUDED TO THE RIGHT OF THE COURSE ABBREVIATIONS.)



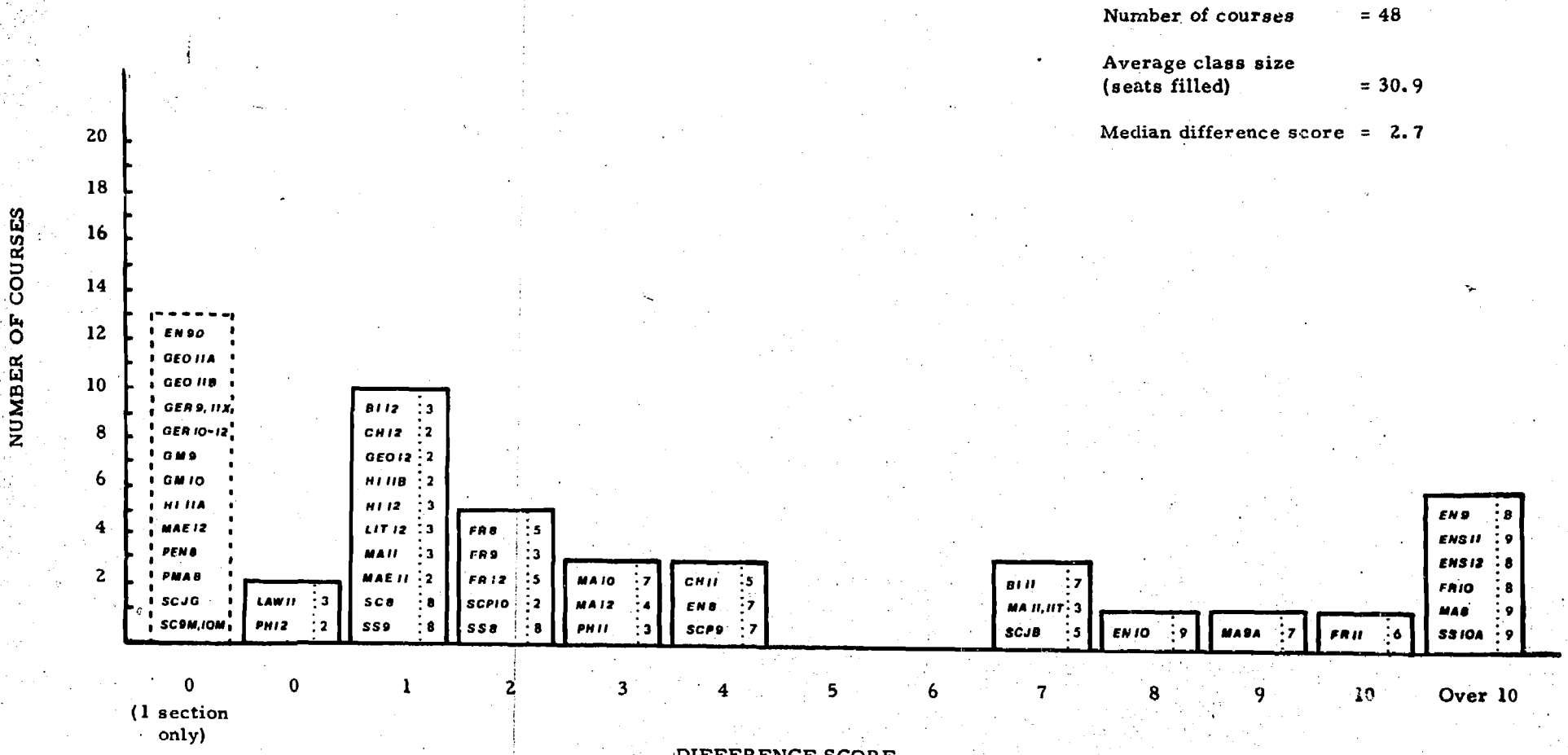
(Difference between the number of seats in the largest section of a course and the number of seats in the smallest section of the course.)

FIGURE 3: CLASS SIZE BALANCING BY COMPUTER FOR SCHOOL 5. (THE NUMBER OF COURSE SECTIONS IS INCLUDED TO THE RIGHT OF THE COURSE ABBREVIATIONS)



(Difference between the number of seats in the largest section of a course and the number of seats in the smallest section of the course.)

FIGURE 4: CLASS SIZE BALANCING BY COMPUTER FOR SCHOOL 9. (THE NUMBER OF COURSE SECTIONS IS INCLUDED TO THE RIGHT OF THE COURSE ABBREVIATIONS)



(Difference between the number of seats in the largest section of a course and the number of seats in the smallest section of the course.)

FIGURE 5: CLASS SIZE BALANCING BY COMPUTER FOR SCHOOL 11. (THE NUMBER OF COURSE SECTIONS IS INCLUDED TO THE RIGHT OF THE COURSE ABBREVIATIONS.)

TABLE VII: A SUMMARY OF THE CLASS SIZE BALANCING IN THE FOUR SAMPLE SCHOOLS

School Number	Population	Timetable System	Average Class Size (No. of Seats)	Number of Courses	% of Courses with 0-3 Difference Scores	% of Courses with 0-6 Difference Scores	Median Difference Score
11	1500-2000	Partial	30.9	48	68.8%	75.1%	2.7
9	1500-2000	Full Year	30.7	64	73.4%	81.2%	1.3
1	1500-2000	Semester	32.1	43	76.7%	83.7%	1.4
5	< 1500	Semester	32.3	35	77.2%	85.9%	2.3
All Schools			31.1	190	73.7%	81.1%	1.7

Some 75% of the courses of school 11 (on a partial semester system) fell within the 0-6 range of difference scores, while 85.9% of school 5's (on a semester system) fell in that range. For all schools, 73.7% of the courses fell in the 0-3 difference score range, and the median difference score was 1.7.

E. SIMULATE RUNS

A summary of the number of simulate runs per school is presented below:

Number of Simulate Runs	Number of Schools
1	1
2	11
3	3
4	1

It appeared that having additional simulate runs was advantageous: three of the four schools with three or more simulate runs were operating smoothly in the first week. (See Table I) However, no significant relationship between the number of simulate runs and the conflict rate was evident.

F. DISCUSSION

The success of a school's scheduling system is related to many factors, --the availability of rooms and teachers, the pupil course-requests, the courses offered, the school size, and, of course, the diligence and endurance of the timetabling committee, counsellors and teachers in their quest to perfect the Master Timetable and to hand-schedule those students with conflicts deemed unresolvable by computer. It is thus both difficult and unwise to form conclusions about computer scheduling when dealing with a non-homogeneous group of schools. However, there are a few noteworthy trends in regard to computer scheduling in Vancouver schools.

Scheduling by computer saves time: over 80% of the Principals indicated that computer scheduling saved both teacher and secretarial time. The degree of timesaving for administrators and counsellors was not determined.

Class lists and textbook rental receipts are the most frequently used extensions of the scheduling system. Several Principals intend to make further use of the innovations and extensions in the future.

The dates of smoothly operating timetables varied considerably--from the day of the school's opening until ten weeks afterward, but the majority of the schools (10/16) were operating smoothly within the first two weeks. The effectiveness of the computer in balancing classes (apparent from the data from the four sample schools, and from the comments of five Principals) makes such early smooth operating dates possible.

Under the manual system, students were often redistributed to better balance the classes and this often disrupted classes for several weeks. Now, with computer class balancing, students can quickly settle into their studies with no fear of being moved.

The data from both the questionnaire and the examination of class size balancing suggest that schools on a partial semester system experience the greatest number of difficulties in scheduling. The partial semester schools had the highest average conflict rate (disregarding the one school on the flexible modular system) and the lowest percentage of courses falling in low difference score ranges. The semester system schools, on the other hand, had the lowest average conflict rate and showed a high percentage of courses in the low ranges of difference scores. Thus it would appear that the more complex the school's schedule (semester system, full year system, partial semester system and flexible modular system, in ascending order of complexity) the more difficulties it experiences in scheduling.

In general, a positive attitude toward computer scheduling on the part of the Principals was apparent: all of them wanted to continue computer scheduling, and the advantages of having computer scheduling that they cited far outnumbered the constraints or limitations. Their expectations for the system in the years ahead were high. Many foresaw the use of further extensions and innovations of the system, and four of the Principals looked forward to the eventual computer generation of master timetables. Three schools noted that the complexity of the timetable was such that it would have been too time-consuming to schedule it by hand.

Many of the constraints and limitations of computer scheduling cited by the Principals could be eliminated through improvement of the present computer software. The difficulties that partial semester schools face, for example, are due to deficiencies in the computer programs (software) which necessitate additional hand-scheduling of students. Software now exists for the Vancouver School Board computer system that could adequately deal with such partial semester systems, as well as with the complexities of a flexible modular system.

It is also within the scope of the present system (again with improved software) to reduce substantially the turn-around time for simulate runs and the actual computer time for the final runs. With the present Honeywell D Software Package, some schools require as long as 17 hours for their final run. With the Honeywell F Software Package now available, the time could be slashed to about 1.7 hours, one-tenth the time. Similarly, simulate runs could be reduced from 6 hours to half an hour. Such a saving of valuable computer time would enable schools to have several additional simulate runs to refine their master timetables. In addition, with fewer time constraints the final runs could be made closer to the school opening date, thus saving counsellors from the chore of hand-scheduling last minute enrollees.

With equipment available today, it would be possible for Principals to conduct all scheduling activities from their own schools. Scheduling information could be entered on a typewriter terminal in the school, then carried to a central computer via telephone lines. All scheduling, updating, etc. could be accomplished this manner, with results being printed on the terminal in a matter of minutes.

A final caution: no matter how sophisticated the computer hardware and software, the burden of responsibility still rests with man:

> In scheduling, the computer simply performs a task according to rules laid down by the principal. The principal can formulate or change rules as he wishes. He can also step in at any point and change scheduling decisions made by the computer. The computer will follow exactly the instructions given to it, whether these instructions are right or wrong. If the correct instructions are given, the computer will schedule correctly more than 200 pupils per minute. Given erroneous instructions, the computer will schedule incorrectly at the same rate. [8]

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[8] Richardson, D. and J. Clark, op. cit., p. 57.

APPENDIX A: EXAMPLE OF A SIMPLE TALLY

CENTRAL HIGH 01 67/68

COURSE DESC.	NO.	GRAND TOTAL	TOTAL		COURSE TALLIES GR. 09		GR. 10		GR. 11		GR. 12		NO GRADE	
			F	M	F	M	F	M	F	M	F	M	F	
ENG 1 E	010	53	31	22	31	22	•	•	•	•	•	•	•	•
ENG 1 A	011	114	67	47	67	47	•	•	•	•	•	•	•	•
ENG 1 B	014	119	26	93	26	85	•	8	•	•	•	•	•	•
ENG 1 F B	015	22	20	2	20	2	•	•	•	•	•	•	•	•
ENG 1 BUS	016	103	73	30	69	22	4	7	•	1	•	•	•	•
ENG 1 GEN	018	121	22	99	19	86	3	13	•	•	•	•	•	•
ENG 2 E	020	44	24	20	•	•	24	20	•	•	•	•	•	•
ENG 2 A	021	86	37	49	•	•	37	49	•	•	•	•	•	•
ENG 2 B	024	56	14	42	•	•	14	37	•	5	•	•	•	•
ENG 2 F B	025	11	10	1	•	•	10	1	•	•	•	•	•	•
ENG 2 BUS	026	175	119	56	•	•	113	50	6	6	•	•	•	•
ENG 2 GEN	028	71	15	56	•	•	12	48	3	8	•	•	•	•
ENG 3 E	030	15	13	2	•	•	•	•	13	2	•	•	•	•
ENG 3 A	031	98	49	49	•	•	•	•	48	48	1	1	•	•
ENG 3 B	034	53	9	44	•	•	•	1	9	41	•	2	•	•
ENG 3 F B	035	20	17	3	•	•	•	•	17	3	•	•	•	•
ENG BUS	036	113	82	31	•	•	•	•	77	30	5	1	•	•
ENG GEN	038	93	14	79	•	•	•	•	13	70	1	9	•	•
ENG 4 E	040	23	19	4	•	•	•	•	•	•	19	4	•	•
ENG 4 A	041	61	26	35	•	•	•	•	•	•	26	35	•	•
ENG 4 B	044	29	3	26	•	•	•	•	•	1	3	25	•	•
ENG 4 F B	045	14	12	2	•	•	•	•	•	•	12	2	•	•
ENG 4 BUS	046	94	75	19	•	•	•	•	•	•	75	19	•	•
ENG 4 GEN	048	71	17	54	•	•	•	•	1	•	16	54	•	•
DEV READG	065	118	50	68	26	24	15	24	7	17	2	3	•	•
CR WRIT.G	090	26	11	15	•	•	•	•	3	8	8	7	•	•
P SPEAK.G	091	26	11	15	•	•	•	•	3	8	8	7	•	•
ANC HIST	110	281	124	157	124	154	•	2	•	•	•	1	•	•
CIVICS FB	115	21	17	4	17	4	•	•	•	•	•	•	•	•
CIV BUS.	116	168	84	84	84	83	•	•	•	•	•	1	•	•
GEOGRAPHY	158	32	8	24	•	•	6	15	1	8	1	1	•	•
ECONOMICS	191	53	20	33	•	•	•	•	6	6	14	27	•	•
ECONOMICS	196	91	41	50	•	•	•	•	7	16	34	34	•	•
M MATH 1E	210	38	18	20	18	20	•	•	•	•	•	•	•	•
MATH 1A	211	102	57	45	54	40	3	4	•	1	•	•	•	•
MATH 1B	214	176	76	100	46	54	15	28	13	9	2	9	•	•
ARITH FB	215	26	22	4	22	4	•	•	•	•	•	•	•	•
ARITH BUS	216	90	67	23	67	20	•	3	•	•	•	•	•	•
G MATH 1	218	112	19	93	19	86	•	4	•	2	•	1	•	•
PREMATH1	219	59	12	47	7	40	5	7	•	•	•	•	•	•

APPENDIX B: EXAMPLE OF A PAIRING MATRIX

		COURSE NUMBERS			TOTAL REQUESTS FOR COURSE 065		COURSE CONFLICT MATRIX					NUMBER OF POTENTIAL CONFLICTS BETWEEN COURSES 035 and 135 PAIR & TALLY MATRIX									
CENTRAL HIGH		01		67/68																	
COURSE DESC.	NO.	044	045	046	048	065	090	091	110	115	116	120	125	126	130	135	136	140	141	146	155
	TOTALS	29	14	94	71	118	26	26	281	21	168	157	7	118	160	21	184	20	54	49	49
ENG 1 E	010	•	•	•	•	7	•	•	53	•	•	•	•	•	•	•	•	•	•	•	•
ENG 1 A	011	•	•	•	•	13	•	•	114	•	•	•	•	•	•	•	•	•	•	•	•
ENG 1 B	014	•	•	•	•	14	•	•	112	•	•	3	•	3	•	•	•	•	•	•	•
ENG 1 F B	015	•	•	•	•	2	•	•	•	15	4	•	•	•	•	•	•	•	•	•	•
ENG 1 BUS	016	•	•	•	•	8	•	•	•	6	83	•	•	5	•	•	1	•	•	•	3
ENG 1 GEN	018	•	•	•	•	12	•	•	•	•	80	•	•	6	•	•	•	•	•	•	1
ENG 2 E	020	•	•	•	•	4	•	•	•	•	•	30	•	•	•	•	•	•	•	•	•
ENG 2 A	021	•	•	•	•	9	•	•	•	•	•	78	•	•	•	•	•	•	•	•	•
ENG 2 B	024	•	•	•	•	5	•	•	1	•	•	47	•	•	2	•	1	•	•	•	•
ENG 2 F B	025	•	•	•	•	•	•	•	•	•	•	•	7	•	•	•	•	•	•	•	3
ENG 2 BUS	026	•	•	•	•	13	•	•	•	•	•	•	•	88	•	•	12	•	•	•	41
ENG 2 GEN	028	•	•	•	•	6	•	•	•	•	•	•	•	23	•	•	9	•	•	•	1
ENG 3 E	030	•	•	•	•	1	2	2	•	•	•	•	•	•	13	•	•	•	•	•	•
ENG 3 A	031	•	•	•	•	3	7	7	•	•	•	•	•	•	90	•	•	•	1	•	•
ENG 3 B	034	1	•	•	1	8	2	2	•	•	•	1	•	•	49	•	•	•	•	1	•
ENG 3 F B	035	•	•	•	•	1	•	•	•	•	•	•	•	•	•	19	1	•	•	•	•
ENG BUS	036	•	•	6	•	6	•	•	•	•	•	•	•	•	•	2	103	•	•	•	•
ENG GEN	038	1	•	2	9	6	•	•	•	•	1	•	•	•	1	•	71	•	•	1	•
ENG 4 E	040	•	•	•	•	•	7	7	•	•	•	•	•	•	4	•	•	8	7	•	•
ENG 4 A	041	•	•	•	•	•	7	7	•	•	•	•	•	•	1	•	•	10	31	•	•
ENG 4 B	044	29*	•	•	•	•	1	1	•	•	•	•	•	•	2	•	1	2	16	1	•
ENG 4 F B	045	•	14*	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
ENG 4 BUS	046	•	•	94*	•	1	•	•	•	•	1	•	•	•	•	•	3	•	•	24	•
ENG 4 GEN	048	•	•	•	71*	4	•	•	1	•	•	•	•	•	•	•	5	•	•	24	•
DEV READG	065	•	•	1	4	118*	•	•	32	3	14	15	•	10	10	2	10	•	•	2	3
CR WRIT.G	090	1	•	•	•	•	26*	26	•	•	•	•	•	•	7	•	•	3	4	•	•
P SPEAK.G	091	1	•	•	•	•	26	26*	•	•	•	•	•	•	7	•	•	3	4	•	•
ANC HIST	110	•	•	•	1	32	•	•	281*	•	•	•	•	•	•	•	•	•	•	•	•
CIVICS FB	115	•	•	•	•	3	•	•	•	21*	•	•	•	•	•	•	•	•	•	•	•
CIV BUS.	116	•	•	1	•	14	•	•	•	•	168*	•	•	•	•	•	•	•	•	•	•
GEOGRAPHY	120	•	•	•	•	15	•	•	•	•	•	157*	•	•	•	•	•	•	•	•	•
ECONOMICS	125	•	•	•	•	•	•	•	•	•	•	•	7*	•	•	•	•	•	•	•	1
ECONOMICS	126	•	•	•	•	10	•	•	•	•	•	•	•	118*	•	•	•	•	•	•	5
M MATH 1E	130	2	•	•	•	10	7	7	•	•	•	•	•	•	160*	•	•	•	1	•	•
MATH 1A	135	•	•	•	•	2	•	•	•	•	•	•	•	•	•	21*	•	•	•	•	•
MATH 1B	136	1	•	3	5	10	•	•	•	•	•	•	•	•	•	•	184*	•	•	2	•
ARITH FB	140	2	•	•	•	•	3	3	•	•	•	•	•	•	•	•	•	20*	8	•	•
ARITH BUS	141	16	•	•	•	•	4	4	•	•	•	•	•	•	1	•	•	8	54*	•	•
G MATH 1	146	1	•	24	24	2	•	•	•	•	•	•	•	•	•	•	2	•	•	49*	•
PREMATH1	155	•	•	•	•	3	•	•	•	•	•	•	1	5	•	•	•	•	•	•	49*

(The reader will recognize that the above is a partial matrix.)

VANCOUVER SCHOOL BOARD EDUCATION DEPARTMENT

QUESTIONNAIRE RE: COMPUTER SCHEDULING TO PRINCIPALS OF SECONDARY SCHOOLS

It is necessary, at this time, to attempt to make an assessment of the use of computers for scheduling students in secondary schools. We would appreciate having your responses to the following questions:

1. By what date in September, 1972, was the timetable operating smoothly in your school? (This would include the scheduling of students who appeared at school on September 5th but whose requests for courses were not included in the scheduling run in August. It would also include the processing of those students who failed to return to school in September, as well as the balancing of size of classes, where required. It would not include the re-scheduling of students who made special requests to change courses after September 5.)

   Date: _____

2. How does your response to item 1, above, compare with the time taken when timetabling was done entirely by hand?

3. Has the use of computers reduced the amount of time that teachers spend in timetabling activities?

4. Does the use of computers in scheduling save secretarial time that can be devoted to other tasks?

5. During the final computer run in August for how many students did the computer print out a conflict sheet?

6. The following innovations and extensions may be accomplished with computer scheduling. Check those that are operating in your school.

Partial Semestering	___	Permanent Record Card Labelling	___
Semestering	___	Class Lists	___
Modular Scheduling	___	Library Loans and Acquisitions	___
Grade Reporting by Computer	___	Double Lunch Hour	___
Attendance Accounting by Computer	___	Extended School Day	___
Marks Analysis	___	Identification to Subject Teachers	
Textbook Rental	___	of Students with Special Needs	___
Record Keeping	___	Pupil Personnel Data	___
		Data from Guidance Testing Program	___

7. What do you consider to be the advantages of having computer scheduling? (i.e., what are its strengths and benefits for your school?)

8. What do you consider to be the limitations (if any) of computer scheduling? What constraints does it impose on the operation of your school?

9. What are your expectations from computer scheduling in the years ahead?

10. Do you want to continue to have computer scheduling?

Yes_____ No_____

_____ _____ _____

Principal School Date

APPENDIX D: UPDATED MASTER SCHEDULE

CENTRAL HIGH — UPDATED MASTER SCHEDULE — 67/68

COURSE NUMBER	SEC.	DESCRIPTION	SEM	DAYS	PER	PR/ CODE	ROOM	CREDIT	SEATS START	SEATS OPEN	SEATS USED	TEACHER NO.	TEACHER NAME
255	01	PHYSICS	3	ALL	31	1	202	100	28	05	23	236	JOHNSON ROBT.
255	01	PHYS LAB	3	MW	3	1	202		28	05	23	236	JOHNSON ROBT.
255	02	PHYS LAB	3	TF	3	2	202	100	28	07	21	236	JOHNSON ROBT.
255	02	PHYSICS	3	ALL	4	2	202		28	07	21	236	JOHNSON ROBT.
255	03	PHYSICS	3	ALL	85	2	202	100	28	05	23	236	JOHNSON ROBT.
255	03	PHYS LAB	3	MT	8	2	202		28	05	23	236	JOHNSON ROBT.
255	04	PHYS LAB	3	RF	8	1	202	100	28	06	23	236	JOHNSON ROBT.
255	04	PHYSICS	3	ALL	9	1	202		28	06	22	236	JOHNSON ROBT.
255	05	PHYSICS	3	ALL	1	2	202	100	28	07	21	509	BATES DAVID
255	05	PHYS LAB	3	TR	2	2	202		28	07	21	509	BATES DAVID
255	06	PHYS LAB	3	WF	52	1	202	100	28	06	22	509	BATES DAVID
255	06	PHYSICS	3	ALL	5	1	202		28	06	22	509	BATES DAVID
256	01	SR SCI	3	ALL	3		211	100	32	02	30	105	JORDAN PAUL
256	02	SR SCI	3	ALL	9		003	100	32	04	28	105	JORDAN PAUL
306	01	LATIN 2	3	ALL	6		009	100	32	01	31	986	BRADY FRANCES
306	02	LATIN 2	3	ALL	8		009	100	32	05	27	986	BRADY FRANCES
306	03	LATIN 2	3	ALL	9		009	100	32	04	28	986	BRADY FRANCES
306	04	LATIN 2	3	ALL	0		009	100	32	04	28	986	BRADY FRANCES
306	05	LATIN 2	3	ALL	4		009	100	32	05	27	411	BRADY FRANCES

GLOSSARY OF COMPUTER TERMS

BALANCING (CLASS SIZE)	Making the number of students in each section (or class) of a course the same or as nearly so, as possible (as opposed, for example, to filling up three classes and leaving the fourth partly empty).
CONFLICT	Occurs when two (or more) courses chosen by the student are available only in the same block or period.
CONFLICT RATE	The percentage of students who have one or more conflicts.
CONFLICT SHEET	A single page printed by the computer for each course in which the student had a conflict. It shows all the courses chosen by the student and all the blocks in which those subjects are available, including the courses which are in conflict.
COURSE DESCRIPTION--COURSE NUMBER CONVERSION TABLE	A list of the names of all the courses offered by the school together with the corresponding course code numbers. If there are several sections of the course only one entry appears on the table. (This table is prepared manually by the school staff).
DIFFERENCE SCORE	The score calculated by subtracting the number of students in the smallest section of a course from that of the largest section.
FLEXIBLE MODULAR SYSTEM OF SCHEDULING	A system in which the length of each period is a particular number of "modules"; for example, typing might take 1 module of 20 minutes, auto mechanics might require 6 modules (two hours), science, 3 modules (60 minutes, etc.)

Note: (In such a system the master timetable provides for a wide variety of options but when all students have been scheduled the system is quite inflexible because of the many variables that the system accommodates.)

FULL YEAR SYSTEM	A Full Year System is one in which time-tabling is on an annual basis and in which the master timetable remains relatively unchanged throughout the year.

HARDWARE	The mechanical, electrical, and magnetic devices and materials with which an automatic computer system is constructed.
LISTING	One or more pages of information which has been printed by the computer; for example, a list of all the students in the school by student surname, in alphabetical sequence.
MASTER TAPE	The magnetic tape on which is stored one record for each student in the school. The tape is permanently kept at the computer site and brought up to date whenever necessary.
MASTER TIMETABLE (OR MASTER SCHEDULE)	A two-dimensional representation (courses offered X blocks or periods in the cycle) of all curricular offerings in the school, each individual offering being called a "section". The master timetable is usually produced by hand.
MODULE	The unit of time for specifying the duration of a subject period in modular scheduling systems (usually either 15 or 20 minutes). Duration of the class would be a multiple of this unit (e. g., 15 minutes, 30 minutes, 45 minutes, etc.).
OUTPUT	One or more pages of information printed by a computer. Output might also include an up-to-date version of a file stored on magnetic tape at the computer.
PAIRING MATRIX	A computer printout in two dimensions which summarizes students' choices of all possible pairs of courses. This is useful in anticipating potential conflicts and thus avoiding such conflicts by the way in which the school timetable is set up.
PARTIAL SEMESTER SYSTEM	A system in which for some courses a student must attend from September through June in order to complete the course whereas for other (semestered) courses, he need attend only from September through January or February through June.
PRINTOUT	One or more pages of information which has been printed by a computer.

RUN	The process of doing work on a computer; for example, doing a "scheduling run" and/or doing a "grade reporting run".
SECTION	A class size group of students that study a particular course together in the same block or period.
SEMESTER SYSTEM	A semester system is one in which the timetabling is on a semester basis, i.e., there is a different master timetable for each semester. For a semester course, a student will attend from September through January, or from February through June. Some courses may be offered in both semesters.
SIMULATE RUN	This is the same as a scheduling run except that the operation is stopped after students have been placed in the courses of their choice and, where this is impossible, conflict sheets have been printed. The computer does not print the student timetables or class lists for subject teachers, etc. The Simulate Run reveals how many conflicts are likely during the final run and indicates the effectiveness of the manually-created master timetable.
SMOOTHLY OPERATING TIMETABLE	A situation which occurs early in September after the final scheduling run and all conflicts have been manually resolved but before students start to request changes in their timetables.
TALLY	A separate computer run (which occurs a few weeks before the simulate runs) to produce a printout of the total number of students who have chosen each course. This is useful to the school for determining approximately how many sections (or classes) will be required for each course.
TURN-AROUND TIME	The elapsed time between the school submitting required information to the computer (such as students' course-choices) and the delivery of the resulting computer printout to the school.

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