MASTER SCHEDULE BUILDING

AND

THE FLEXIBLY SCHEDULED SCHOOL

by

Nelson Stanley Logan

December 1970 UTEC-CSc-70-106

This research was supported in part by the University of Utah Computer Science Division and by the Advanced Research Projects Agency of the Department of Defense and monitored by Rome Air Development Center, Griffiss Air Force Base, New York 13440, under Contract No. F30602-70-C-0300, ARPA Order No. 829.

"The gulf between what exists and what might be is largely due to the need for reform in all those educational phenomena on which nongrading and team teaching depend: curriculum, materials testing, teacher education, and information processing."

John I. Goodland*
Department of Education
U.C.L.A.

*Goodland, John I. Application of Electronic Data Processing Methods in Education. (Los Angeles: Dept. of Education, University of California, L.A.)]965.

ACKNOWLEDGMENTS

Work of any kind cannot be cultivated unless the right atmosphere prevails which allows the nurturing of the project. In this regard, this report could not have been written without the unrestrictive support of Dr. David C. Evans. This project was also influenced by Mr. Robert S. Barton through many hours of conversation about man-machine interface problems in particular, and the philosophy of Education in general.

Teresa Shapiro, a fellow researcher, worked long and diligently to make this project a reality and Dr. Robert G. Steffensen made numerous constructive comments on the educational content.

TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

This paper contains a model of a technique for increasing the quality of educational and instructional opportunity for all students. This model is developed around the flexible or modularly scheduled secondary school. Also included is a procedure containing a computer program, with which the administrator can develop the Master Schedule of the school.

Chapter 1

INTRODUCTION

1.1 The Problem.

Educators do not lack grand goals or lofty motives. The history of the profession of education is blessed with both. However, a void exists in knowing how to get from the theory, to the practical implementation of these goals.[9]

One time honored cardinal tenant for nearly every teacher has been to individualize learning. This tenant has been passed down from generation to generation of teachers since the early years of professional preparation courses in education; and seldom have national task forces, professional group statements, or presidential conferences failed to mention individualized teaching in one way or another. Over the past thirty years, educators have dreamed of ways to approach personalized teaching in a traditional school setting of one teacher to thirty students. The goal has not been achieved to the satisfaction of either the profession or the students themselves. The classroom has not been student oriented--not even teacher oriented--but textbook oriented, and the organization of instruction used in the schools has provided for group and not individual teaching. The means, the secondary school class schedule, is agnostic to individualized instruction and to the teaching customized to the unique requirements of each student.[10]

Some secondary schools of America are trying to adjust the means, which is the organization of the learning environment to achieve the desired end, more individualized learning.[1] Schools must be organized so that each individual student with unique capabilities, interests, and background can develop the full measure of his talent. The educational requirements of this new age places increased demands on the schools to offer quality customized education.

A wide-spread change in our society is taking place. Discovery in nearly every field of knowledge rises with almost every sun, and values are far different from those of a generation ago. The world's interests have become national, and often, personal interests. Schools must help youngsters find their way in a new world which demands group interaction yet puts a heavy premium on individual accomplishment. Changes have been introduced both in how Americans work and how long they labor. Education must keep pace with these developments.[2] Mental work has replaced physical activity in many occupations and the emphasis in the future will be on more highly specialized rather than on common labor. More social adjustments are in the offering as the technological implications take hold of our society. Still, amid all these changes, schools are organized and operated in nearly the same way they were in the early days of the Quincy Grammar School in Boston, in the mid 1850's. The Quincy Grammar School was a bold

social experiment, universal educational opportunity. This idea of secondary education that has developed in the United States has been one of this country's boldest thrusts on the frontier of human affairs. During the 18th and 19th centuries America forged a new concept that secondary schools should be freely available to all youth who wish to attend. Then in the first half of the twentieth century the United States took another bold step by making education compulsory, not just through elementary school but also through the secondary school years. The revolutionary idea of a high school education has been almost achieved and until recently, no other country ever envisioned, much less attempted to realize, such a school system.[2] A further unique feature of secondary education in America, in addition to its universal character, has been the comprehensive high school--that high school in each community which is intended to serve everyone, irrespective of his status or aim in life. Here have mingled the bright and the dull, the devout and the heathen, and the children of the rich and poor. In place of the rigid system and separate school as developed in Europe, the United States then offers its children the comprehensive high school.

But even as we look back into the past with the pace setting that the United States has done, the moment in history has come again to take another step. This one is in the direction of adding excellence to universal educational opportunity. The road to improvement in education

up to the present has been concerned with more "things" such as more teachers, more books, more supplies, more buildings and more money. Correspondingly, these additions have been accompanied by the imposition of more services and quality demands on the school. With more students to educate, the professional educator is faced with an almost untenable situation. Somehow, while passing down the road to improvement in education, teaching for individualized learning has been by-passed.

1.2 A Solution.

The following pages contain a model of a technique for increasing the quality of education and instructional opportunity for all students. This model will be developed around the flexible or modularly scheduled secondary school, and includes a procedure by which the administrator can develop the master schedule of the school.

The secondary school that uses a flexible schedule is taking a bold first step in getting from theory to practice in individualizing learning that calls for: 1) Varying the rate, the depth, and the breadth of instructional opportunity for each student according to his own needs and capabilities. 2) Giving teachers the opportunity to perform these functions in a teaching environment where they can do their best, 3) Altering the size of the class so students will sometimes be in a large group, sometimes in a small group, and sometimes in independent study, and

4) Assigning time to subjects according to the requirement of mastery rather than according to the lock-step mold of a schedule which treats unequal subjects as equals.

However, even in a flexibly scheduled school where consideration has already been given to the elements of the formula the school uses in instruction (i.e., in its teaching talent, student learning arrangements, methods of teaching and learning, and in the utilization of time and technological aids to instruction), success is limited because of the many limiting constraints in building the master schedule manually. The master schedule of a school may be thought of as a description of the organizational framework of a school. The model presented in this project eliminates many of the current constraints in building the master schedule and at the same time optimizes the remaining constraints. The procedure which has been devised provides the administrator of a school with a functional tool for making this organizational description.

The work referred to in this introduction has been done at East High School in Salt Lake City, Utah. It is felt if students of education study this plan, and if administrators and teachers help to implement it, this approach can lead to greater quality in education that hitherto has not been possible with the present traditional approach.

Chapter 2

THE MODEL*

2.1 What Is a Good School?

American education is waking up after thirty or forty years of hibernation. American education is currently involved in a dynamic reform.[5] Old problems are being attacked with new approaches. Curriculum reform is being actively pursued. New approaches are being proposed in the area of modern mathematics and science, foreign languages and social studies. These and other practices are no longer foreign to the public schools. But to achieve quality education, new curriculum alone is not enough.[9] The methods used in instruction and the way students are encouraged to learn must themselves undergo drastic changes. The full potential of the new curricula cannot be realized within the organizational framework of the conventional school. The school must be organized in such a way as to encourage students to be involved actively in the learning process. Students must be allowed to meet with teachers individually or in small group discussions; and the pace and the content of the instruction for each stu-

---

*This thesis is not intended to be an outline for implementing a flexible schedule into a school. There are two or three current articles which deal with this logistics problem.[8][11][12][13] What is intended is the description of a model for flexible scheduling and a technique that an administrator can beneficially use in the construction of the all-important master schedule.

dent must be varied. If schools are to be significantly better then they must be substantially different.

What is meant here by the words "good schools" is, schools with both a concern and an operational procedure to assist every student, irrespective of his learning ability, in his quest for an education.

There are no standard tests devised that can measure a refined school. The range of interests and the degree of difference within the school's population defies test measurement. Moreover, among the things tests measure are selective facts and restrictive generalizations, and they don't reveal the true nature of a quality school. Education is an affection for and an understanding of a process, not a body of multiple choice questions. The goals of the school must be to instill a love of learning, to develop a thirst for inquiry and to encourage a continual broadening interest in theoretical and practical affairs.

A good school will send a number of its students to college or to a technical college or vocational school. Some schools serve an area in which the social, economic and ethnic complexion is such that college is not a sought-after value while other schools exist essentially for college preparation. America needs expert workers whether it is in the research laboratory or on the production line. Good citizenship with all that it implies is a national demand and a prized human value. The school's organization for learning needs to give students opportunities for

learning how to work productively, a result of rational thinking in action. For some students this may mean learning how to work in a retail store or in a good service occupation. Human satisfaction comes from self-development, but whatever the potential level and individual possesses it is not necessarily measured by a college degree or familiarity with Chaucer or Oppenheimer.

The good school is concerned with all students, including the slow learner, the emotionally and culturally deprived, as well as the well-adjusted, capable and ambitious youngster. The standard which makes a school excellent is measured by the indigenous characteristics of the particular school population. Comparison of standardized test norms or National Merit Scholarship winners is at the very least an inadequate measure of how well a school meets realistic challenges. The raw talents, family background, cultural advantage and previous experiences as well as the aspiration level of any school population is likely to be significantly different from neighborhood to neighborhood. Each of these factors influences the lives of the students and should help shape the educational objectives of the school.

Flexible or modular scheduling techniques then is suggested as a way of helping all children of all people to develop their full interests and capabilities. The flexible schedule is geared to the entire spectrum of the school population: the bright, the dull, the interested

and the disinterested. A flexible schedule is an approach to teaching and learning which addresses the teacher's professional judgment and the student's responsibility for his own learning.

2.2 Definition of Terms.

2.2.1 Flexible Schedule.

The term "flexible schedule" appears on the surface to be a curious dichotomy. Flexible implies variability and fluidity while on the other hand, schedule implies uniformity and regularity. This combination of words, however, is not in contradiction with each other. The term "flexible schedule" means an organization of instruction which implies classes of varying size within and between courses; instructional groups which meet at varying frequencies and for varying lengths of time.[14] It also implies team teaching in any content area, for any group of students in the school, and requires professional decisions by teachers about students, content material, and teaching methods.[4]

2.2.2 Large Group.

Three kinds of general groups seem appropriate within the context of a flexible schedule. First, there is a subject-material presentation group. This is usually a large group with from thirty to perhaps three hundred students in it. While these groups are considered large, it is not their size, but their function that is

significant. These groups are involved usually with activities such as listening to a lecture, viewing a film, or even taking a test.

2.2.3 Small Group.

A second learning group is the one in which a student questions, discusses, clarifies, proposes and in general exercises his own ideas and knowledge with the help of an inquiring partner, the teacher. Of necessity, this group must be small, generally from ten to fifteen students. Any more participants in this group would hinder the individual in having adequate opportunity to discuss and question. A group this size is manageable in discussion and free enough for questioning.

2.2.4 Independent Study.

The third learning activity and perhaps the most significant is the independent study. Usually independent study is the business of one person although sometimes two or three work together profitably. In the area of cooperative student efforts, Dr. Dwight Allen has said,

> This approach divides student labor and leads to a cumulative effort on assignments and tests. Sometimes advantage can be taken with encouragable students who really produce virtually nothing on tests and convince them that they are getting away with something if you let them work together. You really don't jeopardize much if you pick five students who are likely to come up with an "F" on an examination and allow them to put their efforts together.

It has long been a known fact of practicing teachers that students often times learn more from their fellow

students than they do from the teacher. Of course, this won't work for everybody. Some students will react well, some won't. Dr. Allen continues by saying,

> But schools have to get over the notion that is firmly engraved in them that education is a unique and individual competitive effort. It is a little unreal to train students competitively to go out in a society and perform cooperatively.[17]

However, informal activity such as independent study, is not scheduled on a regular basis, but open for the student to set and use it as he sees fit.

2.2.5 The Purpose of the Three Group Types.

The large and small groups are scheduled. They are established by the faculty after careful consideration and with judgments made about the nature of the course content and the students' requirements for mastery. Individual study time is open for the student to pursue whatever inquiry that he feels appropriate and productive. Just because independent study is not scheduled does not mean it is not organized, nor does it mean that teachers have no idea about what he is studying.

Independent study time has the purpose of developing skill and assimilating content, reinforcing processes into general understanding, to expand areas of interest and learning objectives and in general to enlarge the capacity for his self-development. Small groups are involved with a general investigative problem area, evaluating ideas, clarifying the content of previous presentations and

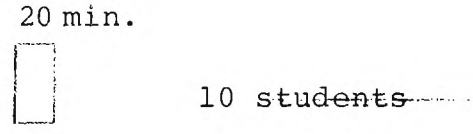
developing understanding about them, strengthening speaking skills, and, in general, sharing experiences interpretations of previous and current work. Large groups exist to develop background, generalizations, and to summarize and conclude broad fundamental ideas. These presentations can conserve teaching time and provide consistency and quality to them.

2.3 The Fundamental Building Block: The Module.

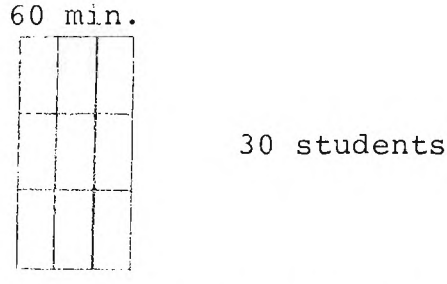
2.3.1 The Module as Seen by the Curriculum Builder.

How are these three group types going to be built into a schedule? What are the units of time? What are the class sizes? These and other questions come to the fore. The curriculum like other resources within the school may be thought of as an object to be scheduled. The curriculum is constructed from components called modules which are derived from units of time and class size. The length of the module is determined by what is considered to be the smallest unit of time necessary for a small group learning activity to be productive or the minimum length of time with which all of the curricular activities within the school can be built. If classes are contemplated which range from forty to one hundred twenty minutes in duration, then a twenty-minute time period as the basic time unit would be appropriate.[2] Similarly, the module implies class size. The class size needs to be the minimum size desired for any instructional purpose--usually about ten

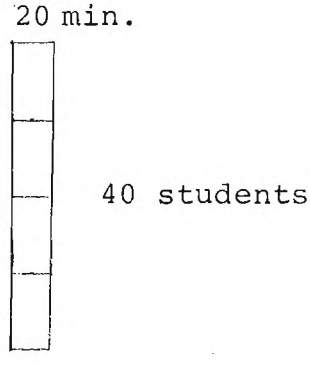
students. Suppose, for example, that a module is chosen which is defined as having a time length of twenty minutes and a class size of ten students. It could be graphically represented as:

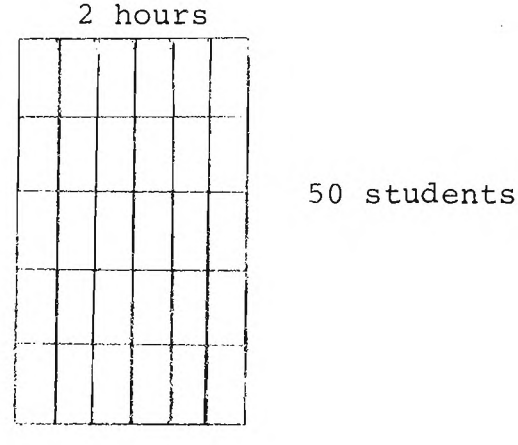


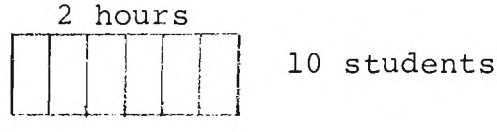
Therefore, a one-hour class with thirty students would appear as:



Using other combinations of the basic unit will produce a large variety of class structures.







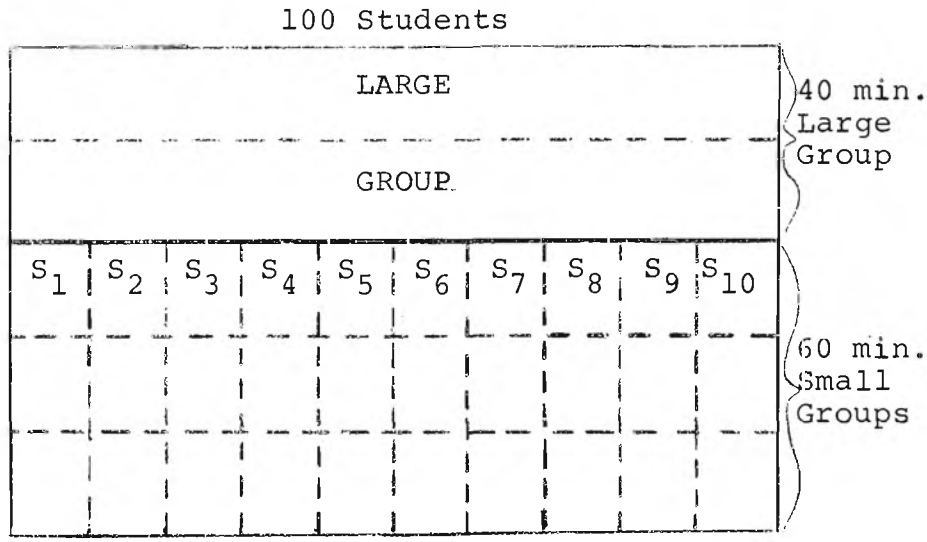


FIGURE 1

This figure represents a large group that meets for 40 minutes and ten small groups that meet for 60 minutes. The modular class size in this example, as defined by the curriculum builder, is ten students.

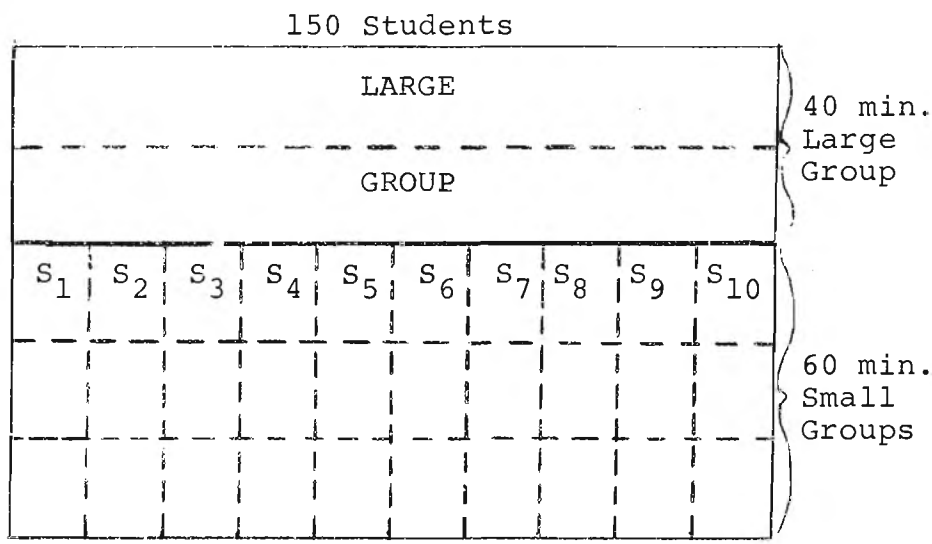


FIGURE 2

Figure 2 represents a class that has a graphic representation as the class in Figure 1. However, the curriculum designer, in this case, has defined the module class size to be 15 students. Therefore, figure 2 represents a total of 150 students.

A more realistic example might be an American History class with one hundred students. The course structure is shown

in Figure 1. It is constructed with a large group that meets for forty minutes and ten small groups that meet for sixty minutes. If the assignment of meetings called for the large and small groups to meet twice a week each, then there would be a total of three hours, twenty minutes of scheduled class room time for that class. Consider the course structure in Figure 2. The graphical representation "looks" the same as that in Figure 1, however, this structure perhaps represents one hundred fifty students instead of one hundred students. The structure in Figure 2, besides representing a different class, could also imply a different definition for the module as to the number of students it contains. In Figure 1, the module contained ten students while in Figure 2, the module would contain fifteen students. This illustrates the wide range of variation in course structure the curriculum developer can call upon. When a particular modular unit is selected by the school administration each course may alter slightly this class size from the standard (say ten students) to some other size, (say to seven or to eighteen students) depending on the instructional purpose that is to be accomplished.*

---

*At East High School whereas the modular time unit was held constant at twenty minutes for all classes, the size of the module varies from eight to twenty students in the small groups and from thirty to three hundred students in the large group.

		MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
	1	Personal	Chemistry	Personal	Chemistry	IS
9:00	2	Arts	Large Group	Arts	Large Group	IS
	3	Small Group	IS	Small Group	IS	IS
	4	College	Arch. Draw	College	IS	IS
10:00	5	Alg & Trig	Large Group	Alg & Trig	IS	IS
	6	Small Group	IS	Small Group	IS	IS
	7	IS	IS	Type	IS	Type
11:00	8	IS	Am. History	Large Group	Am. History	Large Group
	9	IS	Small Group	English	Small Group	Coun. & Guid.
	10	IS	College Alg &	Large Group	College Alg &	IS
12:00	11	IS	Trig Lg. Group	IS	Trig Lg. Group	Am. History
	12	IS	IS	IS	IS	Large Group
	13	Type	Arch Drawing	French	Chemistry Lab	Arch Drawing
1:00	14	Large Group	Small Group	Large Group	Small Group	Small Group
	15	IS	IS	IS	IS	IS
	16	Phys. Ed.	French	Phys. Ed.	French	Phys. Ed.
2:00	17	Large	Small Group	Large	Small Group	Large
	18	Group	IS	Group	IS	Group
	19	English	English	IS	English	IS
3:00	20	Small Group	Small Group	IS	Small Group	IS
	21	IS	IS	IS	IS	IS

FIGURE 3
Flexible Schedule

Not only is the schedule quite different in a Flexible Schedule environment but it offers more time for other classes of interest for the student.

IS = independent study (1 student)
SG = small group (10-20 students)
LG = large group (30-300 students)

2.3.2 The Module as Seen by the Student.

The module, as used by the curriculum developer, is derived from both units of time and units of class size. However, the module, as used by the student, represents only a unit of time. Figure 3 shows a typical student schedule in a flexibly scheduled school. A student can look at this schedule and see on Monday, for example, that he is in class for the first six modules of the day and then he has six modules of independent study time.

2.4 Conventional Schedules -vs- Flexible Schedules.

The schedule in a traditional school is constructed with seven one hour time units which describes the school's day. In a flexibly scheduled school, the day is divided up into modules of from fifteen minute to thirty minute duration. If a fifteen minute module were chosen then the day would be constructed with thirty modules, similarly a thirty minute module would require fifteen modules for a complete day. Instructional requirements and learning tasks would dictate the frequency and the duration of class meetings and the type of instructional group used for any one school.

Moreover, there are some assumptions that the conventional school schedule implies that the use of a flexible schedule does not. The instruction in the traditional organization is characterized by "sameness", every day looks much like every other day in organization. Every teacher

has about the same number of groups and the same number of students as every other teacher. All subjects are studied for about the same length of time. The set of assumptions that the flexible schedule uses differs considerably from this lock-step-method. It is based on the view that every day's order need not be (and will probably be better if it is not) the same as any other day. Teaching assignments have different demands and require different assignments of time with variation and instructional technique and group sizes. The number of groups any particular teacher will have may, in fact, be quite different than what some other teacher may have; and of course, different subjects require different lengths of time and are carried out in class sizes that vary. Classes with one set of purposes and objectives will meet for different lengths and frequency than classes with some other instructional purposes and objectives.

In Figures 3 and 4 a typical flexible and traditional schedule are shown graphically. It can be seen that the traditional schedule is made up of seven periods a day, whereas the flexible schedule is constructed from twenty-one, twenty minute modules.*

---

*Home room is often part of the first period of the day, but the example of the flexible schedule makes this difficult because of the two different classes on the first three modules of Monday through Thursday and the independent study time on Friday. This problem is easily resolved however, by appending a "zeroth" module, as it were, at the beginning of each day.

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
9:00	English	English	English	English	English
10:00	Foreign Language	Foreign Language	Foreign Language	Foreign Language	Foreign Language
11:00	Science	Science	Science	Science	Science
12:00	Lunch	Lunch	Lunch	Lunch	Lunch
1:00	Mathematics	Mathematics	Mathematics	Mathematics	Mathematics
2:00	Social Science	Social Science	Social Science	Social Science	Social Science
3:00	Physical Education	Art	Physical Education	Art	Physical Education

FIGURE 4

"sameness" is the most prominent feature of a traditional schedule.

The traditional schedule in Figure 4 implies that each class is a self-contained unit, with presumably one teacher and thirty students or so. The flexible schedule in Figure 3 shows the time lay-out and the group type but there is no indication of the class size or teaching arrangement. For example, the large group in chemistry may have sixty students and be teamed with three teachers whereas the large group in American history may have two hundred fifty students and teamed with two teachers, while physical education has one hundred fifty students and one teacher.

The type of instruction selected depends upon the educational purpose, and the proposed instructional pattern differs from the conventional pattern mainly in its emphasis on independent study time, small group work time and the variation in large group size.

2.5 The Cycle of the Scheduled Class Work.

The day is the cycle for the schedule in most schools. Each day of the schedule is about the same as every other day. In Figure 3, we can see that Monday's class schedule is very much like Tuesday's and every other day of the week. The programs produced for teachers and students under the flexible scheduling technique, every day of the week might be and probably will be different from every other day in the week, and the schedule will repeat itself only every week.[2] The advantage of the weekly cycle is that it allows for longer periods of study to be scheduled,

unequal time distributions to be constructed and in general gives latitude for organizing special groups to meet once or twice a week without having to meet five times a week for equal lengths of time. Courses can have activities which can meet twice a day and not meet at all on a particular day. The cycle can, however, be a two-day or a three-day arrangement as well as a single day or a week. For example, some experimental programs have been run at Brigham Young Laboratory Schools where they have been working on "Daily Demand Computer Scheduling", where the students are rescheduled each day.

The week was selected as the cycle because, among other things, teachers could choose from a wide range of distribution of time and frequencies of class meetings. By using the week as the cycle, it is felt that teachers will think in terms of five days when making decisions about the size, the number and the duration of learning groups as opposed to a single day.[2] Experience at East High School has shown that students respond favorably to variability of the week cycle. There seems to be an adventure and freshness to the week's cycle of classes that was not found in the traditional schedule. Some early apprehensions that people had, such as students forgetting their schedules has not been found to be a problem.

2.6 The Purpose of Grouping.

Setting group specifications for every learning group

within the school has advantages for both the teacher and the students. For teachers, it helps limit their range of considerations and for students, it creates a comfortable and potentially meaningful atmosphere for free investigation.

When the final decision is made and the groups are specified it may be that they will be on a random basis. However, it does not seem wise to come to this decision until consideration has been given to the alternatives. The number of ways that students can be grouped for instructional purposes is almost unlimited. The teacher, for example, could organize a small group specified on the basis of chronological age, sex, achievement in reading, computation or any other intellectual ability, personality characteristics, behavioral patterns, skill mastery, ethnic background, stated vocational choice and many others.[14]

The sole purpose of any grouping is to establish an atmosphere in which optimum learning can take place. The original ideas of homogeneous grouping have indicated that sometimes teachers can provide for individual differences when the span of differences is reduced within a group. Also, students of common interest and proficiency are frequently stimulated while feeling secure in a group of students of similar characteristics. This is not to suggest that students be grouped in all subjects by a single criterion, for experience has shown that this practice is unsatisfactory. For an example, homogeneous grouping was

very much in the vogue in the 1930's when the intelligence quotient was used as an index for grouping students in all classes. However, unfortunately it was discovered that an individual may have a high IQ score but at the same time have a deficiency or lagging interest in one or more subjects.[14]

Some grouping is done so that instruction can be varied by the teacher in either depth or breadth, or both. This allows the group to consider ideas on the level appropriate to the understanding of the learner. On the other hand, grouping is sometimes organized because the teacher wants a group of students to establish a particular cohesiveness for a specified purpose as in the case of grouping done by certain behavioral characteristics. For example, perhaps one English teacher would like to group all of the shy and relatively introverted female students. The purpose here to provide an atmosphere where able but retiring youngsters could gain security difficult for them to find in other more heterogeneous groups.

There will be a large mixture of class organizations and groupings within the school because the large groups will more likely be heterogeneous in nature although it is not uncommon to have several tracks or levels of instruction in large schools with populations in excess of a thousand. The grouping for the large group classes is necessarily wider in range of abilities and characteristics than the smaller more intimate groups. Whatever the

arrangements and specifications for grouping that are decided upon, the factor that must always be kept in mind is the best arrangement of students to achieve the stated objective of instruction.

2.7 Team Teaching and the Professional Staff.

The final area of consideration and one of the pillars of the flexible scheduling model is the professional staff. When all teachers have been actively involved in the previously mentioned curriculum development, they will have gained appreciation for the objectives, the content of the courses, the methods of instruction and the number of classes that will perhaps be taught; then the assignment of the teaching staff can be made. The flexible schedule calls upon teachers to work together cooperatively whether or not they are in a teaming arrangement. Teams of teachers can be organized in a variety of ways. All teachers, for an example, in a single subject area to teach the same course can be considered members of a team. An alternate method of organizing teams is by blocks of students. In this method teachers of several disciplines who have a common group of students are in a team. This is the model used by the University of Chicago Laboratory School. The former arrangement was used by East High School because of the success it has had and because of the ease with which the school can move eventually to a non-graded curriculum. The Chicago model has however, been

used successfully in a number of continuous progress educational schools at the elementary level. When a team of teachers is responsible for the instruction of all students who take a particular course the team cooperatively makes decisions about content, assignments and student evaluation. A teaching team is created with the integration of the professional staff and other support staff into a productive unit to execute a particular course of study.[3] The organization of such a functional group for a particular educational purpose is not new. For example, the field of coaching has long used the fundamental idea of team teaching. A similar application of these team teaching ideas in the classroom has certain advantages. 1) Some teachers can perform very well in front of a large group, others work better with small groups. Therefore, by making optimal use of the strengths of the professional staff the teaching position is held at a very high level. 2) Some teachers have a very high degree of competency and by putting them in a single classroom, seeing only thirty students each hour causes other students within the school to be deprived of this teaching specialist. The teaching team then, could help rectify this inequity. 3) Placing a teacher in a teaching team and making him an integral part of that team, improves communication and cooperation among the teachers in that team as well as in that department, fosters departmental cohesiveness and improves morale and in general professional growth. 4) Producing what can

be called "active grouping" where a unique or special team teaching arrangement is provided for, which contains teachers from more than one department, gives an interdisciplinary flavor, improved interdepartmental communications, to say nothing about student benefits.

2.8 Summary.

The purpose of the flexible schedule is to allow students to progress at their own rate and to receive extra help--particularly, the fast student or the slow student. It also allows for more individual study time and time for individual help. It allows for the opportunity to schedule various activities which before could not be scheduled or to schedule classes which arbitrarily interfere with other classes, such as field trips, class meeting, intramural events, assemblies, television programs, etc. The flexible schedule is built on the premise that the school administration and professional staff will, with the opportunity, build an enriched program. The teacher is faced with increased responsibility. He is assigned the normal task of helping students with assigned work, counseling more able students into enriched programs that are now available and helping less able students into a program communicant with their interest. Departments can arrange programs which best fit the teacher and the student and help develop an atmosphere of purpose and responsibility. In general the teacher plays a much more active role in the design and

execution of a particular curricular element. The student too has increased responsibilities. He now has time outside of scheduled class to meet with teachers who can help him or whom he finds particularly challenging. He must accept increased responsibility for his own progress and, in general, plays a much more active role in the determination of the work that he undertakes.

Chapter 3

MASTER SCHEDULE INFORMATION PROCESSING

Even after careful consideration has been given to the many problems that can hinder the installation of a flexible schedule into a school, success can still be elusive. Even after 1) an inspired administration has gathered together a willing and well informed faculty, 2) a carefully worked out public relations program has generated community support, 3) the student body has been prepared and is eager to accept their responsibility in this new venture and 4) the curriculum has been designed and modularly built; why isn't success virtually guaranteed? The reason lies in the construction of the master schedule. Building the master schedule for a school is not as fundamentally important as teaching techniques, curriculum development, or group organization; however, it can still determine the degree of success that is obtained.

3.1 Master Schedule Takes Longer to Create.

There are a number of reasons why a flexible master schedule is harder to build than a conventional master schedule. To illustrate the most prominent reasons, East High School experience is used as an example.

1) Team teaching: With a traditional school each teacher is a self contained unit, teaching from four to six classes a day. The same situation existed at East

High School where virtually no team teaching took place, except on the coaching staff, before the installation of a flexible schedule. But now, over fifty percent of the faculty are involved in at least one teaching team, with fifteen percent of the faculty* involved in two teaching teams.

While team teaching has many educational advantages for the student, it serves only to complicate the building of the master schedule. The fact that teachers' schedules overlap, places restrictions upon the other classes, within the curriculum, for which those teachers are responsible. For example, suppose a teacher is a member of two different teaching teams, where the content of the two classes are relatively unrelated. Because this teacher is a member of both teams, for scheduling purposes, these two classes interfere with each other. Moreover, if this teacher also teaches classes which are not team taught, these classes have restrictions placed upon them as to where they will be scheduled. Finally, it should be pointed out that as a school moves toward a non-graded curriculum and teaching teams are made up of teachers for an intra-disciplinary function, the whole scheduling problem can mushroom in a non-linear fashion.

---

*East High School has a teaching faculty size that varies in the neighborhood of 75 teachers.

2) Number and type of classes offered: East High School offered its student population about 125 different classes under its traditional schedule. There were more classes the faculty wanted to include but there was simply no time available. Now, under a flexible schedule, the curriculum has grown past the 200 class mark.* Besides the number of class offerings being increased the configuration of many classes has changed as well. For example, in the practical or fine arts where a class would meet three times a week for one hour per class meeting for a total of three hours per week under a traditional schedule; under a flexible schedule, a class meets twice a week for six modules which is a total of four hours of formal class meetings. While this adds a great deal to the instructional attractiveness of the class, at the same time it complicates the scheduling problem because of the large number of consecutive modules used.

3) The number of classes taken: With the redesign of each class, the amount of scheduled class time associated with each class is in general reduced. Therefore, the scheduling problem would appear to be somewhat simplified.

---

*An interesting side note here, is that this increase in curriculum class load has taken place on the same budget and with the same faculty size. With these enriched class offerings, it is now possible for a student to meet current state graduation requirements in two years. Also the average student now completes nearly three and a half years of credit in his 3 year schedule.

However, with the enriched program now being offered to the students, they are taking more classes. Whereas a student in a traditional school would take from five to seven classes, he now takes from eight to ten classes. The complexities introduced by increased class offerings and student response to them completely overshadows any advantage gained by a decrease in scheduled class time. With this increase in class offerings, the enrollment per class will, in general, be reduced, but the complications stem from the number of class combinations possible.

4) Class structure: With the curriculum being built around the use of three group sizes, that is, large group, small group and independent study, this necessarily causes complications in scheduling. A single class in a traditional schedule will probably become divided into a large group and several small groups within a flexible schedule. There are now several items to be scheduled instead of one. Additional complexities arise for what will be called "large group-small group continuity." Large group-small group continuity means that a teacher is to be involved with the same students in both the large groups and the small groups. For example, suppose 300 students are enrolled in a class which has in its instructional organization three large group sections (100 students each) that are team taught and twenty small group sections (fifteen students each)--each small group section being taught by one member of the team. The students can be scheduled in any

one of the three large groups and any one of the twenty small groups. However, another class also with 300 students enrolled, three large groups and twenty small groups, but which is not team taught, must be handled differently. First, three different teachers will teach each of the three large groups. And with this situation it is often not desirable to have students crossing from a large group taught by one teacher to a small group taught by another teacher. Hence, the constraint called large group-small group continuity eliminates this cross over.

3.2 Data Gathering.

Once the recommendations have been made by the staff concerning the content and methods of instruction and after the faculty requests have been summarized and reviewed by the principal, the curriculum offerings are presented to the student body for their selection. The traditional scheduling procedure begins by generating the master schedule. Then, the pupil requests are framed into the master schedule. In a flexible scheduling system, however, just the opposite is done. After the student class selections are made, the master schedule can be constructed. Often the administrator of a traditionally scheduled school will move courses or change teaching assignments in an attempt to match students' requests to the independently determined master schedule.

The process of juggling and redistributing classes in

the master schedule is both a time consuming and unsatisfactory operation. The school's schedule is a complex mosaic. Each student selection and teacher request is an intricate geometric piece that must be placed in the overall framework of available resources. Rather than determining the form and forcing the pieces into it, in the flexible scheduling model an analysis of the pieces is performed and then the schedule is constructed.

The body of information concerning faculty availability and facility restrictions must be assembled at the outset before the actual schedule construction process begins (see Figure 5). This data needs to yield information about available faculty time and instruction requirements for each teacher in terms of teaching assignments.

It is not unlikely that a teacher, let's say, in the music department, is required to teach at two different schools during the day and therefore is unavailable for a portion of the day. The specifications about when that teacher will be available, need to be outlined. Or, in another example, a school may have only a single gymnasium and this facility must be shared between not only the boys' and girls' gym classes, but perhaps pep club, cheerleaders practice, dance and other related classes. The gymnasium will be quite fully scheduled and some of the classes will undoubtedly have some constraints placed upon them. Without facility and teacher availability information, a

Course Name: Humanities

Team: yes [x] no [ ]

Large and Small Group Continuity: yes [ ] no [x]

Large Group Specifications	
TEACHER(S):	Smith, Jones, Brown, Aldrich
NUMBER OF SEC:	1
SECTION SIZE:	200
MODULES/MEETING:	2
MEETINGS/WEEK:	1
NUMBER OF ROOM(S):	1
ROOM(S):	201,202,203,204,205
Day & Time Pattern:	M-F 4-18

Small Group Specifications				
TEACHER(S):	Smith	Jones	Brown	Aldrich
NUMBER OF SEC:	5	5	5	5
SECTION SIZE:	10	10	10	10
MODULES/MEETING:	3	3	3	3
MEETINGS/WEEK:	2	2	2	2
NUMBER OF ROOM(S):	1	1	1	1
ROOM(S):	206	210	210	210
Day & Time Pattern:	M-F 1-18	M,W,F;T,R 1-21 4-21	M-F 1-21	M-F 1-21

FIGURE 5

A representative form for gathering pertinent data concerning group organization, teaching structure, time and day patterns.

satisfactory master schedule cannot be constructed.

3.3 How To Eliminate Conflicts.

The goal, for any master schedule builder, is to have the schedule constructed so well that it will satisfy every student request, every teacher recommendation for group organization , and time and day pattern requirements. While sometimes this goal cannot be completely realized, there are at least two reasons why it is more likely to be realized under a flexible schedule than a traditional one. 1) Under a flexible schedule, the day is split up into smaller units of time. The example that has been used, East High School, has twenty-one modules per day. This allows for many more combinations of scheduling patterns than in a six or seven period day. 2) The scheduling procedure used is such that it eliminates the possibility of most class conflicts and most clerical errors by use of data processing.

There are those who hold to the idea that conflicts are not really a very serious problem in scheduling. Their view is one which does not place value on the student being in a particular course or a specific section of a course. Any combination of courses that fits into the schedule is considered acceptable. To take this position means that the school's curriculum is supposedly made up of interchangeable parts--each of which has equal value to every student. Some people say that conflicts are

inevitable and therefore they simply live with the fact that they exist. All too often this year's schedule is only a modification of last year's schedule. For this reason most traditionally scheduled schools do not give attention to the formulation of specifications for sections within a course.*

The flexible scheduling model used here completely rejects these propositions. Each student's selection and the new specifications developed by the staff every year are of the utmost importance as the schedule is constructed. The flexible scheduling model places strong emphasis on the importance of individually programmed planning and on customized teaching. Any conflict with what a teacher feels is the best learning arrangement or conflicts with a class a student selects, is considered a serious hindrance to the goal of individualized instruction. The added time it takes to develop a conflict-free-schedule is worth-while in terms of ultimate student advantage. The flexible scheduling model procedure helps eliminate these

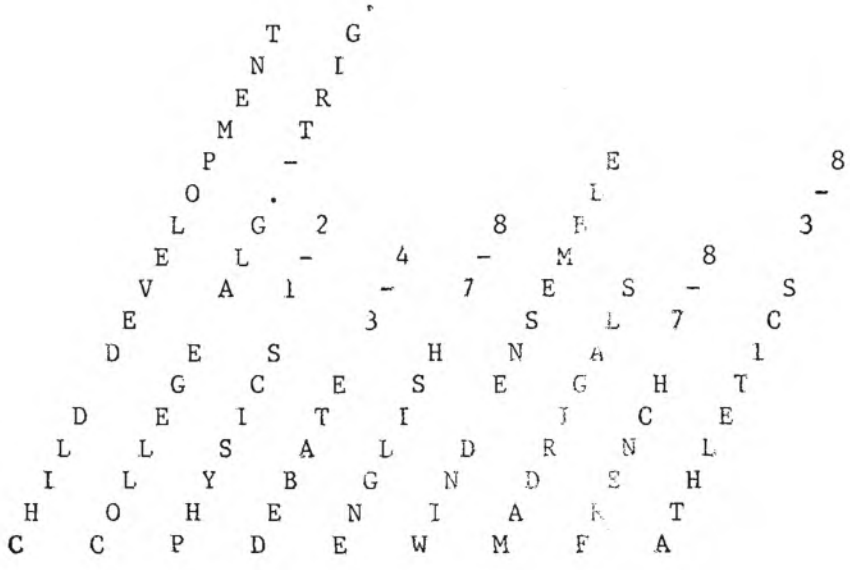
---

*Recently the University of Utah in conjunction with the installization of a computerized registration system, provided its students the opportunity of selecting classes from a list of offerings. To the surprise of the Registrar and the University Administration, the curriculum structure that had existed did not really reflect the wishes of the student body. There was a much higher demand in one area of the curriculum and less interest in another area. That is, while say, 15 sections of a particular speech class was offered only 7 were needed to satisfy student demand, however, the opposite was true for English or Physics.

abridgments on student and teacher choices.

The master schedule building procedure begins with the placement of learning groups on the master schedule. For this placement to be satisfactory, duplicate assignments must be eliminated. Therefore, assurance that students or teachers will be free to meet with these groups must be guaranteed. If the person constructing the master schedule handles the student and teacher requests for class groups in such a way that information is obtained about the number and the location of conflicts, they may be eliminated as the master schedule is finally ordered. A careful analysis of the so-called matrix can spotlight potential trouble spots.

The conflict matrix is a comprehensive view, in a systematic fashion, of all the student class requests. Figure 6 gives an elementary view of a portion of a conflict matrix. The horizontal and vertical axes of the conflict matrix are made up of the courses offered in the curriculum. Since these two axes are the same, the matrix is symmetric and the numbers on the main diagonal represent the class requests. The non-main diagonal numbers correspond to the intersection of requests for the two classes being considered; that is, the number of students requesting both classes. Since the conflict matrix is symmetric, the lower triangular matrix, in figure 6, is left out. As a specific example, consider the row (horizontal line) representing wind ensemble. This class has



	C	C	P	D	E	W	M	F	A
CHILD DEVELOPMENT	83	67	28	2	89	7	5	0	9
COLLEGE ALG.-TRIG.		131	27	5	90	32	2	3	56
PHYSICS 1-2			119	16	74	31	3	2	39
DEBATE 3-4				13	22	6	4	0	7
ENGLISH 7-8					66	11	13	3	12
WIND ENSEMBLE						25	4	0	6
MADRIGALS							6	0	0
FRENCH 7-8								2	2
ATHLETICS 3-8									39

FIGURE 6

Representation of an elementary conflict matrix

been selected by twenty-five students. Of these students, four have also requested madrigals, none have requested French 7-8 and six have requested athletics.

3.4 Generating the Master Schedule.

The conflict matrix is useful. The conflict matrix along with class specifications supply the raw data with which the master schedule is built. It will point to the placement of courses on the master schedule. To ignore the development of the matrix is to invite conflicts in succeeding steps of schedule construction. However, if it is constructed haphazardly, its value is limited. The conflict matrix needs to be constructed in a specific way which is essential in developing a good master schedule.

As has been indicated earlier, the administrator may want or may be required to place restrictions upon certain classes because of teacher specification or because of limited facility requirements. The degree of specification that he gives will determine the flexibility with which classes can be placed upon the master schedule. If a class has exact specifications given, that is, the days are exactly specified and the modules (when a class is to meet) are exactly specified, this situation will be called, class specifications with "hard constraints". For an example, the athletic program is usually in the afternoon in most schools. It is required that they meet daily. So, if the administrator specifies that athletics is to meet partially

on school time and is to meet daily, for three modules per meeting and he specifies that those modules will be 19, 20, and 21, then he has, in fact, absolutely specified all the variables for that class. There may be other classes which have less stringent restrictions placed upon them. Constraints upon a class which aren't exact as far as time and day pattern is concerned, give some leeway as to the days where the class can be placed, or some leeway as to the times of the day that the class can be held will be called class specifications with "soft constraints". The third category, of course, is one in which there are no constraints at all. There will be the number of modules per meeting and the number of meetings per week that the class is to be held, but other than these, the specifications are purely free.

For the purpose of scheduling there are two more specifications that are important, 1) Whether or not the class is to be team taught, and 2) How often the class is to meet.

Since more than one teacher on a team requires the intersection of several schedules to be free at the same time, scheduling team-taught classes is more difficult than scheduling a class with only a single teacher.

The second item is the meetings per week. If a class only meets once a week, it is relatively easy to find a location within the schedule for it to be taught. However, if a class is taught three times or more per week, the

problem becomes more difficult. Therefore, the meeting specification, the number of meetings per week that are required, plays a minor but important role.

Because of each of these items just specified, it is necessary not to simply build a conflict matrix with the classes placed randomly on it, but to place them in a specific order. To make this point a little clearer, consider again Figure 6. The last class in the conflict matrix is athletics, with an enrollment of thirty-nine students. Physics, with an enrollment of 119 students, has an intersection with athletics of thirty-nine students. This means that all of the enrollees in athletics are also requesting physics. If physics, then, were to be scheduled at the same time that athletics is held, there would immediately be thirty-nine conflicts. However, looking at Madrigals which has a class size of six, there are no conflicts between Madrigals and French 7-8 or athletics. Therefore, Madrigals could be taught at the same time as French 7-8 or athletics.

Class specifications are ranked in the following way. The most important specification is time and day pattern restrictions. Teaching organization specifications are next, followed by meeting specifications. After all of the classes have been ordered according to this procedure the first class on the list would be the most restricted or

hard constrained class.* The second class would be the next most constrained and etc., until the last class would have the fewest constraints.

Therefore, if the conflict matrix is constructed with the classes ranked by importance of constraint and if concern is given to the class conflicts that are indicated by the conflict matrix, a master schedule can be generated which will guarantee that only a minimum number of student requests will not be honored by the master schedule. Figure 7 shows some hypothetical rankings for the classes used in Figure 6. For simplification, the designations between large groups and small groups are left out.

Trigonometry and college algebra, in Figure 6, is a class that illustrates another important point. This class conflicts with every other class on the schedule. So when is it to be scheduled? It has to conflict with something, but what? It's relatively apparent that if it has to conflict with any class, it should conflict with one in which the fewest conflicts occur. In this particular case, it is with madrigals where there are only two conflicts. However, suppose that the specification for madrigals and the specifications for college algebra and trigonometry are not the same and there is not enough time for college algebra and trigonometry to meet. How is enough time made

---

*In the case of East High a class of this type would be team taught with exact time and day pattern specifications, and would meet five times a week.

Class	Time Pattern (Modules)	Day Pattern (M,T,W,R,F)	Teaching Organization (TEAM)	Modules/ Meeting	Meetings/ Week
Athletics	19-21	M,T,W,R,F	yes	3	5
French 7-8	9-12	M,W,R	yes	2	3
Madrigals	1-3	M,T,W,R,F	no	2	4
English 7-8	none	M,W,F	yes	3	3
Debate 3-4	4-21	M,T,W,F	no	2	3
Physics 1-2	none	none	yes	3	3
College Alg.-Trig.	none	none	no	3	2
Child Development	none	none	no	3	1

FIGURE 7

A hypothetical ranking of the classes shown in Figure 6. (the distinction between large and small groups is not included for simplification.)

available? Simply back off one more class and pick the next class with the fewest number of conflicts with college algebra and trigonometry. In this particular case, it is French 7-8. Now we have two class times, that of madrigals and that of French 7-8 which can be combined together for scheduling college algebra and trigonometry. And again, if this is not enough time for the specifications given to college algebra and trigonometry or it cannot be scheduled for some other reason, the above procedure is repeated until enough time is made available.

Chapter 4

RESULTS AND CONCLUSION

In an age when yesterday's unknowns are today's knowledge, it is difficult to be up-to-date in making assertions about what technology, especially in the field of Computer Science, can or cannot do. Computer programs have been built, for example, that have shown the usefulness of data processing in the school scheduling problem once the master schedule of a school has been built. But it was felt that the master schedule contained too many variables and was too complex for the computer to be used significantly. Recently, however, some pioneering work has taken place in at least two of the country's major universities, Stanford University[12] and Massachusett's Institute of Technology[6], toward the development of computer techniques for the construction of a school's master schedule. While these first works have some drawbacks for widespread use, they have shown the feasibility of building master schedules with the use of computers.[6][12][2]

4.1 What should be expected with the use of the Computer.

It is readily apparent that computer programs cannot be built that will produce a "good" master schedule if insufficient information has been supplied. Nor can such programs create needed rooms and additional teachers or

extend the length of the school day. However, it is not unreasonable to expect that techniques can be devised which will free teachers and administrators from the burden of routine scheduling matters which often cause educational decisions to be made for clerical expediency. It can also be expected that statistics such as teacher, student , room schedules, and combinations of these will be made available to the staff of a school. Perhaps the most important expectation is for a computer program that will be helpful in satisfying a higher percentage of the scheduling requirements by accommodating more student and teacher preferences.

4.2 The proof of the pudding is in the "numbers".

After all of the verbage about educational philosophy and computer techniques has been completed, the question naturally arises--did it work? If every student request, teacher requirement and room specification has been satisfied, success is absolute. However, to satisfy every student request is difficult since some known conflicts will not be removed from the master schedule by the administration. This was the situation at East High School. For example, the administration knew that a conflict existed between chemistry (AP) and Physics (AP). But, because of teacher requirements, these two classes had to be taught concurrently, and the administration deemed the conflict necessary. Similarily, the gym classes have some

serious conflicts with several other classes, to name a few--Journalism, English (AP), Creative Writing, and Biology (T). The gymnasium is a facility which houses a large number of classes other than the traditional gym class. Consequently, the facility is completely and absolutely specified. Therefore, with no other gym facilities available, these conflicts are left unresolved. The above examples elude to the fact that complete removal of class conflicts may be organizationally unrealistic. However, the program technique as described in chapter 3, reduces to a minimum the effect of these conflicts.

The populations used in the initial stages of this project were: 1813 students, 81 teachers, 85 rooms, and 194 classes, (6 off-campus extracurricular classes are not included); which resulted in 23,608 student class requests. Of these class requests, 99.2% were fulfilled, along with 100% of the teacher requirements and 100% of the room specifications.

Figure 8 is a representative student schedule and figure 9 is a portion of an "animated" conflict matrix which depicts possible student class conflicts. It is used as an indicator of potential trouble areas.

4.3 How It Works.

After all of the data has been gathered (as depicted in Figure 5) concerning the teacher and room specifications, course organization and student requests, it is the

NAME: Ayres, Anna E.

CLASS	GROUP	SEC	TEACHER	MON	TUE	WED	THU	FRI	ROOM
251 Trig. Coll. Alg.	LG	1	Mrs. MacKay	0	3-4	0	3-4	0	202
251 Trig. Coll. Alg.	SG	3	Mrs. MacKay	0	0	14-16	0	14-16	321
340 Socio. - Psy.	SG	1	Mr. James	1-2	0	1-2	0	0	310
340 Socio. - Psy.	LG	3	Mr. James	0	14-15	0	0	0	203
531 Latin 1-2	LG	1	Mrs. Karras	9-10	0	0	0	0	202
531 Latin 1-2	SG	2	Mrs. Karras	0	7-8	7-8	0	7-8	228
795 Child Devel.	SG	1	Mrs. Scott	15-16	0	0	1-2	0	35
12 Med. Serv. 1-2	LG	1	Miss Raymond	4-5	0	0	0	0	202
12 Med. Serv. 1-2	SG	2	Miss Raymond	0	0	0	0	4-6	212
442 Chemistry	LG	3	Mr. Freeman	0	0	11-13	0	11-13	127
442 Chemistry	SG	6	Mr. Kendall	0	0	0	11-13	0	14
172 English 7-8	LG	4	Miss S. Richards	0	0	0	17-18	0	201
172 English 7-8	SG	12	Miss S. Richards	17-18	0	17-18	0	0	210
88 Jones - SRS	SG	3	Mrs. Jones	0	0	6-6	0	0	238

FIGURE 8

A Representative Student Schedule

440 CHEMISTRY (AP)
LARGE GROUP WITH 1 SECTIONS AND 20 STUDENTS ENROLLED

Large Group Conflicts

Time Conflict	Class Number	Class Name	Number of Sections	Potential Student Conflicts
*	11	Health 1-2	5	6
	15	Physical Ed. 5-6(Boys)	5	7
	53	Athletics 3-8	1	6
	170	English (AP)	2	5
	134	Creative Writing 3-4	1	4
*	233	Algebra 3-4	5	2
	251	Trig. & College Algebra	3	6
	252	Trig. & Analyt.	1	5
	261	College Algebra Fnc.	1	5
	271	Analyt. Calculus	1	2
	290	Calculus (AP)	1	5
	293	Computer Science	1	5
	320	American History	1	7
	321	American History 1-2	6	2
	340	Sociology-Psychology	3	2
	366	Const. Law 1-2	3	4
*	470	Physics 1-2 (AP)	1	3
	472	Physics 1-2	2	7
	475	Air Space 1-2	1	2
	535	Latin 5-6	1	2
	558	Spanish 9-10	1	2
	651	Sculpture 1-2	2	2
*	811	Type 1-2	3	2
	931	Jr. Choir	1	2
	941	Acapella	1	5
	991	Advanced Orchestra	1	2

Small Group Conflicts

*	134	Creative Writing 3-4	3	4
	170	English (AP)	5	5
*	252	Trig. & Analyt.	2	5
	261	College Algebra Fnc.	2	5
*	271	Analyt. Calculus	2	2
*	293	Computer Science	4	5
	320	American History (AP)	5	7
	472	Physics 1-2	5	7
	475	Air Space 1-2	5	2

FIGURE 9

This is an animated conflict matrix which shows the potential class conflicts between Chemistry(AP) and all other classes. The classes with an * beside it are classes which are presently scheduled at the same time as Chemistry(AP).

responsibility of the administrator to construct with these puzzle pieces a completed master schedule picture. How is this to be done?

Assume that all of the classes have been previously sorted according to their constraint specifications--the first class being the most constrained, the second class being the least constrained. All of this data is stored within a time-shared computer to which a video display terminal is connected and placed in the administrator's office.* Also stored within the computer is a program to assist in the construction of the master schedule (written according to the procedure outlined in Chapter Three.) The administrator initiates the execution of the Master Schedule building program from the terminal. The program has been written to schedule classes according to the specifications given by the administrator. As long as there are no ambiguities in those specifications, that is, as long as the administrator has not requested that more than one class be taught concurrently in the same room or in different rooms but by the same teacher, the procedure continues with the program scheduling classes. During the execution of the program, messages appear upon the terminal after each class has been scheduled. In this way the

---

*At the writing of this paper this procedure has only been simulated on a batch-processing computer. However, implementation upon a time-sharing computer is nearing completion.

progress of the scheduling program can be monitored. This whole procedure continues until either the master schedule is completed or an unresolvable ambiguity occurs requiring an administrational decision to be made. If the scheduling process is interrupted the administrator is given, via terminal message, the type and location of the problem within the class specifications.

The administrator has available diagnostic program tools which allow him to interrogate any of the partially created teacher or room schedules or to change any of the class specifications he desires. In this way unforeseen difficulties can be removed as they occur. Moreover, the Master Schedule-building procedure can be reinstated from any point deemed suitable.

For example, assume a Humanities class has a large group specification as follows: meet 1) in Room 206, 2) twice a week, 3) two modules per meeting and 4) between the tenth and fifteenth modules. This class, because of 4) and because week day specifications are not given, is specified with soft constraints. Assume also that several other classes have already been scheduled and that all of the time between the tenth and fifteenth modules for Room 206 has been scheduled. The Humanities class cannot therefore, be scheduled. When this situation is encountered the administrator has several options open to him. Perhaps, 1) a different room can be assigned to Humanities, 2) the limits, tenth to fifteenth modules are not

necessarily binding and can be changed, or 3) the specifications of one of the classes already scheduled can be changed and rescheduled to make room for Humanities. Whatever the decision, the administrator can make the necessary changes in specifications and reinitiate the scheduling program at the terminal.

It should be clear, from this example, that with the computer "tools" provided in this program, the administrator has complete control over the Master Schedule building process. Upon completion, teacher and room schedules can be obtained, students' schedules also prepared and class lists generated.

4.4 Further Research.

1) While there has been a flurry of excellent research work done at both the elementary[4][15] and high school levels[1][2] over the past five years, there has been, surprisingly, relatively little done at the junior high school level. While the non-graded organization of the elementary schools is not entirely appropriate for the junior high school, neither is the modular organization as proposed for the high school. There needs to be a marriage of these two educational techniques--tempered for the needs of the junior high aged student.

2) As computers have become easier to use, from the layman point of view, Computer-Aided-Instruction has been an intriguing frontier to the educator. All the way from

the elementary class room to medical school, educators (as well as vendors) are interested in CAI. CAI does offer some flexibility that other machines (like television) do not. The student may start and stop the machine at will, have material repeated and, in some cases, have elementary questions answered about the material. Programs can be written that provide what is called "tutorial" presentation. These "presentations", in order to be programmed, must assume a learning style--a style which would usually reflect the logic of the author(s) of the program. A fertile area of research, it seems, would be to use CAI not just for presenting materials, for their own sake, but for the purpose of learning more about learning styles.

3) The idea of non-graded schools has been recognized as an educational technique with merit.[4][10][15] One of the desirable aspects of such a non-graded technique is to develop curriculums which teach skills and concepts and not just subject matter. However, the clerical staff required to monitor student process in an effort to determine what the student is ready for next is prohibitive. Some initial research work has indicated that computer technology can be of value. However, much work is in order.

4) Computers have long been known for their storage capacity and because of this fact, computerization of student records and other educational information has been thought of as being worthwhile. However, the question as

to what extent anecdotal records are valuable and/or should these records be kept at all, leads to an area of important research.

5) People are more and more, trying to use computers in the teaching act itself. While this is meeting with varying degrees of success in general subject matter areas, why couldn't the computer be used very successfully in teaching the basic principles about computers? Not just teaching programming languages but fundamentals such as substitution, replication, iteration, recursion, and etc.

FIGURE 10

Percentage of Students Experiencing
0-4 Scheduling Conflicts

On studying the charted figure 10, an immediate dichotomy results since normally one would expect a scheduling algorithm to be very successful in the beginning and gradually worsen as the number of students increased. But, as was indicated in earlier chapters, the data was biased so that the students with the most difficult request schedules would be scheduled first; therefore the poor success rate. The last students scheduled were the ones with the easiest request schedules to satisfy; hence success increased gradually until a plateau was reached, as indicated in the figure. At this writing no satisfactory mathematical proofs have been developed which prove the validity of the statements in this thesis.

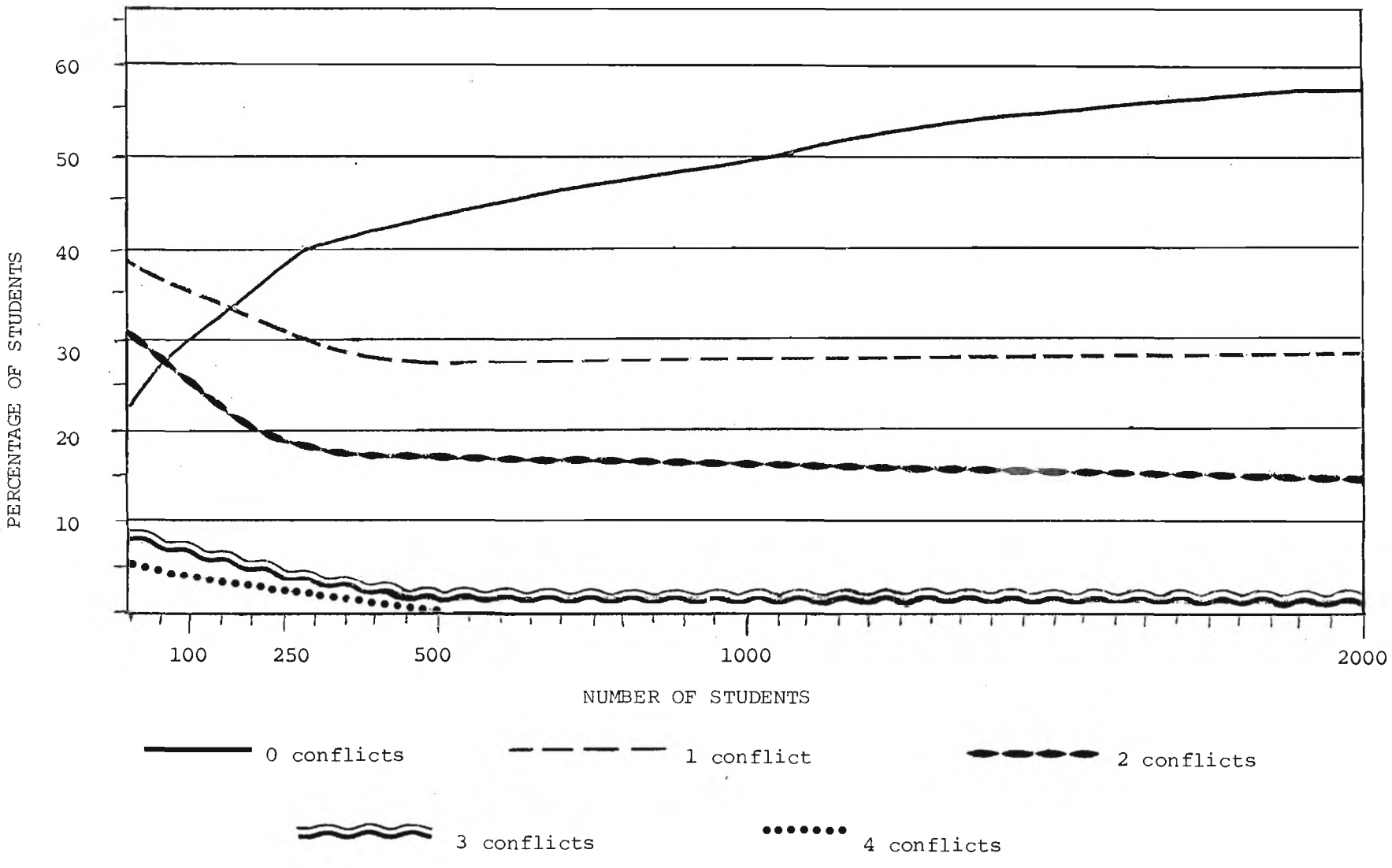

60
50
40
30
20
10
PERCENTAGE OF STUDENTS
100
250
500
1000
2000
NUMBER OF STUDENTS
0 conflicts
1 conflict
2 conflicts
3 conflicts
4 conflicts

Figure 10

BIBLIOGRAPHY

A. Books

1. Brown, Frank B., The Non-Graded High School. Englewood Cliffs, N.J. Prentice-Hall, 1963.

2. Bush, Robert N. and Allan, Durght W. A New Design for High School Education. McGraw-Hill Book Co., 1964.

3. Elsbree, Willard S. and McNalley, Harold J. Elementary School Administration. New York: American Book Co., 1959.

4. Goodlad, John I. and Anderson, Robert H. The Non-graded Elementary School. Revised Edition. New York: Harcourt, Brace and World, 1963.

5. McCleary, Lloyd E. and Hencley, Stephen P. Secondary School Administration. New York: Dubb, Mead Co., 1965.

B. Periodicals

6. Murphy, Judith and Sutter, Robert. School Scheduling by Computer: The Story of Gasp. New York: Educational Facilities Laboratories, Inc., 1964.

7. Allen, Dwight W. "How You Can Individualize Instruction--Right Now." Nation Schools. January-June. Vol. 81. No. 4.

8. Fish, Kenneth L. "Adopting a Modular Schedule?" National Association of Secondary School Principles Bulletin. Sept.-Dec., Vol. 52. 1968.

9. Goodlad, John I. "The Future of Learning and Teaching," AV Communication Review. Vol. 16. No. 1. Spring, 1968.

10. _____. "Meeting Children Where They Are." Saturday Review. March 20, 1965.

11. Hoffman, Orrin. "Flexible Schedule," Journal of Secondary Education. Vol. 43. 1968.

12. Kenney, James B. "What Can Computer Scheduling Programs Do?" Nation Schools. July-Dec. Vol. 82. No. 5.

13. Sleight, Ralph H. "Administrative Problems as a Result of Flexible Scheduling," Journal of Secondary Education. Vol. 42. 1967.

C. Unpublished Materials

14. Miller, George L. "Innovations in Grouping for Instruction," Salt Lake City, Utah: Annual Conference of Crucial Issues. William M. Steward School, University of Utah, November 18, 1960. (Mimeographed.)

15. Read, Edwin A. "Establishing Exemplary Centers For Continuous Progress Education." Salt Lake City, Utah: Operational Grant P.L. 89-10, Title III. August 1966. (Mimeographed.)

APPENDIX I

> "It is the task of a programmer to reduce the problem to linear form, which he does by absorbing the structure (of the problem) into the logic of the program."--J. K. Iliffe*

This section is intended to explain, roughly, what data structures were used and how they were implemented, and in general how the project was completed from a data processing point of view.

I.1 Work Done at East High.

1) The first step taken was to ascertain what classes were to be offered for the next year. The vice-principal gathered this information from each department along with the specification for each class, and submitted it to the principal for his approval. 2) From this list each student selected his class choices listed in order of preference, and had them approved by his counselor and his parents. 3) A conflict matrix was developed from the student requests and class counts produced. From the class counts, final decisions were made by the vice-principal about class sizes and the number of sections each class would have. 4) At this point the master schedule was developed. At the same time, the teacher and room schedules were obtained and checked for class load

---

*Iliffe, J. K. Basic Machine Principles.

balance. Final course specifications were made and the completed master schedule produced. 5) Student schedules were produced and distributed to the counselors for conflict correction, class changes, and distribution to the students.

I.2 Data Structure.

The data structures used in this project were quite "straight forward."

I.2.1 Course Data.

Each class and each section of a class was treated as an independent entity and stored in variable length records. These records were linked together in a simple list structure using forward pointers (see Figure I.1). If the class is team taught, the "team" element within each record is a pointer to a list containing the teachers involved in teams. If the class is not team taught then the element contains the teacher number itself.

I.2.2 Teacher and Room Schedules.

The teacher and room schedules were conceptually visualized as three dimensional arrays, and for simplicity, were stored in the computer as three dimensional arrays even though seldom more than 75% full. It was felt that the ease and speed of handling the data was worth the trade-off in wasted storage. (See Figure I.2).

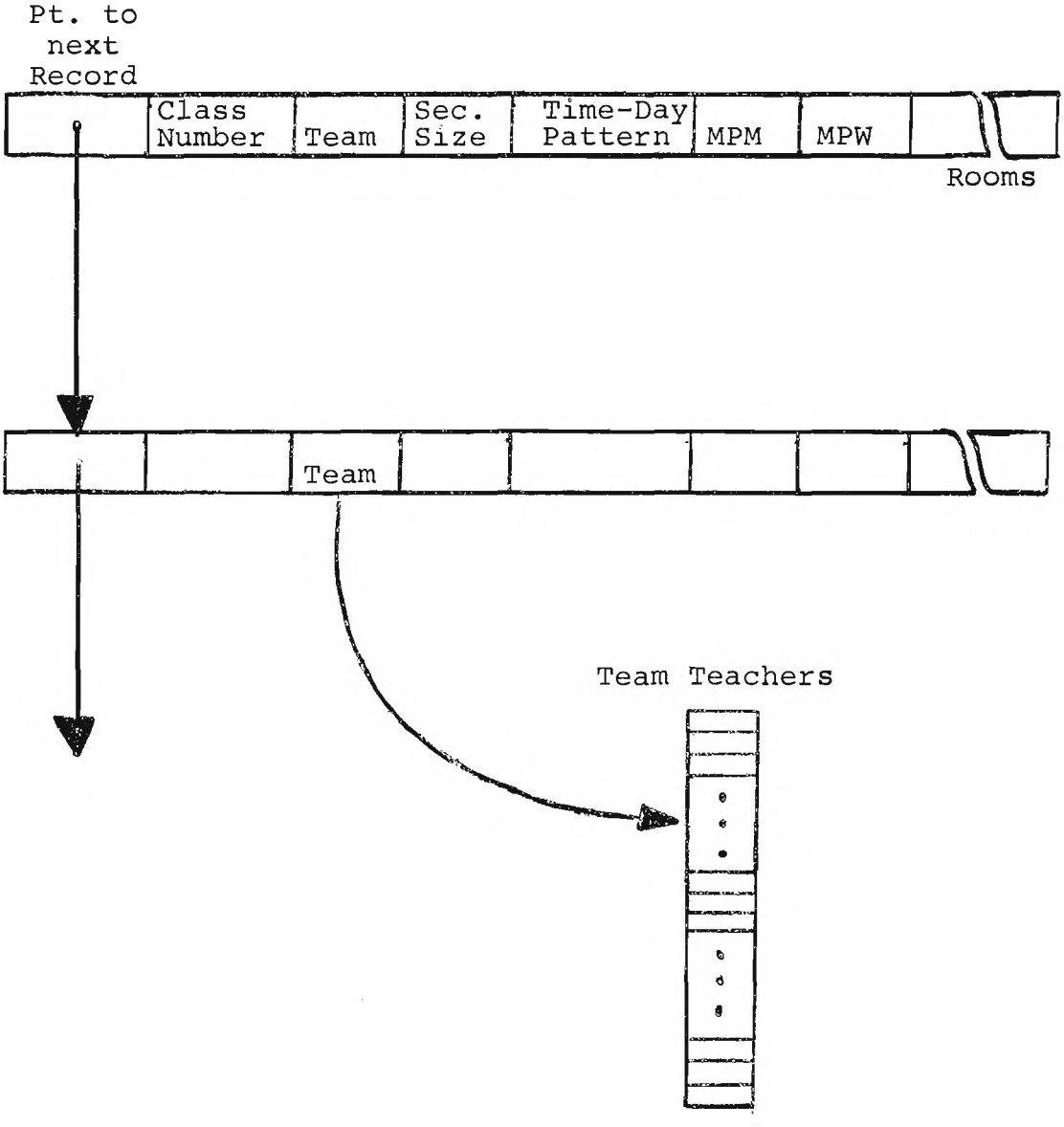


FIGURE I.1

A simple list structure for
course and teacher data

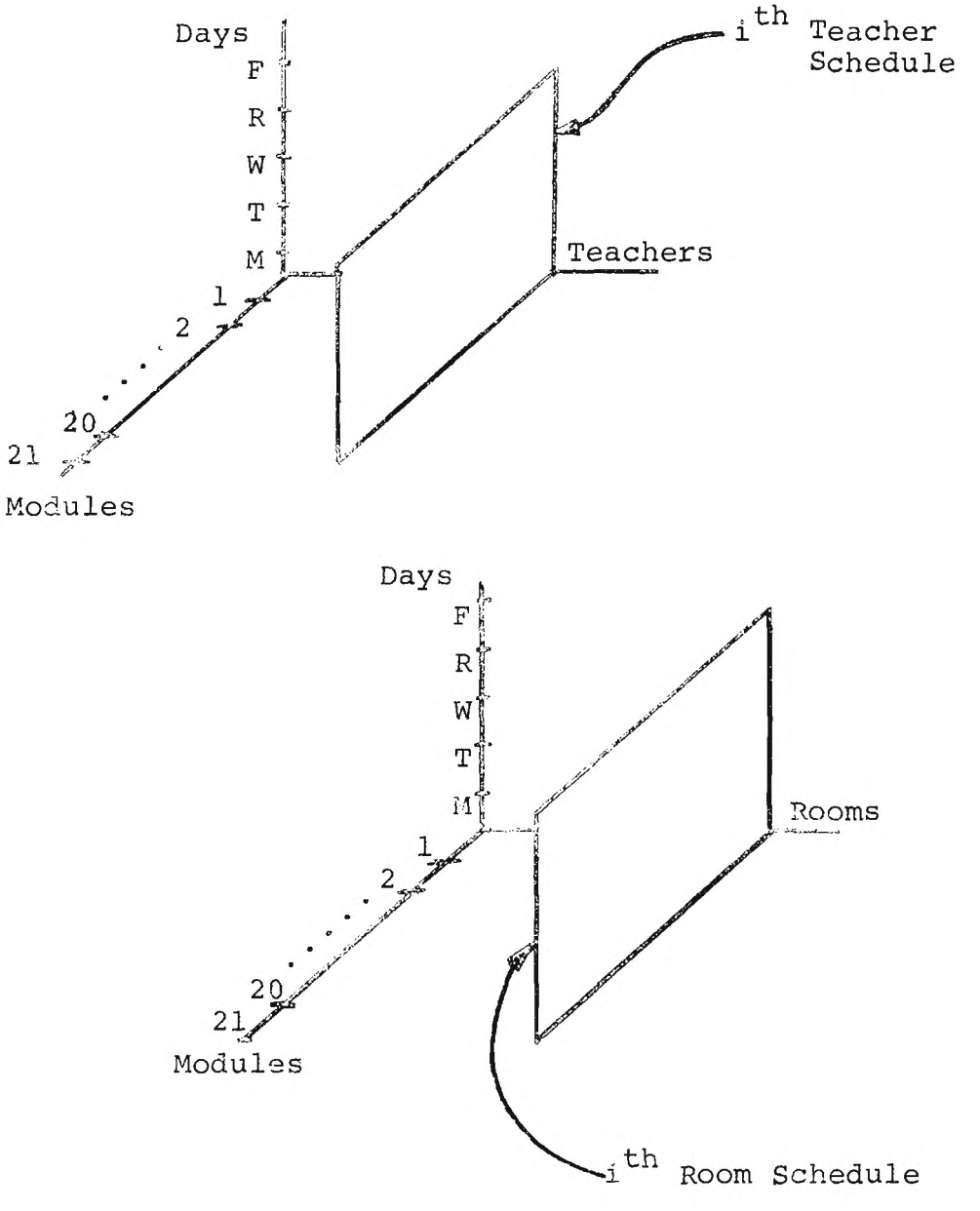


FIGURE I.2

A representation of the data structure used for storing Teacher and Room assignments.

I.2.3 Conflict Matrix.

The conflict matrix is a two dimensional symmetric array. Each axis represents the classes a school offers (See Figure I.4). Since the matrix is symmetric,

$$a_{21} = a_{12}$$

$$a_{32} = a_{23}$$

.

.

etc.

and the lower triangular matrix can be eliminated. However, the matrix should not be stored in the computer in the form of a matrix since the amount of redundant information grows as N^2 where N = number of classes.

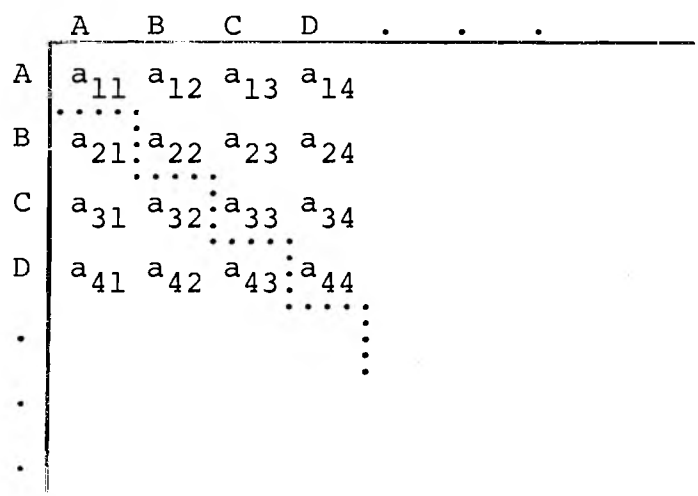


FIGURE I.3

A representation of a Conflict Matrix where A,B,C, D, . . . , represents classes. The main diagonal elements indicating the number of students in the intersection of the two classes.

Therefore, the matrix in I.4

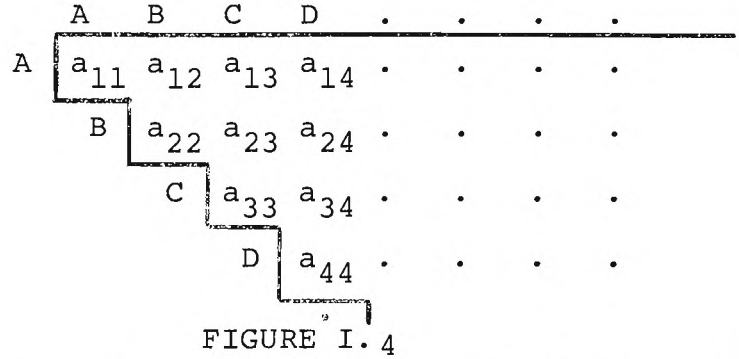


FIGURE I.4

A representation of a Conflict Matrix with the lower triangular matrix removed.

is mapped into a linear array, I.5.

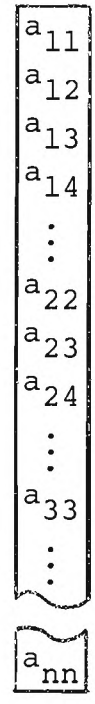


FIGURE I.5

A linear array which contains the "mapped" elements of the matrix in I.4.

The mapping function is easily derived as follows: consider the matrix called "M" and linear array "L"

$$M = \begin{cases} a_{11}a_{12}a_{13}a_{14} \\ \alpha_{21}a_{22}a_{23}a_{24} \\ \alpha_{31}\alpha_{32}a_{33}a_{34} \\ \alpha_{41}\alpha_{42}\alpha_{43}a_{44} \end{cases}$$

$$L = \begin{cases} l_1 = a_{11} \\ l_2 = a_{12} \\ l_3 = a_{13} \\ l_4 = a_{14} \\ l_5 = a_{22} \\ l_6 = a_{23} \\ l_7 = a_{24} \\ l_8 = a_{33} \\ l_9 = a_{34} \\ l_{10} = a_{44} \end{cases}$$

Let d = the matrix dimension. In this case d = 4. To calculate the index in the "L" array for the element a_{44}, r = 4 and c = 4 where r = row and c = column, the steps are as follows. 1) Calculate the number of elements in the first (r-1) rows. Therefore, $(r-1)d - (r-2)\frac{(r-1)}{2}$ where (r-1)d is the total number of elements in the first (r-1) rows and $(r-2)\frac{(r-1)}{2}$ is the number of "excess"

elements in the first (r-1) rows, namely α_{21}, α_{31} and α_{32}. In this case

$$(r-1)d = (4-1)4 = 12$$

and

$$(r-2)\frac{(r-1)}{2} = \frac{(4-2)(4-1)}{2} = 3$$

therefore

$$(r-1)d - \frac{(r-2)(r-1)}{2} = 12-3 = 9.$$

2) Add the last row elements (which in this case is only one.) This can be represented as

$$c - (r-1)$$

and for this case

$$c - (r-1) = 4-3 = 1$$

Altogether the mapping function for the elements of "L" given the row and column in "M" or $l_i = a_{r,c}$ is

$$i = (r-1)d - \frac{(r-2)(r-1)}{2} + c - (r-1)$$

or rewritten as

$$i = \frac{(r-1)}{2}(2d-r) + c$$

and for this example

$$i = (\tfrac{3}{2})(4) + 4 = 10$$

which is correct. With this mapping function the conflict matrix can be thought of as a two dimensional array while actually being stored as a one dimensional array.

APPENDIX II

A Flow Chart of the Master Schedule Building Program

The following general flow chart illustrates the basic logic in the Master Schedule building program.

II.1 Definitions.

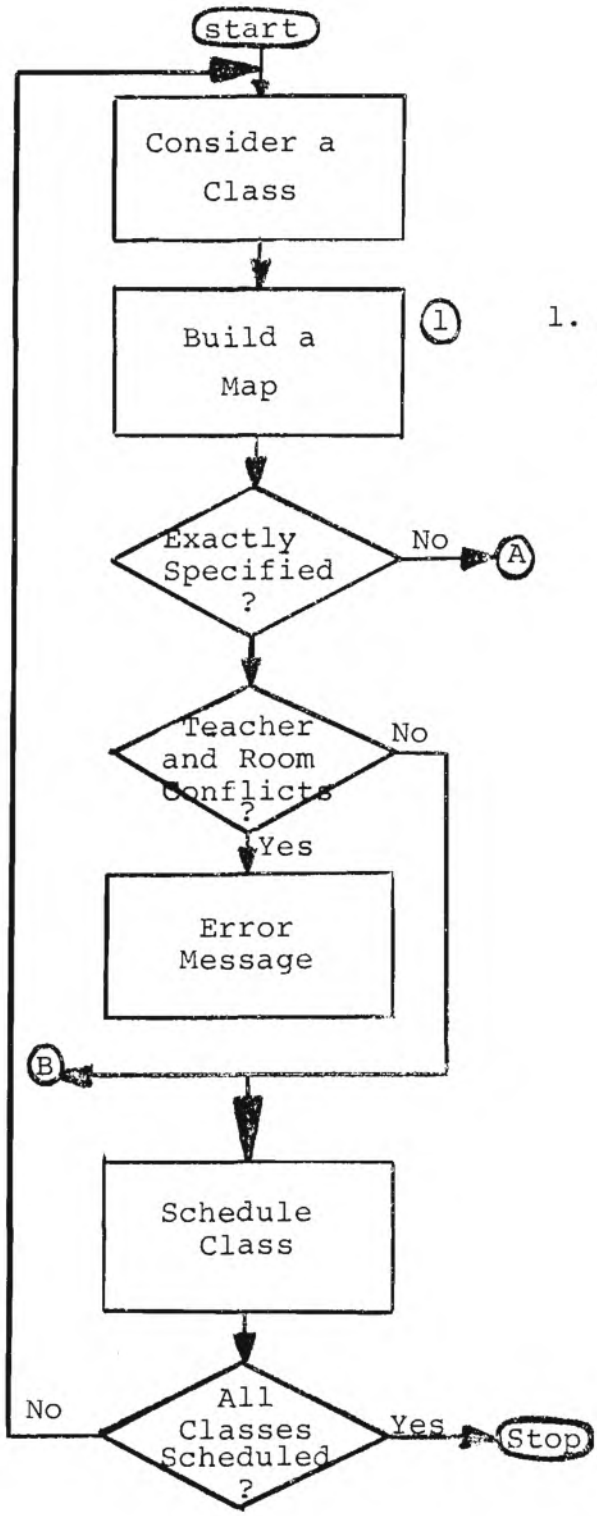
map - a two dimensional array representing a school week (21 modules per day, 5 days a week.)

class - a defined curricular offering.

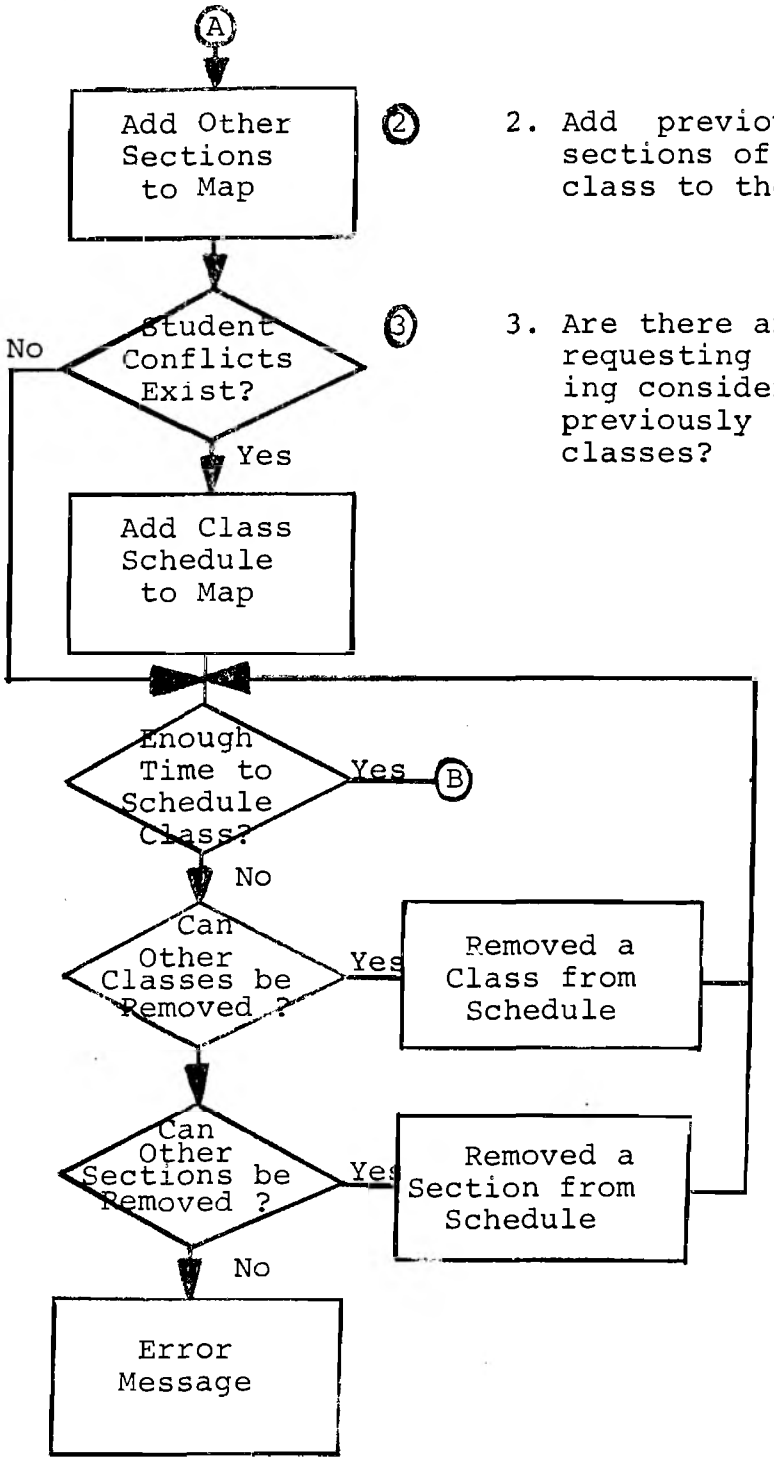
section - a replication of a class.

II.2 Flow Chart.

(See Page 67-68.)



1. Fill in the map with the preliminary teacher and room schedules.



2. Add previously scheduled sections of the same class to the map.

3. Are there any students requesting the class being considered and any previously scheduled classes?

VITA

Name	Nelson S. Logan
Birthdate	28 May 1939
Birthplace	Princeton, Kansas
High School	Wichita High School East Wichita, Kansas
Universities	Wichita State University Wichita, Kansas 1958-1961
	University of Utah Salt Lake City, Utah 1963-1969
Degrees	B. S., Education Wichita State U., 1961
	M. S., Mathematics University of Utah, 1965
	Ph.d., Computer Science University of Utah, 1969
Professional Experience	Mathematics Teacher, 1961-65 Junction City High School Junction City, Kansas
	Numerical Analyst, 1963-1965 U. of Utah Computer Center University of Utah Salt Lake City, Utah
	Educational Analyst, 1968-69 Utah Educational Data Processing Project Salt Lake City, Utah