ABSTRACT

AN INVESTIGATION OF THE SUITABILITY OF VARIOUS TYPES OF BIOLOGY LABORATORY DESIGNS FOR CERTAIN INSTRUCTIONAL PRACTICES

By

John T. Norman Jr.

The purpose of this study was to investigate the instructional suitability of various laboratory designs, as perceived by the secondary biology teachers currently teaching in these laboratories.

To provide a framework for the investigation of this problem, the human engineering approach to design evaluation was used in the study. In this approach it is first necessary to describe the structure and function of the system to be evaluated. This analysis is then generally followed by observations of how well various alternative designs accomplish the desired functions of the system.

The problem in this study was thus studied in two parts. Part I dealt with a description of four high school biology laboratory systems. These systems were described in relation to the significant interacting elements of: the instructional process, the teacher and student participants, and the arrangement of the physical facilities. These four laboratory systems differed primarily in the design of their physical

facilities. Specifically, these four laboratory design types were: (1) split lecture-laboratory design, (2) perimeter tables design, (3) central-fixed tables design, and (4) central-movable tables design. A pre-survey instrument was constructed and sent to the Class B and Class C high schools in Michigan, to obtain the specific information needed for the above description of the four types of laboratory designs. Part II of the study consisted of an evaluation of these four types of laboratory designs as to their perceived suitability for different types of instruction, namely: independent study, small group instruction, and large group instruction. The form of this evaluation was a teacher opinion survey. A survey instrument was developed and sent to a random sample of Michigan Class B and Class C high school teachers from each of the four design categories identified in the pre-survey. On this survey instrument the biology teachers rated the suitability of their laboratory design for the instructional methods of: independent study, small group instruction, and large group instruction. Of the 140 survey instruments mailed, 133 instruments were returned for a 95.0 per cent response.

This survey was followed by field visitations to discover possible explanations for laboratory design adequacy and inadequacy.

Internal consistency reliabilities were calculated for each of the survey item types and the resultant coefficients indicated a high degree of reliability for each of these categories. Optimum weights were determined for each of the items by the reciprocal averages method, so that the data would be more quantifiable.

A repeated measures analysis of covariance procedure was applied to the ratings from the survey instrument, to determine if the four types of laboratory designs differed in their instructional suitability, as perceived by the high school biology teachers currently teaching in these laboratories. The covariate used here was "recency of laboratory construction," because it was found to have a fairly high correlation with the dependent variable of perceived instructional suitability. The repeated measures were the instructional methods item categories of: independent study, small group instruction, and large group instruction. Based on this analysis, the teachers from the four laboratory design groups differed significantly in their perception of their laboratory design's suitability for the three instructional methods of independent study, small group instruction, and large group instruction: furthermore, there was no significant interaction between the design groups and the repeated measures. Comparisons of the four design group means indicated that: (1) the mean scores of the split design group were significantly greater than the mean scores of the perimeter, central-fixed, and central-movable design groups for the instructional methods of independent study, small group instruction, and large group instruction; (2) the mean scores of the perimeter design group were not significantly different from the mean scores of the central-fixed design group for the instructional methods of independent study, small group instruction, and large group instruction; (3) the mean scores of the perimeter design group were significantly greater than the mean scores of the central-movable design group for the instructional methods of independent study, small group instruction, and large group instruction; and (4) the mean scores of the central-fixed design group were not significantly different from the mean scores of the central-movable design group for the instructional methods of independent study, small group instruction, and large group instruction.

Categorization of the teachers' recommendations for improving the instructional adequacy of their biology laboratory designs indicated that the following categories were mentioned most frequently: (1) more functionally designed laboratory tables, ventilation system, individual student stations, and room darkening facilities; (2) more classroom space for individual and small group activities; (3) more electrical outlets, gas outlets, sinks, and faucets; and (4) more storage space.

Findings from field visitations to typical laboratories from each of the four design groups indicated that: (1) the pre-survey laboratory design drawings were accurately done; (2) the directions and the items from both the pre-survey and instruments were clearly understood; (3) teachers from the split and perimeter design groups were more satisfied with their laboratory design's instructional adequacy than were those from the central-fixed and central-movable design groups; and (4) the physical design variables of room lighting, leg room beneath tables, and storage space were frequently mentioned as having an affect on the instructional adequacy of the laboratory facility.

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CHAPTER I

INTRODUCTION

The effect that the physical environment of a building can have on its occupants was recognized by the late Sir Winston Churchill when he said, "We shape our buildings; thereafter they shape us."[1] Churchill was reported to have made this statement to express his fear that proposed changes in the design of the House of Commons building might seriously alter future patterns of government.[2] Similarly, there are many prominent educators today who feel that the physical environment of a school classroom can affect the nature of the instruction and learning that takes place within that classroom. Brandwein says that a reason for the lack of instruction in "inquiry" or "process" in science classrooms today is that "school buildings are, in large part, not built to facilitate the arts of investigation."[3]

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[1] "Schools of Tomorrow," Time, LXXVI, No. 11 (September 12, 1960), 74.

[2] Edward T. Hall, The Hidden Dimension, (Garden City, N.Y.: Doubleday and Company, Inc., 1966), p. 100.

[3] Paul F. Brandwein, "Observations on Teaching: Overload and 'The Methods of Intelligence,'" The Science Teacher, XXXVI (February, 1969), 38-39.

Addison Lee also emphasizes the importance of good facilities to the instructional process when he says.

> Science teaching, like research, is important to the advancement of science. Teaching, like research requires satisfactory equipment and facilities--it cannot be successful without them.[4]

The foreword of a National Science Teachers Association report on science facilities states,

> The continuing attention given to science teaching facilities by the National Science Teachers Association is evidence of the conviction that science facilities are far more than facilitating or enabling implements in the science program of the school.[5]

Therefore, these educators acknowledge that the physical environment of the classroom can affect the instructional process.

To study scientifically classroom environmental relationships, it is helpful to think of the classroom as a dynamic "system" involving humans, the physical environment, and the instructional process.[6] The attempt to relate aspects of the physical environment of the classroom to other important aspects of this system

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[4]Addison E. Lee, "In My Opinion," The American Biology Teacher, XXV, No. 5 (May, 1963), 324, citing from BSCS High School Biology: Equipment and Techniques for the Biology Teaching Laboratory.

[5]National Science Teachers Association, Science Facilities for Our Schools K-12, (Washington: NSTA, 1963), p. i.

[6]SER 3: Environmental Analysis, School Environments Research Project, Architectural Research Laboratory, (Ann Arbor: The University of Michigan, July, 1965), p. 1/2.

contributes to the development of an environmental science of the classroom. John Dewey says,

> Facts which are . . . interrelated form a system, a science. The practitioner who knows a system . . . is evidently in possession of a powerful instrument for observing and interpreting what goes on before him. This intellectual tool affects his attitudes and modes of response in what he does.[7]

In this study, the environmental variable, the classroom, is examined to determine its perceived effect on the instructional process.

Statement of the Problem

The purpose of this study is to investigate the instructional suitability of various laboratory designs as perceived by secondary biology teachers.

To provide a framework for the investigation of this problem, the human engineering approach to design and design evaluation is utilized. The use of the human engineering approach to facility design problems is fairly novel in education, but it has been used successfully in other fields for the design of such things as factory workspaces, aircraft cockpits, automobile interiors, and space vehicles.[8] Human engineering is a scientific approach to the problems of designing workspaces

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[7]John Dewey, Sources of a Science of Education, (New York: Liveright Publishing Corp., 1929), p. 20.

[8]Alphonse Chapanis, Man-machine Engineering, (Belmont, California: Wadsworth Publishing Co., Inc., 1965), p. 10.

which people are expected to use so that the users will accomplish their tasks more ably and efficiently.[9] Woodson and Conover imply that the application of the human engineering approach to school facility design problems could produce a more functional environment[10] when they say,

> Frequently, human engineering is considered to be something which is applied to a very limited list of design problems . . . Unfortunately, we have tended (particularly in the United States) to ignore some of the more common everyday problems--- in terms of not applying good human engineering principles. For example, very little has been done in the design of . . . schools.[11]

The problem in this study is examined in two parts. Part I deals with a description of how the human engineering approach might be applied to the design of functional biology laboratory facilities. Using this approach, one can describe the significant interacting elements in the system called the biology laboratory; these elements can be grouped under the categories of human operators, physical environment, and the instructional process. Part II of the study consists of an investigation of the instructional suitability of selected types of laboratory designs as perceived by secondary biology teachers who are currently teaching in these rooms. The

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[9]Wesley E. Woodson and Donald W. Conover, Human Engineering Guide for Equipment Designers, Second Edition (Berkeley: University of California Press, 1964), p. 1-1.

[10]Ibid., p. 1-3.

[11]Ibid.

laboratory designs are examined in terms of the spatial organization of their major fixed and movable facilities. With regard to the major elements of a laboratory system, this study deals with the spatial factor of the physical environment (independent variable), in relation to its perceived effect on the instructional process (dependent variable). The reason for selecting the spatial factor out of all of the other possible physical environmental factors is that it seems the most important factor related to the success of the instructional process in secondary biology laboratories. According to the National Council on Schoolhouse Construction, the importance of this spatial factor in schools should be recognized "because the spatial factor can make it possible to either carry on the desired educational program efficiently or virtually preclude certain desired developments . . ."[12] The dependent variable of perceived instructional suitability was chosen here because it is one of the most important indicators of the success of the entire biology laboratory system.

Objectives and Questions

Part I.--To describe the human engineering approach to design, and how it might be applied to the planning of functional secondary biology laboratories.

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[12]National Council on Schoolhouse Construction, NCSC Guide for Planning School Plants (East Lansing: NCSC, 1964), p. 92.

Questions:

1. What does the human engineering approach to the design of workspace yield?
2. What are the significant interacting elements that describe the system called the secondary biology laboratory?
3. Is there sufficient data available at this time to predict the instructional suitability of various biology laboratory designs?

Part II.--To evaluate selected types of secondary biology laboratory designs as to their perceived suitability for different types of instruction, namely: large group instruction, small group instruction, and independent study.

Questions:

1. Is the teacher's perception of the suitability of his laboratory for large group instruction, for small group instruction, and for independent study, affected by his laboratory's design type?
2. Is the teacher's perception of the suitability of his laboratory for large group instruction, for small group instruction, and for independent study, affected by the possible confounding variables of:
   a. recency of laboratory construction?
   b. type of curriculum materials used?

c. average class size?

d. amount of academic biology coursework completed by the teacher?

e. number of years of biology teaching experience?

3. What recommendations do these secondary biology teachers have for improving the instructional adequacy of their biology laboratory designs?

Need for the Study

The need for research on the effect of biology room designs on instruction results from the apparent importance of the physical environment to the instructional process, and from the general lack of knowledge concerning such environmental relationships.

The Physical Environment and the Instructional Process

Though it is generally held that teacher behavior can greatly influence student learning,[13] what a teacher will aspire to do is considered to be dependent upon what he perceives to be possible.[14] And the physical

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[13]Archie L. Lacey, Guide to Science Teaching in Secondary Schools, (Belmont, California: Wadsworth Publishing Co., Inc., 1966), p. 73; D. A. Prescott, The Child in the Educative Process, (New York: McGraw-Hill Book Co., 1957), pp. 6-7.

[14]B. Othanel Smith, "Conditions of Learning," Designing Education for the Future, No. 2: Implications for Education of Prospective Changes in Society, (New York: Citation Press, 1967), p. 68.

environment of the classroom is thought to influence teacher perception of the instructional practices that are possible.[15]

According to B. Othanel Smith, learning in the classroom is largely a result of teacher behavior in initiating and guiding student activities, in reinforcing student responses, and in accentuating student involvement in the learning process.[16] Gage says, furthermore, that "changes in how learners go about their business of learning occurs in response to the behavior of their teachers or others in the educational establishment."[17] Thus, these educators feel that student learning can be greatly affected by teacher behavior.

There are, also, several educators who feel that teacher behavior is influenced by the physical environment of the classroom. For example, Hurd says,

> Outstanding facilities always denote a good learning environment. The arrangement of a room and its equipment should make possible the teaching techniques essential to the achievement of the specified objectives.[18]

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[15] National Science Teachers Association, Science Facilities for Our Schools K-12, op. cit.

[16] Smith, op. cit., p. 73.

[17] N. L. Gage, "Theories of Teaching," Theories of Learning and Instruction, Sixty-third Yearbook of the National Society for the Study of Education, Part I (Chicago: NSSE, 1964), p. 271.

[18] Paul DeH. Hurd, "How to Achieve Outstanding High School Science Facilities," American School and University, XXVII (1956), 317.

Likewise, Lehmann states that adequate physical facilities that are managed intelligently can multiply teaching-learning possibilities.[19] He says,

> At the very least, it is reasonable to expect that the classroom . . . can be designed to keep out of the way of the teaching-learning nexus. To ask a little more, we should expect the space to be ample, responsive to change, or even to the whimsical demands of teacher talent. . . . It could possibly be the catalyst for an improved total experience in learning.[20]

Alfred Novak says, furthermore, that the degree to which laboratory experiences in biology are "structured" depends on the type of facilities available.[21]

Hence, if teacher behavior does influence learning, and if the physical environment of the classroom does influence teacher behavior, then it would be important for educators to have knowledge about such environmental relationships.

Need for Knowledge about Environmental Relationships

It is estimated that in the next ten years the American people will spend over forty billion dollars

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[19] C. F. Lehmann, "Analyzing and Managing the Physical Setting of the Classroom Group," *The Dynamics of Instructional Groups*, Fifty-ninth Yearbook of the National Society for the Study of Education, Part II (Chicago: NSSE, 1960), p. 254.

[20] *Ibid.*, p. 267.

[21] Alfred Novak, "Scientific Inquiry in the Laboratory," *The American Biology Teacher*, XXV, No. 5 (May, 1963), 343.

building educational facilities, and that a large portion of this will go for science teaching facilities.[22] However, there is no generally accepted theory in education which can describe or predict which science facility would be best for a particular type of instruction.[23]

In the fifty-ninth yearbook of the National Society for the Study of Education, Hurd and Johnson declare that one of the major problems in science education today is, "How can the adequacy of facilities for instruction in science be increased?" Furthermore, they state that appropriate facilities are essential to any level of creditable teaching performance.[24] Martin stresses the particular need for adequate science teaching facilities for individualized instruction. He says that many of our high school facilities today are stereotyped because they were copied originally from those provided in German universities that were designed primarily for lectures,

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[22] Robert B. Sund and Leslie W. Trowbridge, Teaching Science by Inquiry in the Secondary School, (Columbus: Charles E. Merrill Books, Inc., 1967), p. 225.

[23] O. M. Stephan, "The Design of Biological Laboratories for Secondary Schools," The Design of Biological Laboratories, H. V. Wyatt, Editor (London: F. J. Milner & Sons Limited, n.d.), p. 18.

[24] Paul DeH. Hurd and Philip G. Johnson, "Problems and Issues in Science Education," Rethinking Science Education, Fifty-ninth Yearbook of the National Society for the Study of Education, Part I (Chicago: NSSE, 1960), p. 336.

demonstrations, and prescribed experiments.[25] In discussing four serious gaps that have appeared in the science education spectrum in recent years, Stotler says that one of these gaps is in the physical facilities for teaching science. He says that the filling of this gap involves more than the provision of funds. What is needed, he says, "is a clear understanding of the activities in which modern-day science students should engage and the type of facilities and equipment which will encourage the many aspects of problem solving.[26] Likewise, Eugene Lee says that of the two major headaches facing public education today, one of these is the provision of adequate facilities and equipment for optimum learning conditions. He mentions there is a particular need for adequate laboratory facilities in the secondary school.[27] Thus, there appears to be an acknowledged need for more functional science facilities.

The need for more research on the instructional adequacy of school facilities is further emphasized by

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[25]W. Edgar Martin, "Facilities, Equipment, and Instructional Materials for the Science Program," Rethinking Science Education, Fifty-ninth Yearbook of the National Society for the Study of Education, Part I (Chicago: NSSE, 1960), pp. 231-232.

[26]Donald Stotler, "The Supervision of the Science Program," Rethinking Science Education, Fifty-ninth Yearbook of the National Society for the Study of Education, Part I (Chicago: NSSE, 1960), p. 218.

[27]Eugene C. Lee, New Developments in Science Teaching, (Belmont, California: Wadsworth Publishing Co., Inc., 1967), pp. 47-48.

Lehmann. He says that in the last decade architects and educators have gained much information on the relationship between school facilities and discomfort, accident and disease. However, what is not clear, he says, is the relationship between the building facilities and the teaching-learning process. In mentioning the paucity of research in this area, he stresses that the type of information really needed is that which would show the extent single physical facility variables bear upon the total matrix of the class or a group.[28] The lack of scientific research on environmental relationships is also emphasized by Handler who says that a large body of folklore has come into existence, as well as the "art of pretentious know-how" in designing school facilities. He says that "scientifically grounded knowledge about the effects buildings should have on their inhabitants seems to be minimal." Furthermore, he emphasizes the need for an accelerated program of research on environmental relationships so that we can have an "environmental science sufficiently broad to serve as a basis for environmental design."[29] The need for scientific research on the effect

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[28] Lehmann, op. cit., p. 253.

[29] SER 2: Environmental Evaluations, School Environments Research Project, Architectural Research Laboratory, University of Michigan (Ann Arbor: University of Michigan, May, 1965), p. 11, citing A. Benjamin Handler, from a paper presented at the Conference of the Building Research Institute, 1960.

of the spatial environment of a school facility on man is also mentioned by Himes. He feels that two-dimensional graphics or three-dimensional models describing the physical characteristics of a particular space are not an adequate description. Such graphics or models, he says, do not adequately account for the psychological and cultural effects of these spaces on people.[30] Edward T. Hall also emphasizes the importance of this non-physical dimension of space which he calls "the hidden dimension." He says that it consists of social and personal space and man's perception of it.[31] Thus, Himes and Hall feel that the spatial environment of a classroom facility has to be experienced in order to be evaluated. They feel that research on the spatial factor of the physical environment can yield experimental data that could not be predicted from a consideration of the physical aspects of the space alone. The School Environments Research project at the University of Michigan has analyzed almost six hundred reference documents dealing with environmental relationships.[32] The result of this analysis, according

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[30]Harold W. Himes, "Space as a Component of Environment," SER 2: Environmental Evaluations, School Environments Research Project, Architectural Research Laboratory, University of Michigan (Ann Arbor: University of Michigan, May, 1965), pp. 58-59.

[31]Hall, *op. cit.*, pp. 1-178.

[32]SER 1: Environmental Abstracts, School Environments Research Project, Architectural Research Laboratory, University of Michigan (Ann Arbor: The University of Michigan, February, 1965), pp. 1-765.

to their recent report, demonstrates that our current knowledge of environmental relationships is "woefully inadequate."[33]

Hence, there is a need for research on the instructional suitability of various types of biology room designs. This need is manifested from the importance given to the effect that the physical environment can have on the instructional process, as well as from the current lack of knowledge in education concerning environmental relationships.

Treatment of the Problem

The study was designed to investigate the instructional suitability of various laboratory designs, as perceived by secondary biology teachers.

Initially, a description of the important interacting elements of the secondary biology laboratory system was obtained. To aid in the description of the physical facilities of this system, a pre-survey instrument was sent to various biology high school teachers in Michigan. The drawings of laboratory designs that were returned from this pre-survey instrument were then used to categorize laboratory design types. Four laboratory design categories were then selected for the subsequent evaluation of their instructional suitability.

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[33] SER 2: Environmental Evaluations, op. cit., p. 10.

To evaluate the instructional suitability of these laboratory designs, a survey instrument was constructed, pretested, revised, and mailed to a random sample of biology teachers from each of the four laboratory design categories. On this survey instrument, the biology teachers were asked to rate the suitability of their biology laboratory design for each of thirty instructional practices. Although not noted on the questionnaire, ten of these instructional practices were indicators of large group instruction, ten were indicators of small group instruction, and ten were indicators of independent study. Space was also provided for these teachers to describe how their biology laboratory designs could be improved for instructional purposes. In addition, descriptive information was collected on variables that might have been confounded with the teacher perception of the instructional suitability of their laboratory design. Hypotheses were examined regarding: (1) differences in the perceived instructional suitability of the four laboratory designs, and (2) the possible overall interaction between the repeated measures of instructional suitability and the different laboratory design types. An analysis of covariance model was used for the analysis of the instructional suitability ratings.

A field visitation was conducted with two biology teachers from each of the four laboratory design categories included in the survey. From these interviews, information was obtained on the validity of the pre-survey instrument and the survey instrument, as well as information on other variables that might be important determinants of the instructional suitability of the laboratory.

Definitions of Terms

The following are definitions of terms used in this dissertation.

Secondary schools refers to those Class B and Class C high schools in Michigan as classified by the Michigan High School Athletic Association.[34]

Laboratory designs refers to the physical environment of the room where biology laboratory is taught, in terms of the spatial organization of the major fixed and movable facilities.[35]

Large group instruction refers here to a category of instructional practice, where at least an entire class of approximately twenty-five to thirty-two students are engaged in the same teacher-dominated activities and presentations.[36]

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[34] Michigan High School Athletic Association Bulletin, November Supplement, Directory Issue 1967-68 School Year, XLIV, No. 4-s (November, 1967), pp. 232-234, 236.

[35] National Council on Schoolhouse Construction, op. cit.

[36] J. Lloyd Trump and Dorsey Baynham, Focus on Change: Guide to Better Schools, (Chicago: Rand McNally & Co., 1961), p. 30.

<u>Small group instuction</u> refers here to a category of instructional practice where two to fifteen students are actively engaged in small group discussions or activities, either with or without the teacher being present in the goup.[37]

<u>Independent study</u> refers here to a category of instuctional practice, where individual students are engaged in different projects and activities on their own, with minimum of outside interference by other students.[38]

<u>Pre-survey instrument</u> refers to the first questionnaire sent to all of the Class B and Class C high schools in Michigan. It called for the biology teachers to draw and label their biology laboratory design on graph paper, as well as to provide other descriptive information pertaining to their laboratory facility.

<u>Survey instrument</u> refers to the second questionnaire that was sent to a random sample of teachers chosen from the four types of biology laboratory designs categories that were selected. In this instrument the teachers were asked to rate the suitability of their laboratory design for thirty listed instructional practices. Other descriptive information collected

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[37]Trump and Baynham, <u>op</u>. <u>cit</u>., p. 24-25.

[38]Trump and Baynham, <u>op</u>. <u>cit</u>., pp. 26-29.

in this questionnaire included recency of laboratory construction, type of curriculum materials predominately being used, average class size, amount of teachers' academic biology coursework, years of teaching experience in biology, frequency of use of the various instructional practices, and recommendations for improving the instructional adequacy of their biology laboratory designs.

Field study refers to the visitations that were made to two biology laboratories from each of the four design categories that participated in the survey.

Human engineering refers to an approach to design problems that consists of two basic processes: systems analysis and system evaluation. The system analysis gives a picture of the structure and functions of the system. Whereas, the system evaluation provides a measure of how well alternative systems serve an intended purpose.

Assumptions and Limitations

It was assumed in this study that the biology teachers could objectively evaluate the instructional suitability of their laboratory design. The limitation of such an assumption might be that these teachers were not capable of making such an objective evaluation. Furthermore, it was assumed that the teacher's drawing of his laboratory design was an accurate representation of the spatial organization of his room. It was assumed, also, that these laboratory designs could be categorized fairly accurately from these drawings.

The fact that the biology teachers were not randomly assigned to the various laboratory designs was a major limitation of the study. Because of this limitation, differences observed in the perceptions of teachers from different types of laboratories could have been attributed to a multitude of other variables besides that of the design itself.

The room design investigated here was limited to that of a single room where biology laboratory was being taught. Perhaps the evaluation of the design of an entire complex of science rooms would have produced a different evaluation.

This investigation was further limited by the variety of biology laboratory design types that were available. The four types of laboratory design categories that were chosen for this evaluation were not as widely different from each other as might be desired.

Another possible limitation of this study could be in the validity of the measures used in the survey instrument as indicators of the instructional practices of large group instruction, small group instruction, and independent study.

This investigation was limited to the perceptions of biology teachers from the Class B and Class C high schools in Michigan.

Organization of the Thesis

Presented in Chapter I was the statement of problem, the need for the study, an overview of the treatment of the problem, and the assumptions and limitations of the study.

Included in Chapter II is a review of related research studies, as well as a description of the human engineering approach to design.

In Chapters III and IV the overall research design of this investigation is described. Included in Chapter III is a description of the secondary biology laboratory systems. This description will include findings from the pre-survey instrument concerning the types of biology facility existing in Michigan. Included in Chapter IV are the procedures used to evaluate the instructional suitablility of various laboratory designs. This includes the survey design, the selection of the sample, the development of the survey instrument, the collection of the data, and the analysis.

In Chapter V, the findings from the survey and the field study are presented.

Finally, Chapter VI contains a summary of the entire thesis, the conclusions, the implications for educational practice, and the recommendations for future research.

CHAPTER II

REVIEW OF RELATED LITERATURE

This review consists of three sections. In the first section, research studies are examined that have dealt with the relationship of the spatial design factors in school facilities and differences in the performances of the occupants of these facilities. This section of the review bears most directly on the problem of this study, the investigation of the relationship of different biology classroom designs to the perceived instructional suitability of these different rooms. In the second section, research that is less directly related to this study is reviewed. This section consists of studies of the relationship of certain non-design factors of the school environment to differences in the performance of the occupants of these facilities. The purpose of this latter review was to identify those non-design factors which have been shown to be significantly related to teacher and student behavior in the classroom. The third section consists of a description of the human engineering approach to workplace design, and the use of this approach in the investigation.

Relationship of Spatial Design Factors to Differences in the Performances of Occupants

The available literature often deals with spatial design environmental factors of the entire school as well as of the individual classroom. Although of primary interest in this study were the classroom spatial design factors, the evidence presented from studies of entire school buildings also relates to this problem. Thus, this section has been divided into two parts, the first part which deals with studies of classroom design factors and the second section which deals with studies of entire school building design factors.

Spatial Design Factors of the Classroom

The National Science Teachers' Association (NSTA) undertook a nation-wide survey of the effectiveness of secondary school science facilities constructed between the years of 1953 and 1958.[1] In this survey science teachers were asked to rate certain facilities within their rooms on the following scale: 1 = superior, 2 = good, 3 = fair, 4 = poor, and m = missing. Most of the items dealt with isolated pieces of equipment or furniture, rather than with the room design as a totality.

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[1]Theodore W. Munch, "Secondary School Science Facilities: Recent Construction--How Effective?" The Science Teacher, XXV (November, 1958), 398-400. 416, 418-419.

However, there were some items that pertained to specific areas of the science room or to characteristics of the room as a totality, and these items are listed in Table 1. The majority of the items here received either "superior" or "good" ratings.

Those teachers who rated a facility as "poor" were asked to state briefly what was wrong. Some of the comments included: a desire for more area in which students could work on projects and store the same for extended periods of time; the preparation area was reported as having inadequate utilities, ventilation, space, and shelving; some felt that the laboratory space could have been better utilized through better desk arrangement; and many approved highly of perimeter work benches or permanent laboratory tables at one end of the room with movable furniture in the center of the room.[2]

Although it was reported that the majority of teachers who responded to this NSTA survey were teaching in multipurpose science rooms,[3] the specific design of these rooms was not ascertained. Therefore, it was virtually impossible to detect from this data which facility designs or equipment designs received the higher ratings. Furthermore, one might question the basis used by the teachers for evaluating their facilities, since

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[2] _Ibid._, p. 416.

[3] _Ibid._, pp. 399-400.

TABLE 1.--Ratings of secondary laboratory facilities constructed between 1953 and 1958.

Item	Rating				
	% Superior	% Good	% Fair	% Poor	% Missing
1. Space utilization	43	38	11	6	2
2. Dispensing area for laboratory materials	26	30	23	8	13
3. Preparation area	38	32	16	6	8
4. Amount of individual work space	35	36	20	6	3
5. Area for "permanent" project "set-ups"	8	21	22	13	36
6. Accessibility to student work areas	44	38	12	4	2

Source: Theodore W. Munch, "Secondary School Science Facilities: Recent Construction--How Effective?" The Science Teacher, XXV (November, 1958), 416.

an adequate basis was not provided in the questionnaire for this purpose. It might be hypothesized that some teachers may have rated their facilities superior because they were comfortable, or because they seemed durable. Despite these limitations, this study did provide some useful information of a broad range of facility and equipment needs of new schools. The data suggested that teachers felt that certain room arrangements were more suitable than others for instructional purposes. This was indicated by the fact that certain types of facilities received high ratings while others received low ratings. Likewise, it was implied by some of the comments of teachers who felt that their laboratory space could be better utilized through better desk arrangement. It also was suggested by the many comments expressing high approval of perimeter or split classroom-laboratory room designs.

Kyzar (1961)[4] compared various aspects of instructional programs and problems in elementary schools having the "open-plan" classrooms with those having "conventional" four-walled classrooms. More specifically, the aspects compared here were: (1) curriculum organization, (2) teaching techniques, (3) social organization, (4) psychological climate, (5) order-maintaining techniques, and (6) provisions for individual differences. Statistically significant differences were found favoring the "open-plan" design classrooms.[5] Of the total list of ten aspects of the instructional program investigated, the categories most directly related to the definition of instruction to be used in this study were: (2) teaching techniques,[6] (6) provisions for individual differences,[7]

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[4]Barney Lewis Kyzar, "A Comparison of Instructional Practices in Classrooms of Different Design" (unpublished Ed.D dissertation, The University of Texas, 1961), pp. 3-4.

[5]*Ibid*., p. 157.

[6]*Ibid*., pp. 170-172.

[7]*Ibid*., pp. 186-194.

and (7) activities utilized.[8] In only one of these latter three categories, (6) provisions for individual differences, were statistically significant differences found favoring the "open-plan" design classrooms. The latter category was the closest to the definition of instruction used in the present study.

Kyzar's data has lent some support to speculation that different biology laboratory designs also might differ in their suitability for various types of instruction. Caution should be taken in generalizing these results, since the data came from a non-random selection of only thirty-six classrooms from just six school systems.[9] Furthermore, each classroom was observed only three times for one and one-half hours within the period of just three days.[10] For such a small sample, unusual events within just one of these six school systems could have biased the results of over sixteen per cent of the classroom data collected. No attempt was made in the study to relate the spatial organization of the major fixed and movable facilities, other than walls, to the type of instruction observed. The physical environment examined in Kyzar's study was the number of walls in elementary classrooms, whereas the physical environment examined in the

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[8] Ibid., pp. 196-199.

[9] Ibid., p. 4.

[10] Ibid., p. 20.

present study was the spatial organization of the major fixed and movable furniture in secondary biology rooms. Thus, Kyzar's study has provided valuable data concerning the relationship of one aspect of the classroom physical environment to instructional practice.

Several researchers have recently investigated the relationship of gross classroom area to instruction facilitated in certain rooms. Stottlemyer (1965)[11] measured the academic achievement of groups of secondary students in rooms from 600 square feet to 950 square feet. The findings from this experiment support the hypothesis that no significant differences in achievement can be attributed to classroom size. Vanzwoll[12] reported twenty-three pilot studies and three more sophisticated experimental studies that recently have inquired into the effect of room size variations upon learning activity. From these studies he concludes that, "there is no indication that instruction has been facilitated by increased area per pupil."

Several reasons might be hypothesized for the lack of significant differences in the achievement of groups

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[11]Richard G. Stottlemyer, "Secondary School Classroom Space Requirements - A Study to Examine Relationships Between Gross Room Area Per Pupil and Academic Achievement," Dissertation Abstracts, XXVII (1966), 90-A.

[12]James A. Vanzwoll, "Classroom Size Standards Shrinking," American School Board Journal, CLIII (September, 1966), pp. 57-58.

of students from different room sizes. First, the criterion of achievement, as measured by traditional achievement tests, was too narrowly defined. Other important outcomes of instruction that might have been evaluated include such things as; changes in student attitudes, preferences, critical judgments, and creativity. Another possible reason for the lack of significant differences related to classroom size might be attributable to a "masking effect"[13] of more important variables. If classroom size is not a very important variable in student and teacher behavior, then it might easily be masked by uncontrolled variables that have a greater influence on behavior. Thus, it is important that in investigating environmental relationships one choose variables of the physical environment that appear to have the most important influence on student and teacher behavior.

Maunier (1967)[14] investigated the relationship of another physical facility factor of the classroom to student academic achievement. Specifically, this investigation sought to ascertain whether a significant difference existed between the academic achievement of sixth grade

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[13] Center for Research on Learning and Teaching, Class Size, Memo to the Faculty, No. 17 (Ann Arbor: The University of Michigan, May, 1966), p. 58.

[14] Russell LeRoy Maunier, "The Relationship of Facilities to Student Academic Achievement," Dissertation Abstracts, XXVIII (1968), 2950 A.

children taught in relocatable facilities and those taught in permanent facilities. The results of the anlysis of data revealed no significant differences between these two groups. Limitations of this study included the fact that the number of classrooms examined here was small, and that all of these classrooms came from one school district.

A recent experimental study by Rose (1969)[15] sought to determine the effect that variations in the qualitative characteristics of space had on the behavior of college students that were performing an educational activity in the space. The educational activity was the performance of a series of educational tasks by means of small group discussion. The dependent variable was the behavior of the students which consisted of: (1) task achievement, (2) quality and quantity of interaction, and (3) attitude expression towards the activity and towards the activity subject matter. The independent variable here was the qualitative characteristics of the space which included considerations of position, form, color, contrast, and textual attributes of the wall, floor, and ceiling of the space.[16] From a pre-test the students'

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[15]Stuart W. Rose, "The Effect on Behavior of the Qualitative Attributes of the Elements that Define an Educational Activity Space" (unpublished Ph.D. dissertation, Michigan State University, 1969), p. 1.

[16]Ibid.

attitudes toward these qualitative characteristics as well as toward the activity was determined.[17] Two spaces were then designed and constructed for the treatment; one of these spaces was called "consonant space," and the other was called "dissonant space." These two types of space differed physically in their size, shape, contrast, textures, and colors.[18] Both spaces, however, had a table and chairs in similar positions.[19] From the pre-test information it was hypothesized that groups of students in these spaces would differ in task achievement, interaction quantity and quality, and attitudes toward the activity.[20] The analysis of the data showed that none of the hypotheses achieved statistical significance.[21] However, with certain reservations, Rose felt that the hypotheses were supported by the direction of the differences of the data from the two groups.[22]

Lack of statistically significant results in Rose's study might well be attributable to the fact that only five groups were tested in each space. Furthermore, the dramatic color differences in the two types of spaces might have caused a "Hawthorne effect" in one of the spaces that could have masked any differences that might

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[17] Ibid., p. 27. [18] Ibid., p. 41.

[19] Ibid., pp. 86-87. [20] Ibid., pp. 57-59.

[21] Ibid., p. 47. [22] Ibid., pp. 47-59.

have been caused by the space itself. The shapes of the table and chairs and their position in the space were kept fairly constant in both spaces. Oddly enough, this design factor that was held fairly constant in Rose's study was the primary design factor that was evaluated in the biology facility study. Nevertheless, Rose's study demonstrated an innovative approach to the research of environmental relationships. It has also contributed data that will help further the development of a scientific theory of classroom environmental design.

Spatial Design Factors of Entire School Buildings

There have been several researchers that have investigated the relationship of the entire school building design to the instructional practices facilitated by this building design.

Monacel (1963)[23] studied the effects of going from an old elementary school building to a new, well-planned school building. The effects looked for were changes in the curriculum experiences and the related attitudes and aspirations of teachers, pupils, and parents. The length

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[23]Louis David Monacel, "The Effects of Planned Educational Facilities upon Curriculum Experiences and Related Attitudes and Aspirations of Teachers, Pupils, and Parents in Selected Urban Elementary Schools" (unpublished Ed.D. dissertation, Wayne State University, 1963), p. 56.

of time that these parties were exposed to the new school facility was seven months, from June 1962 to October 1962.[24] Realistically, the exposure for students was closer to only two months, since school start in September. The findings from this study were compared with the findings from a concurrent similar study.[25] Data from both studies showed almost no change on the part of teachers and students in curriculum experiences and related attitudes and aspirations.[26] The specific nature of the various room designs of both the old and new school buildings were not disclosed. The fact that only data from two schools were collected, greatly decreases the generalizability of the results. However, the most important limitation of this study appeared to be the insufficient exposure time to the new facility for behavior changes to take place. Even if changes had occurred because of the lack of controls one would not be able to ascertain whether these were the results of the planning, of the building design, or of world events in general.

Price (1965[27] studied the acceptance of variable

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[24] Ibid., pp. 88-89.

[25] Ibid., p. 63.

[26] Ibid., pp. 156-171.

[27] John William Price, "An Investigation of Relationships between School Plant Design and Flexibility of Student Grouping in Secondary Schools of Suburban New York" (unpublished Ed.D. dissertation, Columbia University, 1965), pp. 39-41.

grouping plans for teaching and the curriculum of old and new secondary school buildings. Furthermore, the physical needs inherent in these various school programs were examined, and facility modifications were recommended. The findings showed no significant difference between the older and newer schools in the acceptance of the teaching methods examined. It was interesting to note that 75 per cent of the school respondents reported that they used large group instruction, 52 per cent used small group instruction, and 35 per cent used individualized instruction.[28] However, of those schools commenting on housing requirements in another section of the questionnaire, 65 per cent mentioned the need for "Individual Study Areas," 65 per cent mentioned the need for "Additional Large Group Areas," and 59 per cent included the need for "Additional Small Group Areas."[29] Price concluded that three types of spaces were considered important to success of fluctuating class groupings in many of the schools visited. These were (1) space for large numbers of students, (2) space for small groups, and (3) spaces for individual study areas.[30] In this study the type of facility design

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[28] _Ibid._, p. 46.

[29] _Ibid._, pp. 55-57.

[30] _Ibid._, p. 110.

was not determined. The only factor considered here was the age of the facility and its relationship to flexibility of student grouping.

Mace (1967)[31] examined the differences in adapting secondary buildings to large- and small-group instruction with respect to the type of building design and layout plan. The findings showed that no specific design or layout plan was the most limiting or the most facilitating. The schools that were selected for this study were not randomly chosen, and were located in eighteen school districts. This study examined the adaptability of school buildings for certain types of instruction; it did not evaluate the suitability of the current floor plans or designs for these types of instruction.

The relationship of school size to certain teaching practices was studied by Kimble (1968),[32] who concluded that there was little relationship between the classroom behavior of the teacher and the size of the school.

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[31]William Randolph Mace, "Adapting Secondary School Buildings to the Space Needs of Large- and Small-group Instruction." Dissertation Abstracts, XXVII (1968), 2490A.

[32]Richard Morris Kimble, "A Study of the Relationship of School Size and Organizational Patterns to Certain Teaching Practices," Dissertation Abstracts, XXIX (1969), 2928.

The Relationship of Certain Non-design Factors of the Classroom Environment to the Performance of the Occupants

The purpose of this brief section is to identify non-design variables that may be important enough to be controlled in the research design of this study. Since teachers were not randomly assigned to the biology room designs in this study, it was important to try to identify and control variables that might be affecting the responses of the teachers besides the facility design itself. The variables investigated recently included: (1) the age of the facility, (2) the curriculum materials utilized, and (3) the amount of academic coursework taken by the teacher.

Findings from studies by Monacel (1963), Price (1965), and Mace (1967) have shown that teachers from older and newer schools did not differ significantly in certain teaching methods and attitudes examined.[33] Thus, the age of the facility was not considered to be a variable of major importance.

There have been several studies of the relationship of the curriculum materials used to the behavior of the teachers and students. Barnes (1966)[34] found that those

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[33]Monacel, op. cit.; Price, op. cit.; Mace, op. cit.

[34]Lehman Wilder Barnes, "The Nature and Extent of Laboratory Instruction in Selected Modern High School Biology Classes," Dissertation Abstracts, XXVII (1967), 2931-A.

high school biology teachers that had been using Biological Sciences Curriculum Study (BSCS) materials had a greater degree of conformity of laboratory activities to those laboratory activities recommended by BSCS than did the teachers who were using other curriculum materials. Salmon (1968)[35] investigated the relationship of the use of the BSCS programs in biology instruction to the teachers perception of the adequacy of their biology facility. No evidence was found by Salmon to indicate a significant difference between the means of the facility scores of teachers from schools with the BSCS program and those that had no BSCS program. Balzer (1969)[36] in an exploratory investigation of the verbal and non-verbal behaviors of BSCS teachers and non-BSCS teachers reported that there were no significant differences found between the BSCS teachers and the non-BSCS teachers. From these three studies one might conclude that the use of BSCS materials was not found to be a major variable in influencing teacher behavior.

The effect of various amounts of academic coursework on teaching has been investigated by Salmon (1968).[37]

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[35]Richard Joseph Salmon, "The Relationship of Selected Factors to the Biological Facilities in Connecticut Secondary Schools, Dissertation Abstracts, XXXIX (1969). 2616A.

[36]LeVon Balzer, "An Exploratory Investigation of Verbal and Non-verbal Behaviors of BSCS Teachers and Non-BSCS Teachers," Paper presented at the 42nd Annual Meeting of the National Association for Research in Science Teaching at Pasadena, California, February 6-9, 1969

He reported that no evidence was found for a significant relationship between the number of credits in biology that teachers possess and their respective perception of biology facility adequacy. Thus, the variable of teacher academic biology coursework was not considered to be of major importance in this study.

The Human Engineering Approach to the Planning of Functional Workplaces

Human factors engineering is an interdisciplinary approach to design problems, that starts with man and then provides what accessories he needs to carry out or reach a prescribed objective.[38] Fundamental to this design approach has been the "systems concept," which is the idea of a group components designed to serve a given set of purposes. This system concept is applied not only to physical facilities, but also, to the humans who are the users and the operators of the facilities. Thus, has come the term "man-machine system" which denotes any group of men and machines (physical facilities) that operates as a unit to carry out an assigned task or tasks.[39]

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[37] Salmon, op. cit.

[38] Wesley E. Woodson and Donald W. Conover, Human Engineering Guide for Equipment Designers, Second Edition (Berkeley: University of California Press, 1964), pp. 1-1 to 1-3.

[39] Woodson and Conover, op. cit., p. 1-22.

According to Woodson and Conover, the systems approach is applicable to all design problems.[40]

The human engineering approach to the design of workplaces consists of two basic processes: systems analysis and system evaluation[41] (see Figure 1). The system analysis gives a picture of the structure and functions of the system. Whereas, the system evaluation yields a measure or set of measures to indicate how well the system serves its intended mission or objective.[42]

The application of the systems analysis to a design problem does not guarantee that s single optimum workplace layout will be suggested.[43] This is particularly true when the design problem deals with a highly complex system, like the school classroom. Sometimes, through the application of systems analysis to a design problem, certain workplace configurations will be found unsuitable. To determine which of the remaining design alternatives are the most appropriate, they are tested or observed in the system evaluation phase of the human engineering approach.

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[40]Woodson and Conover, *op. cit.*, pp. 1-22.

[41]Clifford Morgan, Jesse S. Cook, III, Alphonse Chapanis, and Max W. Lund, eds., *Human Engineering Guide to Equipment Design*, (New York: McGraw-Hill Book Co., 1963), p. 3.

[42]*Ibid*.

[43]Kenneth W. Heathington and Gustave J. Rath, "Applying Systems Engineering, PPBS, and Cost-Effectiveness to Transportation Problems," *C.A.T.S. Research News* (October-November, 1967), p. 7.

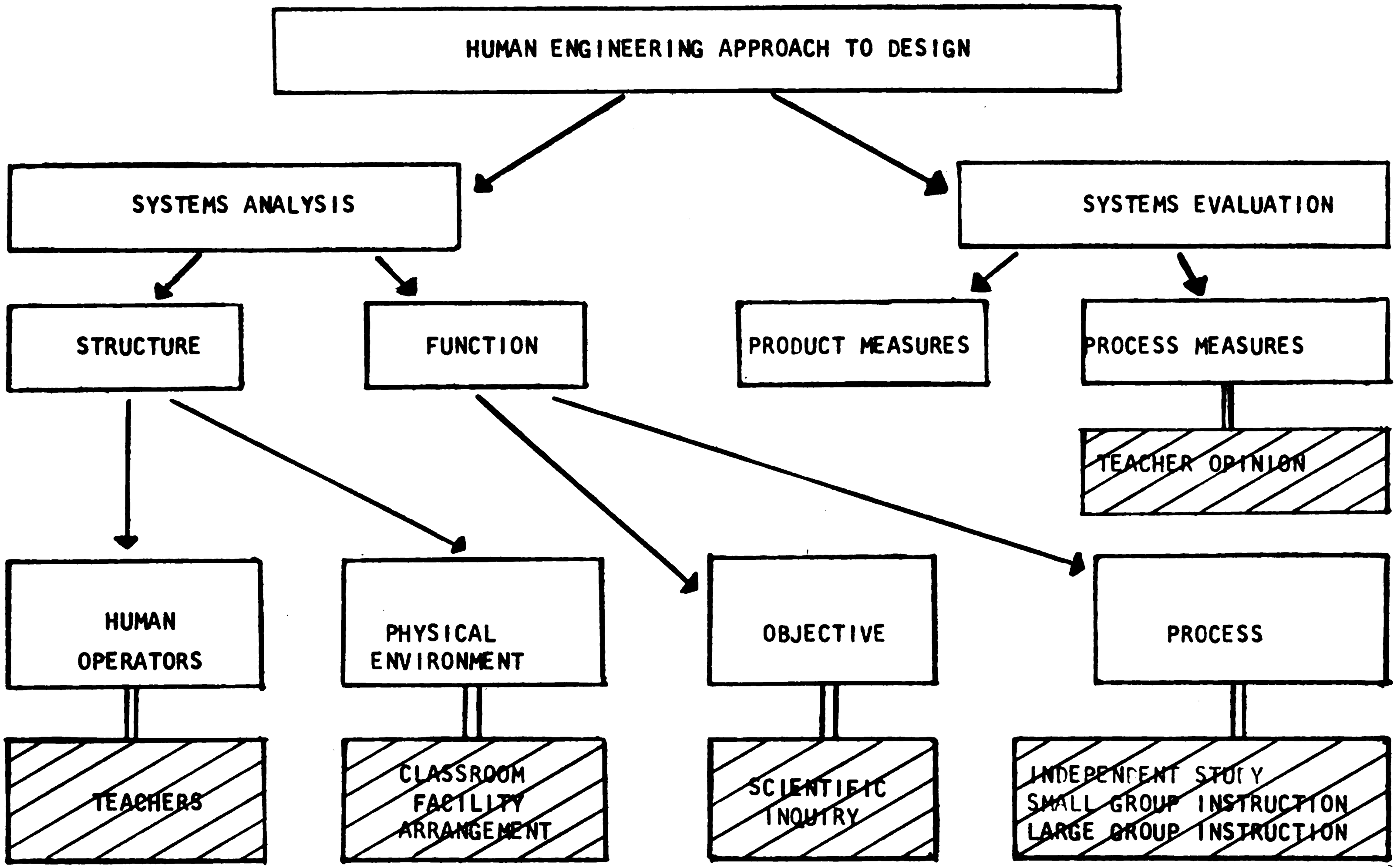

Figure 1.--Illustration of human engineering approach to design and elements used in a biology laboratory system study.

It is important to recognize that it is the functioning combination of man and machine that is the system to be evaluated. Measurements on functioning systems can be made through experimental methods, or through other observational methods, such as: operator opinions surveys, activity sampling, micromotion analysis, and link analysis.[44] Evidence from this evaluation can be used subsequently in the decision-making process to narrow the range of possible design alternatives, and thereby to decrease the uncertainty of future design decisions.

One of the most important aspects of any system evaluation is the matter of deciding what to measure of a man-machine system's output. This "criterion problem" becomes more troublesome as the systems become more complex.[45] Sinaiko and Buckley state that in order for measures of system performance to be valid, they should be related to the primary objective or mission of the system. Furthermore, they declare that the determination of the objective of a system is especially difficult with complex systems, since there are often several

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[44] H. Wallace Sinaiko and E. P. Buckley, "Human Factors in the Design of Systems," Selected Papers on Human Factors in the Design and Use of Control Systems, H. Wallace Sinaiko, ed., (New York: Dover Publications, Inc., 1961), pp. 1-41, reprinted from NRL Report 4996, (Washington: Naval Research Laboratory, August 29, 1957), pp. iv-49.

[45] Ibid., p. 20.

objectives being satisfied at one time.[46] A description of the system is, therefore, necessary to choose a valid criterion upon which to subsequently evaluate the system's performance. A description of the system can also provide insight into important variables important in the evaluation of the system.

Thus, the human engineering approach to workplace design yields a detailed picture of what the system is (systems analysis), as well as an evaluation of how certain workplace layouts can affect the accomplishments of the system (systems evaluation). It is an assumption of the human engineering approach that with such information on hand, more functional design decisions will be made. A limitation of this approach to design problems, therefore, is the fact that this decision-making process, of selecting the most optimum design alternative, has not yet been systematized or objectified.[47]

Use of the Human Engineering Approach in the Design of This Study

The study was designed to evaluate the instructional suitability of various laboratory designs, as perceived by secondary biology teachers who were currently teaching in these rooms.

In terms of the human engineering approach to design,

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[46] *Ibid.*, p. 27.

[47] Morgan, Cook, Chapanis, and Lund, *op. cit.*, p. 321.

this study might correspond to a systems evaluation (see Figure 1). The systems evaluated were the various types of secondary biology laboratories. The laboratory systems differed primarily in the arrangement of their physical facilities.

The specific elements of these biology laboratory systems that were accounted for in this evaluation are represented in Figure 1 by the shaded boxes. These elements correspond to the type of elements that would be described in most human engineering studies. Therefore, the biology laboratory system was analyzed in this study in terms of the following elements: (1) the human operators who were represented by the biology teachers; (2) the objective of the system which was that of fostering student scientific inquiry; and (3) the processes used to meet the objective which were the instructional methods of: independent study, small group instruction, and large group instruction. The evaluation of such a system can focus on the processes being used to meet a stated objective, or the products or achieved objectives of the system. In this study teacher opinions were used to evaluate the success of the processes being used in the system to meet the stated objective (see Figure 1).

Summary

In the first section of this review, recent research studies were examined that dealt with the relationship of classroom and school building facilities to the behavior of the occupants of these facilities. The findings from these studies represent the current scientific knowledge that is available concerning functional school room environmental relationships. In only one of these studies, Kyzar's, were there statistically significant differences found between the practices of teachers from different classroom facilities. But, the facility factor investigated here was the number of walls present in the classroom. Rose, however, did examine certain aspects of the spatial factor of the classroom environment; but the spatial organization of the major room furniture was not examined here. Thus, from this review it appears that no investigator has examined the suitability of various room designs for large group instruction, for small group instruction, and for independent study.

In the second section of this review several studies of the effect of non-design variables on teacher behavior were briefly summarized. Findings from these few studies would seem to indicate that the non-design variables of: age of facility, curriculum materials utilized, and amount of academic coursework taken by the teacher, were not important enough to be controlled in the basic research design of this biology facility study.

In the third section a description was given of the human engineering approach to workplace design, as well as how this approach was used in this study. The human engineering approach to design was said to consist of two basic processes: systems analysis and systems evaluation. This study is a type of system evaluation, in which the man-machine systems evaluated were biology teachers and their teaching laboratories. These laboratories differed, primarily, in the spatial organization of their major fixed and movable facilities. It was shown necessary that a description of these laboratory systems be made prior to the evaluation, so that a valid evaluation criterion could be determined.

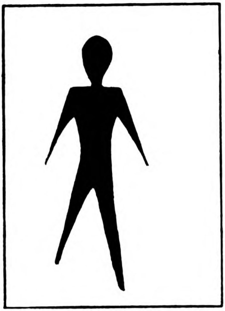
CHAPTER III

DESIGN I: DESCRIPTION OF THE BIOLOGY LABORATORY SYSTEMS

The study was designed to evaluate the instructional suitability of different laboratory designs, as perceived by the secondary biology teachers who were currently teaching in these rooms.

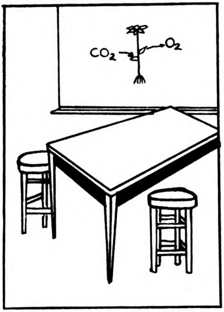
This problem was studied in two parts, and these parts are included in Chapters III and IV. These two parts correspond to the two basic aspects of the human engineering approach to the design of workspace, namely: systems analyses and systems evaluation.

Part I of the research design consists of a description (or analysis) of the secondary school biology laboratory systems in terms of its three principal elements- the instructional process, the teacher and student participants, and the arrangement of the physical facilities. These three elements correspond to the basic elements of any man-machine system, namely: the functions of the system, the human operators, and the physical environment (see Figure 2). Since the independent variable of interest in this study was the type of physical facility arrangements (laboratory design), a pre-survey was done in Michigan to identify the various types of secondary biology facilities.



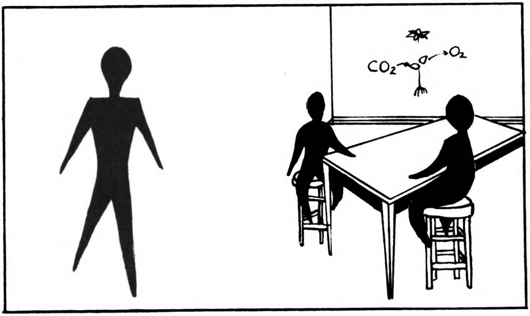
human operator = teacher

Figure 2a



physical environment = classroom facility arrangement

Figure 2b



function = scientific inquiry through independent study, small group instruction, and large group instruction

Figure 2c

Figure 2.--The use of human engineering terminology in this study.

Part II of the research design consists of the procedures used to evaluate four of the types of biology facility arrangments that had been identified from the pre-survey. This evaluation took the form of an "operator opinion survey," in which biology teachers rated their own facility arrangement on its suitability for the three instructional methods: independent study, small group instruction, and large group instruction. This survey was followed by field visitations to explore, in depth, possible explanations for reported laboratory design adequacies or inadequacies.

Description of the Biology Laboratory Systems

A description of the various biology laboratory systems preceded the systems evaluation in this study for the following reasons:

(1) to provide specific data on the various physical layouts of the biology rooms needed for the evaluation;

(2) to provide the basis for a valid criterion for use in the evaluation;

(3) to identify important variables that should be accounted for in the research design of the evaluation;

(4) to provide understandings that might help in generating predictive hypotheses concerning relative laboratory design suitability; and

(5) to provide a framework for the interpretation of the results of the evaluation of alternative laboratory plans.

The biology laboratory system can be described in terms of its three principal elements - the instructional process, the teacher and student participants, and the classroom facility arrangement.

Instructional Process

The instructional process in the biology laboratory consists of a set of operations performed by students and teachers which defines the learning outcomes for the pupil.[1] The instructional process might be further analyzed in terms of an interaction between three sets of factors: (1) goals - the long range objectives for the learner; (2) content - the skills, attitudes, and concepts to be learned; and (3) methods - the various instructional techniques.[2] In this study the criterion variable was related to the latter of these three factors, the instructional methods - namely, large group instruction, small group instruction and independent study.

In most statements of the goals or objectives for teaching high school biology the emphasis is clearly on intellectual achievement.[3] Brandwein said, for example, that instruction

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[1]Joseph D. Novak, "A Case Study of Curriculum Change - Since PSSC," School Science and Mathematics, (May, 1969), p. 375.

[2]SER 3: Environmental Analysis, A Research Project, Architectural Research Laboratory of the University of Michigan (Ann Arbor: The University of Michigan, (July, 1965), p. I-10.

[3]National Science Teachers Association, Theory into Action . . . in Science Curriculum Development (Washington: NSTA, 1964), p. 44.

in the "arts of investigation" is a central objective of teachers of the natural sciences. He added that the "arts of investigation" are represented in statements of objectives today by such terms as - "inquiry" and "process". Furthermore, Brandwein believes that the desire of most contemporary science teachers is to make the "arts of investigation" central to their teaching.[4] Ralph Tyler described this major objective of science teaching as the need: "to help students develop the ability to carry on the whole process of scientific inquiry."[5] This emphasis on intellectual objectives for teaching secondary biology is evident in the recent Biological Sciences Curriculum Study which lists "science as enquiry" as one of the nine unifying themes for its materials.[6] Hurd also reports that the teaching of the scientific method has been found in research studies to rank first as an objective of biology teaching.[7] The specific objectives of providing

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[4]Paul F. Brandwein, "Observations on Teaching: Overload and 'The Methods of Intelligence'" The Science Teacher, XXXVI (February, 1969), pp. 38-39.

[5]Ralph W. Tyler, "The Behavioral Scientist Looks at the Purposes of Science Teaching," Rethinking Science Education, Fifty-ninth Yearbook of the National Society for the Study of Education, Part I (Chicago: NSSE 1960), p. 32.

[6]Joseph J. Schwab, supervisor, Biology Teachers' Handbook, Biological Sciences Curriculum Study (New York: John Wiley and Sons, Inc., 1965), p. 31.

[7]Paul DeH. Hurd, Biological Education in American Secondary Schools 1890-1960, Biological Sciences Curriculum Study, Bulletin No. 1 (Baltimore: Waverly Press, Inc., 1961), p. 181.

biology laboratory and field studies, as reported by the Panel on High School Biology Courses of 1957, also emphasized the intellectual pursuits. An objective listed by this Panel was that "learning in biology should involve an active quest by students that makes them, for the moment at least, scientists in search of discovery."[8]

The content of the secondary biology laboratory is best illustrated by the content of currently used biology textbooks. A recent study of the content biology textbooks compared the Biological Sciences Curriculum Study (BSCS) textbooks with several conventional texts. The conventional texts were found to place a much greater emphasis on the concepts of the "organ and of the tissue" than the BSCS texts. Likewise, the content of the BSCS texts was found to place a much greater emphasis on ecological concepts and on molecular and cellular biological concepts than the conventional texts.[9] It is important to recognize that neither the BSCS programs nor the conventional programs have recommended a single set of conceptual schemes.

The instructional methods used in high school biology teaching can best be differentiated by what Alfred Novak

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[8]Panel on High School Biology Courses of the Committee on Educational Policies, Outline for Sourcebook of Laboratory and Field Studies for Secondary-School Biology Courses (Washington: National Academy of Sciences - National Research Council, 1957), p. 3.

[9]Schwab, op. cit., p. 18.

terms their amount of "structure." According to Novak, in the "completely structured laboratory" a problem is given, the procedure is given, the equipment list is given, the pattern or organization is given, and even the results are given. On the other side of the continuum is the "completely unstructured" or "self-energized laboratory" where everything is done by the student. A whole spectrum of teaching methods can be found between these two extremes of the continuum.[10] Trump and Baynham have recently defined three of the instructional methods that represent points along this continuum, differing in the amount of "structure". These instructional methods are: large group instruction, small group instruction, and independent study.[11]

According to Trump, the basic purpose of large group instruction is "to provide students with background information and to get them so excited about learning that they want to go into the laboratories and resource centers to learn more things for themselves."[12] Although there are typically one-hundred to two-hundred students

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[10]Alfred Novak, "Scientific Inquiry in the Laboratory," The American Biology Teacher, XXV, No. 5 (May, 1963), 343.

[11]J. Lloyd Trump and Dorsey Baynham, Focus on Change: Guide to Better Schools. (Chicago: Rand McNally & Co., 1961), pp. 23-33.

[12]J. Lloyd Trump, "Some Problems Faced in Organizing Science Teaching Differently," The Science Teacher, XXXI, No. 4 (May, 1964), 37-38.

in large group instruction, the traditional classroom of about thirty students would also fall within this category.[13] This type of instruction is basically teacher dominated and highly "structured." It would include such practices as, group laboratory experiments, introducing units of work, demonstrations, explaining terms and concepts, summarizing, or even giving tests.[14]

The purposes of small group instruction include: (1) providing opportunities for teachers to measure individual students' growth and development, and allowing a teacher to try a variety of techniques suited to the various types of individuals, (2) providing students with the opportunity to examine previously held concepts and to alter their approaches to issues and people, (3) permitting students to discuss subject matter, and (4) providing students with opportunities to know their teacher on a personal basis.[15] Thus, the teacher's role in small group instruction is more one of a guide or consultant or advisor. There is less "structure" and teacher domination in small group instruction than in large group instruction.[16] Typically, there are from two to fifteen students in small group instruction.[17]

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[13] Ibid. [14] Ibid., p. 30. [15] Ibid., p. 30.

[16] Ibid., pp. 24-25. [17] Ibid., pp. 24-25.

Independent study is for the purpose of helping individual students "learn how to learn."[18] This would involve various modes of learning such as; reading, viewing, listening, working on automated learning devices, and doing special projects. This is the least "structured" of the three instructional methods. The teacher's role emphasizes the provision of materials and help when they are needed by individual students. Most of the work is done here by the student.[19]

Large group instruction, small group instruction, and independent study are recognized as activities of the secondary biology instructional system. This is illustrated by the results of Martin's survey of high school biology programs, where he found that the procedures most often used in conducting "laboratory" work were (1) small group instruction, 45.2%; (2) individual laboratory work, 20.2%; and (3) large group instruction, 23.6%.[20] These three instructional methods generally take place in the same room - called the

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[18] Trump, The Science Teacher, op. cit., p. 38.

[19] Trump and Baynham, op. cit., pp. 26-29; and A. Novak, op. cit., p. 343.

[20] William Edgar Martin, The Teaching of General Biology in the Public High Schools of the United States. Bulletin No. 9 (Washington: U.S. Department of Health, Education, and Welfare, Office of Education, 1952), pp. 1-46.

"multipurpose room" or the "laboratory-classroom."[21] In such a room it would be difficult to distinguish activities that have popularly been designated as "classroom instruction" from those called "laboratory instruction." Therefore, in this study "instructional methods" refers solely to large group instruction, small group instruction, and independent study whether they are laboratory oriented or not.

Teacher and Student Participants

The human participants in the biology laboratory system commonly include from twenty-five to thirty tenth-grade students, and one teacher.

The students are in the adolescent stage of development, which is the period in which a child is becoming an adult.[22] The phrase "individual differences" best describes the great heterogeneity of physical and psychological characteristics of this student population.[23]

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[21] John S. Richardson, ed., School Facilities for Science Instruction. (Washington: National Science Teachers Association, 1954) p. 129.

[22] Millie S. Smart and Russell C. Smart, Children: Development and Relationships, Second Edition (New York: The Macmillan Co., 1967), p. 441.

[23] Robert E. Bills and Robert L. Hopper, "Adolescents and Their Schools." American School and University, XXVII, (1956), 197.

The major problems encountered by adolescents during this period were recently studied by Adams (1963-1966) and their biggest problems are listed below in order of their importance:

1. School - academic difficulties, extremely few negative comments about teachers.

2. Interpersonal - getting along with one's peer group and other people.

3. Maturity - recognition by others (mostly parents) and one's self.[24]

Thus, the adolescent desires security, friendship, and affection. He needs to learn about people so that he can get along with them. Furthermore, Bills and Hopper state that he should have access to his teacher in a natural way when he is confronted with problems.[25] Adolescents are also said to have strong group feelings which may fluctuate rapidly: they benefit from large groups sometimes, and at other times they badly need the security of smaller groups.[26] There is a wide range of adjustment to these problems from one adolescent to another, and the physical growth of adolescents is variable, since some adolescents enter their period of greatest physical

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[24]James F. Adams, "An Introduction to Understanding Adolescence," Understanding Adolescence: Current Developments in Adolescent Psychology, James F. Adams, ed., (Boston: Allyn and Bacon, Inc., 1968), pp. 5-7.

[25]Bills and Hopper, *op. cit.*, p. 197.

[26]Bills and Hopper, *op. cit.*, p. 197.

growth early and others at a later time.[27] The results are a wide range of physical and psychological characteristics in this student population.

Biology teachers in the laboratory system might be described in terms of their academic course work and their years of teaching experience, yet neither of these characteristics has been found to affect the quality of their biology laboratory instruction. Several studies have attempted to relate the characteristics of biology teachers to the quality of their instruction, but no clearcut relationship has been determined.[28] Even the lesser problem of relating teacher characteristics to preferred instructional method has not been resolved.

Classroom Physical Facility Arrangements

The physical environment within the biology laboratory system is generally limited to the confines of a single room called the classroom-laboratory. The physical features of this room can be described in both quantitative and qualitative terms. Some of the qualitative factors have been delineated by the National Council of Schoolhouse Construction as follows:

1. Spatial factor - the kinds and amounts of space, and the ways that space is organized and treated.[29]

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[27]Bills and Hopper, op. cit., p. 197.

[28]See Chapter II of this study.

[29]National Council on Schoolhouse Construction, NCSC Guide for Planning School Plants, (East Lansing: NCSC, 1964), p. 92.

2. Aesthetic factor - the total effect of the various component parts in terms of balance and beauty.[30]

3. Safety factor - protection of persons and physical assets against such things as structural deficiencies, fire, and disaster.[31]

4. Sonic factor - involves a balanced environment in which sounds that are desired may be effectively propagated, and those sounds that are not desired may be effectively impeded.[32]

5. Thermal factor - involves all those aspects of a specialized environment related to the combined effects of radiant temperature, air temperature, humidity, and air velocity.[33]

6. Visual factor - emphasizes those aspects related to the ability to see comfortably, quickly, and accurately.[34]

It has been said that the spatial factor exercises a "critically determining influence on the educational program."[35] The physical environment studied in this investigation, therefore, consisted primarily of the spatial organization of the major fixed and movable facilities of various secondary biology laboratory designs.

A pre-survey instrument (see Appendix A) was distributed to all of the Class B and Class C high school biology teachers

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[30] _Ibid._, pp. 93-94.

[31] _Ibid._, pp. 94-95.

[32] _Ibid._, pp. 108-109.

[33] _Ibid._, p. 113.

[34] _Ibid._, p. 120.

[35] _Ibid._, p. 92.

in the State of Michigan,[36] to obtain specific information on the types of secondary biology laboratory designs currently being used. On this pre-survey instrument the biology teachers were asked to draw their laboratory design on graph paper and to label it according to a specified key. Some additional descriptive information was collected in this pre-survey instrument regarding the quantities and types of various facilities. The pre-survey instruments were distributed to the biology teachers through the principals of these high schools. Completed pre-survey instruments were returned from 393 biology teachers representing 337 schools. This represented an 82 per cent school response.

The laboratory drawings received in the pre-survey were categorized by design type. When necessary, the quantitative information on the last page of the instrument was used to assist in this classification. The basic types and numbers of biology laboratory designs found are shown in Table 2, and the quantitative information from the last page of the instrument is given in Table 3. The limited variety of the laboratory design

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[36]This classification of high schools was based on the "Classified Lists of Michigan High Schools: 1967-68 School Year," Michigan High School Athletic Association Bulletin XLIV, No. 4-s (November, 1967), pp. 230-236. Class B high schools are those that have from 450 to 1099 students, while Class C high schools have from 250 to 449 students.

TABLE 2.--Basic Biology Laboratory Designs of the Class B and Class C Michigan High Schools in 1969[a]

Design Type[b]	Number of Laboratories	Per Cent of Laboratories
Split	56	14.2%
Perimeter	91	23.2%
Central	213	54.2%
Multipurpose	13	3.3%
Other	20	5.1%

[a]Findings were based on an 82% school response to the pre-survey instrument.

[b]Descriptions of these design types can be found in the pre-survey instrument located in Appendix A.

types found in the Class B and Class C high schools in Michigan was disappointing. One might have expected a rather large number of potential solutions to the problem of laboratory design, particularly since the buildings varied widely in age and geographical location.

From the design categories shown in Table 2, four relatively homogeneous design groups were selected for the subsequent evaluation of their instructional suitability. The names of these four design groups and the number of laboratories in each group are shown in Table 4. In the selection of these groups the large "central" category of Table 2 was divided into several subcategories. These divisions were based on one or more of the following

TABLE 3.--Facilities Available to Michigan Class B and Class C High School Biology Students in 1969[a]

Facility	Percent of Laboratories Having the Quantities of Facilities Indicated[b]					
Shelf Storage for Student Projects (linear feet)	400 (3.1%)	300 (6.1%)	200 (10.4%)	100 (42.5%)	0 (34.9%)	No Response (3.1%)
Student Work Counter Space (linear feet)	90 (19.3%)	60 (32.1%)	30 (23.7%)	15 (11.5%)	0 (12.0%)	No Response (1.5%)
Height of Student Laboratory Tables (measured in inches from floor to work surface)	36 (28.2%)	34 (3.6%)	30 (44.8%)	29 (17.8%)	0 (2.3%)	No Response (3.3%)
Number of Sinks	4 (56.2%)	3 (15.0%)	2 (15.3%)	1 (12.0%)	0 (.8%)	No Response (.8%)
Number of Electrical Outlets	7 (70.5%)	5 (14.2%)	3 (5.6%)	2 (7.6%)	0 (.5%)	No Response (1.5%)
Number of Gas Outlets	7 (45.5%)	5 (10.2%)	3 (4.8%)	2 (28.5%)	0 (10.2%)	No Response (.8%)
Fume Hood	Yes (28.2%)	No (70.7%)	No Response (1.1%)			
Greenhouse	Yes (21.9%)	No (77.1%)	No Response (1.1%)			
Life Alcove	Yes (19.8%)	No (78.6%)	No Response (1.3%)			
Science Library	Yes (54.2%)	No (45.0%)	No Response (.8%)			
Student Special Projects Area or Room	Yes (35.1%)	No (63.4%)	No Response (1.5%)			

[a]Findings were based on an 82% school response to the pre-survey instrument.

[b]The percentages in parentheses indicate the percent of the teachers who selected that alternative in the pre-survey instrument. A copy of this pre-survey instrument can be found in Appendix A.

TABLE 4.--The four types biology laboratory designs selected for the evaluation of instructional suitability.[a]

Design Type	Number of Laboratories
Split	37
Perimeter	39
Central-Fixed Tables	40
Central-Movable Tables	46

[a]These design groups were selected from the basic design categories shown in Table 2.

criteria: (1) whether the laboratory tables were fixed or movable; (2) orientation of the laboratory tables; (3) amount of student work counter space (linear feet); and (4) height of the laboratory tables (inches). A more detailed description of each of the design groups in Table 4 will follow in the succeeding paragraphs.

Split Design

In the split design there are separate areas at opposite ends of the laboratory that are provided for different instructional purposes. One area is basically for demonstration and discussion, while the other area is for laboratory activities. The laboratory tables located at one end of the room are fixed. They may be oriented parallel to the long axis, perpendicular to it, and may extend from the walls. There is less than fifty feet of student work counter space in addition to that provided by the laboratory tables. The laboratory tables are stand-up tables, being taller than thirty-three inches. The lecture desks at the other end of the room are movable. Facing these lecture desks is a demonstration table. Drawings and pictures of two of the laboratory designs in this group are shown in Exhibit I of Chapter V.

Perimeter Design

In the perimeter design there are movable lecture tables in the center of the room, and at least fifty feet of fixed perimeter student work counter space or tables along at least two sides of the room. These perimeter work counters or tables may be either of the sit-down or stand-up variety. The orientation of the movable lecture tables in the center of the room may be either horizontal or vertical. There is a demonstration desk at one end of the room. Drawings and pictures of two of the laboratory designs in this group are shown in Exhibit II of Chapter V.

Central-Fixed Tables Design

In the central-fixed tables design there are fixed laboratory tables in the center of the room. These tables are oriented horizontally to the demonstration table at the front of the room. There is fifteen feet or less of perimeter student work counter space in this room. The central tables are sit-down tables, typically being either twenty-nine or thirty inches high. Drawings and pictures of two of the laboratory designs in this group are shown in Exhibit III of Chapter V.

Central-Movable Tables Design

In the central-movable tables design there are movable laboratory tables in the center of the room. These tables are oriented horizontally to the demonstration table at the front of the room. There is fifteen feet or less of perimeter student work counter space in this room. The central tables are sit-down tables, typically being either twenty-nine or thirty inches high. Drawings and pictures of the laboratory designs in this group are shown in Exhibit IV of Chapter V.

Each of the four types of designs have a demonstration table at one end of the room. Likewise, the great majority of these designs are housed in rectangular rooms. The amount of shelf storage space available for student projects in these four design groups decreases in magnitude going from the split design group to the central-movable tables design group. Both the split and the perimeter design groups typically have approximately one-hundred or more linear feet of shelf storage space; however, both the central-fixed and the central-movable designs typically have about half of the members of their groups having approximately one-hundred or more linear feet of shelf storage space, and about half of the members of their groups having almost no shelf storage space. The size of the room in these four design groups decreases in magnitude going from the split design group to the central-movable tables design group. Both the split and the perimeter design groups typically have more than one-thousand square feet of room area; however, both the central-fixed and the central-movable design groups have typically less than one-thousand square feet of room area.

<u>Summary</u>

The biology laboratory systems have been examined in this chapter with regard to their three principal interacting elements--the instructional process, the teacher and student participants, and the physical facility arrangements. The central objective or goal of this system appeared to be instruction in the arts of inquiry or investigation. The methods through which this objective might be accomplished were illustrated by independent study, small group instruction, and large group instruction. The students in this system are characterized by many physical and psychological individual differences, which would seem to require flexible instructional methods and facilities. The description of the physical facilities here were with special reference to the Michigan high schools. This information was obtained through a pre-survey instrument that was sent to all of the Michigan Class B and Class C high schools.

Laboratory designs described in these pre-survey instruments were categorized, and four design groups were selected for the subsequent evaluation of their instructional suitability to be described in Chapter IV.

CHAPTER IV

DESIGN 2: EVALUATION OF SELECTED BIOLOGY LABORATORY SYSTEMS

This chapter includes: (1) the evaluation design, (2) the selection of the sample, (3) the development of the survey instrument, (4) the collection of data, and (5) the analysis.

Evaluation Design

From the description of the biology laboratory systems given in Chapter III, an important criterion was suggested for the evaluation of the systems. The criterion was the perceived suitability of the design for different methods of instruction, namely, for independent study, small group instruction, and large group instruction. These instructional methods represent the means through which the overall objectives of the system are obtained.

Also in Chapter III, four types of biology facility arrangements were identified and described in Michigan. These facility arrangements constitute variations in the spatial factor of the physical environment of the laboratory system.

The next step in the study plan was to have the biology teachers of these four types of facility arrangements rate the suitability of their own facility for the instructional methods of independent study, small group instruction, and large group instruction. This was done through an "operator opinion survey," in which the operators were the biology teachers. In addition to this evaluation, field visitations were made to laboratories from the four design categories to obtain in depth information on reasons for their instructional adequacy or inadequacy.

Selection of the Sample

The population consisted of the four categories of Michigan Class B and Class C high school biology laboratory designs listed in Table 4 of Chapter III. These design categories were the: (1) split, (2) perimeter, (3) central-fixed, and (4) central-movable.[1] A random sample of thirty-five designs was selected from each of the four design groups for a total sample of 140 designs. The biology teachers using these 140 designs were contacted through a survey instrument.

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[1]Description of these four design categories can be found in Chapter III on pages 62-64.

Development of the Survey Instrument

A survey instrument was developed primarily for the purpose of collecting information on the perceived suitability of the four laboratory designs for the instructional methods of: (1) independent study, (2) small group instruction, and (3) large group instruction.

In the development of this survey instrument, three lists of instructional practices were originally compiled. One list represented independent study, one list represented small group instruction, and one list represented large group instruction. Then the items on instructional practice in these three lists were randomly distributed in the survey instrument, without identification in the instrument as to which of the three types of instructional method they represented. Beside each of these items, a scale of one to five was provided so that the respondents could rate the suitability of their laboratory's design for each of these instructional practices.

Additional sections of this survey instrument pertained to: (1) teacher recommendations for improving the instructional adequacy of their biology design, and (2) data on variables that might have been confounded with the teacher's perception of their laboratory's instructional suitability. These variables included: recency of laboratory construction, type of biology curriculum materials used, average number of biology students per class, amount of biology coursework taken by the teacher, and the years of biology teaching experience.

To develop lists of instructional practices that represented the three instructional methods, the definitions and descriptions of these methods by Trump and Baynham were used as a basic guide.[2] These definitions were discussed in Chapter III. Furthermore, additional sources were used to obtain the specific instructional practice items.[3] The resultant lists of

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[2]J. Lloyd Trump and Dorsey Baynham, Focus on Change: Guide to Better Schools. (Chicago: Rand McNally & Co., 1961) pp. 24-33; J. Lloyd Trump, "Some Problems Faced in Organizing Science Teaching Differently," The Science Teacher, XXXI, No. 4 (May, 1964), 37-39; J. Lloyd Trump, "School Buildings for Modern Programs-Some Informal Comments on Functional Architecture," High School Journal (November, 1966) pp. 79-96.

[3]Sources used included: Paul F. Brandwein, Fletcher G. Watson, and Paul E. Blackwood, Teaching High School Science: A Book of Methods (New York: Harcourt, Brace, and World, Inc., 1958) pp. 475-504; Barney Lewis Kyzar, "A Comparison of Individual Practices in Classrooms of Different Design," (unpublished Ed. D. dissertation, The University of Texas, 1961), pp. 170-172, 186-194, 196-199; Archie L. Lacey, Guide to Science Teaching in Secondary Schools, (Belmont, California: Wadsworth Publishing Co., In., 1966), pp. 73-84; Evelyn Morholt, Paul F. Brandwein, and Alexander Joseph, A Sourcebook for the Biological Sciences, Second Edition, (New York: Harcourt, Brace, and World, Inc., 1966), pp. 2-18; John S. Richardson, ed., School Facilities for Science Instruction, (Washington: National Science Teachers Association, 1954), p. 3.

instructional practices were then read for their clarity and validity by four staff members of the Science and Mathematics Teaching Center at Michigan State University and by the science consultant for the Michigan Department of Education. The lists of items were then revised, and after this revision there were twelve items that represented independent study, twelve items that represented small group instruction, and twelve items that represented large group instruction.

These thirty-six items on instructional practice were then further refined through a pilot study. In the pilot study, three different survey instruments having the same items on instructional practice were distributed. These three instruments differed in the rating scales that appeared beside each of the instructional practice items. All three instruments had a "suitability" rating scale on the right side of each item. However, one instrument also had a "frequency of use" rating scale on the left side of each item, while another instrument had an "importance" rating scale on the left side. Thus, two of the instruments had a double rating scale for each item, while one of the instruments had a single rating scale for each item. The purposes for pretesting these three survey instruments were: (1) to determine which type of instrument yielded the greatest spread of "suitability" rating scores; (2) to eliminate items that were not considered important to biology teaching through the use of the instrument with the "importance scale;" and (3) to see if "frequency of use" of an instructional practice was related to the laboratory's "suitability" for that practice. These three types of survey instruments were sent to a total of thirty biology teachers who had responded earlier in the pre-survey, but had not been selected for this evaluation survey.

Each of the three types of the pilot survey instruments had an excellent return rate. Furthermore, there was no obvious difference in the spread of the suitability scores for these three instruments. Several items were not rated "important" to biology instruction and these items were subsequently eliminated in the final revision of the survey instrument. The "frequency of use" responses appeared to be related to the "suitability" responses for each item on the list. This was determined from a Spearman rank correlation coefficient[4] of r_s=.69 that was calculated between the ratings of the two scales. The double-scaled instrument having "frequency of use" on the left side and "suitability" on the right was selected for the final survey because of interest in the apparent relationship between the ratings of the items on both scales.

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[4]William L. Hays, Statistics for Psychologists, (New York: Holt, Rinehart, and Winston, 1963), pp. 643-646.

From the pilot study six items on the survey instrument were eliminated, two from each of the three types of instructional methods. Likewise, from the pilot study results one type of instrument was selected for the final survey. Other minor revisions were made in the form of the instrument. The final revised survey instrument is presented in Appendix B. In this instrument items numbered 1, 3, 8, 11, 12, 15, 20, 25, 26, and 30 represented independent study; items numbered 4, 6, 7, 9, 10, 14, 18, 23, 28, and 29 represented small group instruction; and items numbered 2, 5, 13, 16, 17, 19, 21, 22, 24, and 27 represented large group instruction.

Hoyt's internal consistency reliabilities were determined from the responses to the final survey instrument for each of the item types. This was done with the use of the Reciprocal Averages Program (RAVE)[5] in the Control Data 3600 Computer. These reliabilities, as shown in Table 5, were considered to be fairly high for all item types.

In order to quantify the ratings, the method of reciprocal averages technique was employed to each item type of the survey instrument. Through this technique it

[5]David J. Wright and Andrew C. Porter, "An Adaptation of Frank B. Baker's Test Analysis Package for Use on the Michigan State University CDC 3600 Computer," Occasional Paper No. 1, Office of Research Consultation, School for Advanced Studies, College of Education, Michigan State University, January, 1968, (mimeographed), pp. 13-54.

TABLE 5.--Hoyt's internal consistency reliabilities by item type in the survey instrument

Item Type	Hoyt's Internal Consistency Reliabilities	
	Suitability Scale	Frequency of Use Scale
Independent study	.86	.79
Small group instruction	.84	.76
Large group instruction	.83	.71

is said that one can quantify qualitative data.[6] This method yields an optimum set of weights for each item in each subsection of the instrument.[7]

Collection of Data

The final 140 survey instruments were then distributed to the various biology teachers through their principals. In order to make sure that the correct teacher got the instrument, the name of the teacher was typed on the cover letter of the instrument. In an effort to increase the number of responses the following additional techniques were used:

[6] Ibid., p. 13.

[7] Ibid., p. 14.

1. The study was sponsored by ESEA Title III of the Michigan Department of Education. This resulted in the use of the Department's letterhead stationery, as well as the use of the signature of a Department official in the cover letters to the principals.

2. Each of the cover letters to the principals were personally signed.

3. A self-addressed envelope was supplied to facilitate returns.

4. A date for the return of the forms was listed in the cover letters for both the principals and the teachers.

5. Follow-up letters were mailed promptly to those who had not returned forms by the designated date. Included with this follow-up letter was a self-addressed postcard for the teachers to explain why they hadn't returned the instrument.

   A week after this follow-up letter was sent, those teachers who had not responded were phoned.

6. A summary of the results was promised to those schools participating in the study.

A copy of the cover letters, survey instrument, and the follow-up letter are included in Appendix B.

Of the 140 survey instruments mailed, 133 instruments were returned for a 95.0 per cent response rate. Seven of these instruments were eliminated from the subsequent analysis because they were not completely filled out. In order to simplify the analysis of the data by having an equal number of respondents in each category, two more questionnaires were randomly eliminated from the analysis. Therefore, 124 instruments (31 for each design category) were used for the analysis of data, and this represented an 88.6 per cent response.

The returns from the final survey instrument were classified dichotomously according to each of the possible confounding variables recorded on the last page of the instrument. Pearson-product correlation coefficients were than determined for each of the possible confounding variables, and their scores on the dependent variable of perceived instructional suitability. These correlations were done in Morris's program[8] on the 3600 Control Data Computer. In this same program, significance tests were computed for each of the correlation coefficients to indicate the one-tailed probability that this correlation was greater than a correlation of zero. These correlation coefficients are presented in Table 6. An examination of these correlation coefficients shows that only the variable "recency of laboratory construction" appeared to be confounded with the dependent variable of instructional suitability.

To determine if significant relationships existed between the scores on the "frequency of use" scales and the scores on the "instructional suitability" scales for

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[8]John Morris, "Technical Report No. 47: Rank Correlation Coefficients," Computer Institute for Social Science Research, Michigan State University, January 5, 1967, (mimeographed), pp. 5-6.

TABLE 6.--Pearson-product correlations between each of the possible confounding variables and their instructional suitability ratings

Possible Confounding Variables	Suitability		
	Independent Study	Small Group Instruction	Large Group Instruction
1. Recency of laboratory construction	.41[a]	.42[a]	.49[a]
2. Curriculum materials used	-.17	-.06	-.08
3. Average class size	.17	.10	.16
4. Academic biology coursework taken by the teacher	.04	.02	.00
5. Years biology teaching experience	.00	.03	.04

[a]Correlations were significant beyond the .01 level.

each of the levels of the dependent variable, Pearson-Product Correlations Coefficients were calculated using this same Morris program.[9] These correlations are presented in Table 7. These correlations support the observations from the pilot study, that the two scales are, indeed, correlated significantly. These findings lend support to the assumption that a teacher's perception

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[9]*Ibid.*

TABLE 7.--Pearson-product correlations between ratings on the "frequency of use" scales and the "suitability"scales

"Suitability" Scale	"Frequency of Use" Scale		
	Independent Study	Small Group Instruction	Large Group Instruction
Independent Study	.49[a]	-	-
Small Group Instruction	-	.31[a]	-
Large Group Instruction	-	-	.41[a]

[a]Correlations were significant beyond the .01 level.

of their laboratory's instructional suitability is related to their utilization of these instructional methods in the laboratory.

Analysis

The purpose of the analysis was to determine if teachers from the four laboratory design categories differed significantly in their perceptions of their laboratory's suitability for the instructional methods of: independent study, small group instruction, and large group instruction. Because of the relatively strong correlation of the variable of "recency of laboratory construction" with the dependent variable of "instructional suitability," it appeared advisable to statistically control for this confounding variable in the analysis.

A repeated measures analysis of covariance model[10] was used to analyse the instructional suitability ratings. The covariate used here was "recency of laboratory construction," which was given the two values: (1) constructed before 1960 and (2) constructed in 1960 or later. The plan for the collection of data in this analysis is presented in Table 8.

TABLE 8.--Analysis of covariance design

Design Group	Subject	Tests M_1 X	M_1 Y	M_2 X	M_2 Y	M_3 X	M_3 Y
D_1	T_1						
	⋮						
	T_{31}						
D_2	T_{32}						
	⋮						
	T_{62}						
D_3	T_{63}						
	⋮						
	T_{93}						
D_4	T_{94}						
	⋮						
	T_{124}						

Key: D_1 . . . D_4 represent the four laboratory design groups. T_1 . . . T_{124} represent the biology teachers that are nested within the various design categories. M_1, M_2, and M_3 represent the repeated measures of instructional practice, namely independent study, small group instruction, and large group instruction. X's represent the values of the covariate. Y's represent the scores of the instructional suitability ratings.

The open-ended responses on the survey instrument regarding recommendations for improving the instructional adequacy of their facilities were typed on cards and subsequently categorized.

Field visitations were conducted with two typical examples of designs from each of the four laboratory design categories included in the survey. The purpose of these visitations was to explore, in depth, possible explanations for laboratory design adequacy or inadequacy. A guide for this visit is included in Appendix C.

Statistical Hypotheses

Because of the lack of research on the instructional adequacy of various room designs, (See Chapter 2), it was decided that predictive hypothesis could not be adequately justified. Therefore, the following null hypotheses were tested:

1. There is no significant difference on the adjusted mean scores for instructional practice suitability between secondary biology teachers from different laboratory designs.

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[10] B. J. Winer, Statistical Principles in Experimental Design, (New York: McGraw-Hill Book Co., 1962), pp. 606-618.

Symbolically: $H_o: \mu_1 = \mu_2 = \mu_3 = \mu_4$

$H_1: \mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4$

Legend: μ_1 = split design group adjusted mean

μ_2 = perimeter design group adjusted mean

μ_3 = central-fixed design group adjusted mean

μ_4 = central-movable design group adjusted mean

2. There is no significant overall interaction between the repeated measures and the different laboratory design groups.

Symbolically: $H_o: \gamma_{DM} = 0$

$H_1: \gamma_{DM} \neq 0$

Legend D=design groups
M=repeated measures
γ_{DM}=interaction between D and M

An alpha of .05 was set as the critical level for statistical significance of both hypotheses. If the overall $F_{.05}$ was significant for the first null hypothesis, then post-hoc comparisons would be made through the Scheffé method.[11]

Assumptions of the Analysis of Covariance Model

The assumptions for the repeated measures analysis of covariance model include:

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[11]William C. Guenther, Analysis of Variance, (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1964), pp. 149-150.

1. Assumptions about the regression effects include:

   a. The treatment effects and the regression effects are additive. Implicit in this assumption is that the within-class regressions are homogeneous. According to Winer, the effects of violating this assumption have not been investigated and thus he recommends a procedure for examining this assumption.[12] Therefore, in this study a test of the hypothesis that the within-class regressions were homogeneous was done. The resultant $F_{3,116}=.69$ was not significant at the .10 level. Therefore, it was concluded that this assumption was met.

   b. The residuals are normally and independently distributed with zero means and the same variance. According to Winer, the F tests in the analysis of covariance are robust with respect to the violation of these assumptions.[13] Thus, it was assumed unnecessary to test these assumptions.

2. Assumptions for the special analysis of variance case of repeated measures include:

   a. The teacher variance within laboratory design groups is homogeneous from group to group in order to assess the differences between design groups. Furthermore, that the teachers by repeated measures interaction within design groups is homogeneous from group to group in order to test the significance of the DM interaction. Winer states that the F tests are robust, however, with respect to minor violations of these assumptions.[14] Thus, it was assumed unnecessary to test these assumptions.

   b. The pattern of the variance-covariance

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[12] Winer, op. cit., pp. 586-587.

[13] Winer, op. cit., p. 586.

[14] Winer, op. cit., p. 305.

matrix must be the same from group to group in order to assess the significance of the DM interaction.[15] If the $F_{.05}$ test for the DM interaction is not significant using the degrees of freedom in the traditional analysis of covariance table, then there is no need to examine the variance-covariance patterns according to Greenhouse and Geiser.[16] In this study, the DM interaction was not significant, thus it was not necessary to explore this assumption further.

3. The usual analysis of variance assumptions of:

   a. Individuals in the various design groups should have been selected on the basis of random sampling from normally distributed populations.[17] However, Box and Andersen state that the F test of the analysis of variance is "remarkably insensitive to general non-normality."[18] Thus, it was assumed unnecessary to test this assumption.

   b. The variance of each of the design groups should be homogeneous.[19] However, Box and Andersen state that the analysis of variance test "where the group sizes are equal . . . is not very sensitive to variance inequalities from group to group."[20]

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[15] Winer, op. cit., p. 305.

[16] S. W. Greenhouse and S. Geisser, "On Methods in the Analysis of Profile Data," Psychometrika, XXXIV (1959), 98-102, 110.

[17] N. M. Downie and R. W. Health, Basic Statistical Methods, Second Edition (New York: Harper and Row, Publishers, 1965), p. 177.

[18] G. E. P. Box and S. L. Andersen, "Permutation Theory in the Derivation of Robust Criteria and the Study of Departures from Assumptions," Journal of the Royal Statistical Society, Series B. XVII, No. 1 (1955), p. 2.

[19] Downie and Heath, op. cit., p. 177.

[20] Box and Andersen, op. cit., p. 2.

Since the design group sizes were equal in this study, it was assumed that this assumption was met.

c. The individuals comprising each of the design groups should be independent.[21] Because of the research design of this study, it was assumed that this assumption was satisfied.

Therefore it was assumed that the foregoing assumptions for the repeated measure analysis of covariance model were satisfied in this study.

Summary

A teacher opinion survey was devised to evaluate the instructional suitability of four types of secondary biology laboratory designs, namely: the split design, the perimeter design, the central-fixed design, and the central-movable design.

A survey instrument was constructed, pretested, revised, and distributed to a random sample of Michigan Class B and Class C high school biology teachers from each of the four types of laboratory designs. On this survey instrument the teachers were asked to rate the suitability of their laboratory design for each of thirty instructional practices. These instructional practice items could later be grouped into the item types of: independent study, small group instruction, and large group instruction. Internal consistency

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[21]Downie and Heath, op. cit., p. 177.

reliabilities were calculated for each of the item types and the resultant coefficients indicated a high degree of reliability for each of these categories. Optimum weights were determined for each of the items in each of the item categories, so that the data would be more quantifiable.

An analysis of covariance model was used to analyze the survey data. The covariate here was the recency of laboratory construction, which was found to have a fairly high correlation with the dependent variable of perceived instructional suitability.

The assumptions underlying the analysis of covariance model were examined, and this model was found appropriate for analyzing the survey data in this study.

A hypothesis was tested regarding differences in the perceived instructional suitability of teachers from different laboratory design categories. Furthermore, the hypothesis of no overall interaction between the repeated measures and the laboratory design types was tested.

Field visitations were made to typical examples of these laboratory designs to gain, in depth, information on design adequacy or inadequacy.

CHAPTER V

ANALYSIS OF RESULTS

Presented in this chapter are the findings from the analyses of the survey and field study data.

Survey Findings

The following null hypotheses were tested:

1. There is no significant difference on the adjusted mean scores for instructional practice suitability between secondary biology teachers from different laboratory designs.

Symbolically: $H_o: \mu_1 = \mu_2 = \mu_3 = \mu_4$

$H_1: \mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4$

Legend: μ_1=split design group adjusted mean

μ_2=perimeter design group adjusted mean

μ_3=central-fixed design group adjusted mean

μ_4=central-movable design group adjusted mean

2. There is no significant overall interaction between the repeated measures and the different laboratory design groups.

Symbolically: $H_o: \gamma_{DM} = 0$

$H_1: \gamma_{DM} \neq 0$

Legend: D=design groups
M=repeated measures
γ_{DM}=interaction between D and M

An alpha of .05 was set as the critical level for statistical significance of both hypotheses.

Differences in the instructional suitability ratings for the four laboratory design groups were analyzed by the repeated measures analysis of covariance procedure presented by Winer.[1] The repeated measures were the scores for the survey item categories of: independent study, small group instruction, and large group instruction. The covariable used here was recency of laboratory construction. The F test was used to compare the relationship between the adjusted design group means. The unadjusted design group means and standard deviations are shown in Table 9.

Treatment of the data using the analysis of covariance technique indicated (Table 10) that: (1) significant differences existed between the adjusted design groups, and (2) the overall laboratory design group by repeated measures interaction was not significantly different from zero. Thus, the hypothesis of no significant difference between the design group means was rejected, and the hypothesis that the design group by repeated measure interaction was equal to zero was not rejected.

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[1]B. J. Winer, Statistical Principles in Experimental Design, (New York: McGraw-Hill Book Company, 1962), pp. 606-618.

TABLE 9.--Unadjusted design group means and standard deviations of the instructional suitability survey scores (equal cell N=31)

Design Group	Independent Study		Small Group Instruction		Large Group Instruction	
	$\overline{X}j$	s	$\overline{X}j$	s	$\overline{X}j$	s
Split	34.58	6.7	37.55	6.4	41.00	8.1
Perimeter	31.32	6.0	33.71	6.7	38.32	6.2
Central-Fixed	26.45	7.5	29.35	6.6	34.61	6.0
Central-Movable	23.90	6.9	28.64	6.3	33.55	6.6

TABLE 10.--Analysis of covariance results for the instructional suitability survey scores

Sources	SS	df	MS	F
Design Groups (D)	3,545.39	3	1,181.79	11.42[a]
Teachers within D	12,311.41	119	103.45	
Repeated measures (M)	3,813.64	2	1,906.82	
DM Interaction	114.53	6	19.09	1.48
Residual	3,087.83	239	12.92	

[a]significant at the .05 level of confidence.

Contrasts of design group means were made over the repeated measures, since there was no design group by repeated measures interaction. The Scheffé technique as presented by Guenther[2] was used for this analysis. These contrasts indicated (Table 11) that: (1) the mean scores of the split design group were significantly greater than the mean scores of the perimeter design group; (2) the mean scores of the split design group were significantly greater than the mean scores of the central-fixed design group; (3) the mean scores of the split design group were significantly greater than the mean scores of the central-movable design group; (4) the mean scores of the perimeter design group were not significantly different from the mean scores of the central-fixed design group; (5) the mean scores of the perimeter design group were significantly greater than the mean scores of the central-movable design group; (6) the mean scores of the central-fixed design group were not significantly different from the mean scores of the central-movable design group.

In the survey instrument the biology teachers were also requested to list recommendations for improving the instructional adequacy of their biology laboratory designs.

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[2]William C. Guenther, Analysis of Variance, (Englewood Cliffs; N.J.,: Prentice-Hall, Inc., 1964), p. 149.

TABLE 11.--Scheffe' contrasts of adjusted design group means

		Perimeter 33.20	Central-Fixed 31.31	Central-Movable 29.56
Split	36.92	3.71[a]	5.60[a]	7.35[a]
Perimeter	33.20	——	1.89	3.64[a]
Central-Fixed	31.31	——	——	1.75

[a]significant at the .05 level of confidence.

Of the 133 survey instruments returned, 104 answered this question. The recommendations were categorized, and a summary of these can be found in Table 12.

Field Study Findings

Two biology laboratories from each of the four design groups were visited to explore, in depth, possible explanations for their instructional adequacy or inadequacy. Teachers from these laboratories were interviewed, and photographs were taken of the facility. The photographs and the teachers' original pre-survey drawings are presented in Exhibits I-IV.

From the photographs and from the on-site facility measurements, it was concluded that the pre-survey instrument was accurately interpreted and completed.

TABLE 12.--Recommendations of teachers for improving the instructional adequacy of their biology laboratory designs[a]

Recommendation	Frequency[b]
More functionally designed laboratory tables, ventilation system, individual student stations, and room darkening facilities	40
More classroom space for individual and small group activities	33
More electrical outlets, gas outlets, sinks, and faucets	32
More storage space	31
More equipment	27
More display area	15
Need separate areas for laboratory and for lecture	10
Need a greenhouse	9
Need a science reference library	8
Need an animal room	2

[a]These findings were based on the opinions of 104 of the 133 survey respondents who answered this question.

[b]The term "frequency" represents the total number of such recommendations received from the survey respondents. Most respondents listed more than one recommendation.

Likewise, the comments of teachers in the visitation indicated that the directions were clearly understood for completing the final survey instrument.

The question was asked "What is most needed to improve your biology teaching?" Teachers from the split and perimeter designs listed things that would not have affected the basic design of their rooms such as, reference materials, and equipment. However, teachers from the central-fixed and central-movable designs, generally felt the need for a new or greatly altered laboratory room.

The question was asked "How adequate is your biology room design for independent study, small group instruction, and large group instruction?" Teachers from the split and perimeter designs expressed greater satisfaction in the instructional adequacy of their room designs than did the teachers from the central-fixed and central-movable designs.

Other variables that were mentioned as having an affect on the instructional adequacy of the laboratory design included: improper lighting, inadequate legroom beneath the student tables, scheduling of other teachers in the room, and lack of storage space for both teachers and students.

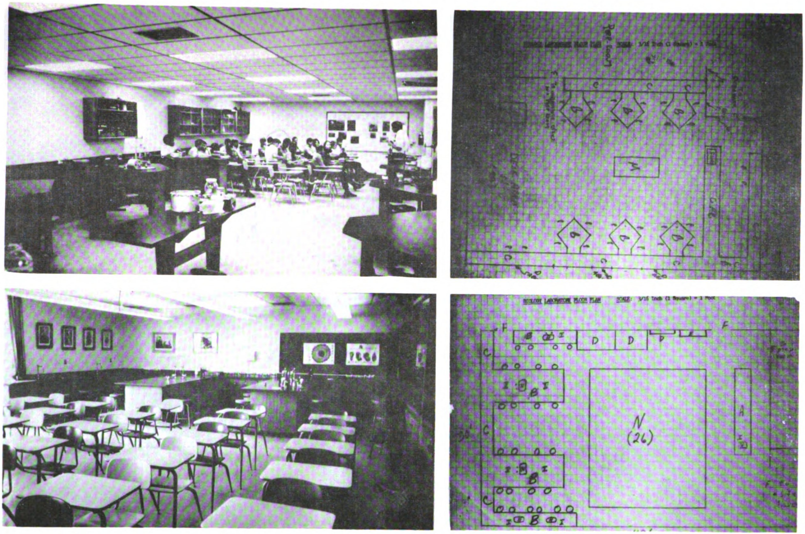

Exhibit I - Photographs and Drawings of the Two Split Biology Laboratory Designs Visited in the Field Study

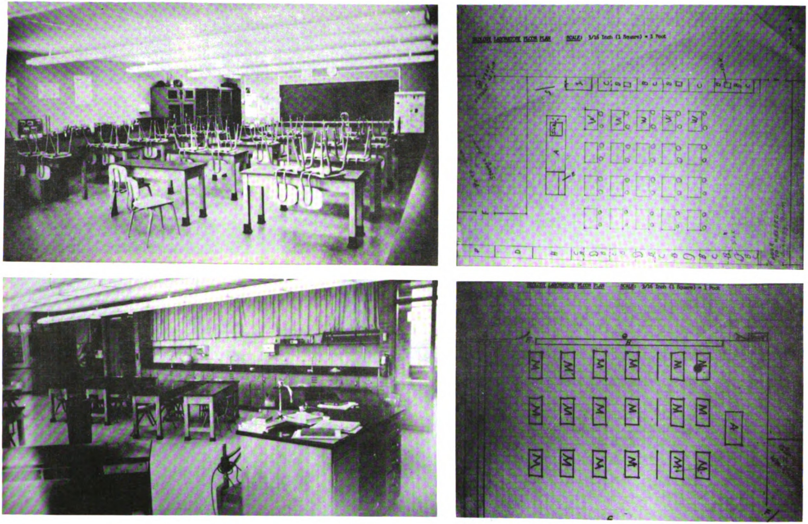

Exhibit II - Photographs and Drawings of the Two Perimeter Biology Laboratory Designs Visited in the Field Study

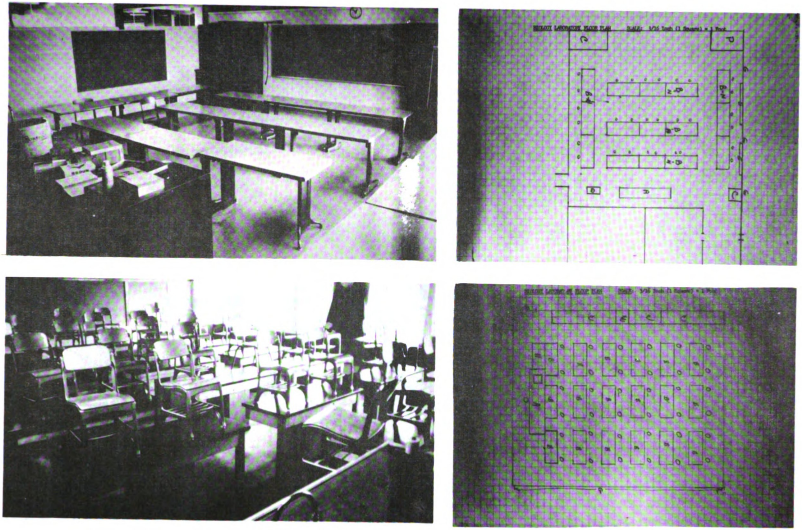

Exhibit III - Photographs and Drawings of the Two Central-Fixed Biology Laboratory Designs Visited in the Field Study

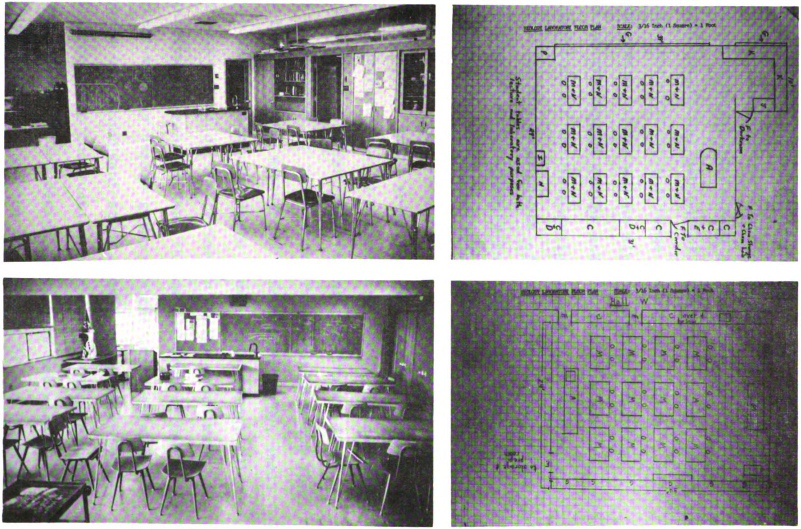

Exhibit IV - Photographs and Drawings of the Two Central-Movable Biology Laboratory Designs Visited in the Field Study

Summary

Teachers from the four laboratory design groups differed significantly from each other in their perception of their laboratory design's suitability for the instructional methods of independent study, small group instruction, and large group instruction. Furthermore, there was no significant interaction between the design groups and the repeated measures. Comparisons of the four design group means indicated that: (1) the mean scores of the split design group were significantly greater than the mean scores of the perimeter, central-fixed, and central-movable design groups for the instructional methods of independent study, small group instruction, and large group instruction; (2) the mean scores of the perimeter design group were not significantly different from the mean-scores of the central-fixed design group for the instructional methods of independent study, small group instruction, and large group instruction; (3) the mean scores of the perimeter design group were significantly greater than the mean scores of the central-movable design group for the instructional methods of independent study, small group instruction, and large group instruction; and (4) the mean scores of the central-fixed design group were not significantly different from the mean scores of the central-movable design group for the instructional methods of independent study, small group instruction, and large group instruction.

Categorization of the teachers' recommendations for improving the instructional adequacy of their biology laboratory designs indicated that the following categories were mentioned most frequently: (1) more functionally designed laboratory tables, ventilation system, individual student stations, and room darkening facilities; (2) more classroom space for individual and small group activities; (3) more electrical outlets, gas outlets, sinks, and faucets; and (4) more storage space.

Findings from field visitations to typical laboratories from each of the four design groups indicated that: (1) the pre-survey laboratory design drawings were accurately done; (2) the directions and the items from both the pre-survey and survey instruments were clearly understood; (3) that the split and perimeter design groups were more satisfied with their laboratory design's instructional adequacy than were the central-fixed and central-movable design groups; and (4) the physical design variables of room lighting, leg room beneath tables, and storage space were frequently mentioned as having an affect on the instructional adequacy of the laboratory facility.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The purpose of this study was to investigate the instructional suitability of various laboratory designs, as perceived by the secondary biology teachers currently teaching in these laboratories.

To provide a framework for the investigation of this problem, the human engineering approach to design evaluation was used in the study. In this approach it is first necessary to describe the structure and function of the systems to be evaluated. This analysis is then generally followed by observations of how well various alternative designs accomplish the desired functions of the system.

The problem in this study was thus studied in two parts. Part I dealt with a description of four high school biology laboratory systems. These systems were described in relation to the significant interacting elements of: the instructional process, the teacher and student participants, and the arrangement of the physical facilities. These four laboratory systems differed primarily in the design of their physical facilities. Specifically, the four laboratory design types were:

(1) split lecture-laboratory design, (2) perimeter tables design, (3) central-fixed tables design, and (4) central-movable tables design. A pre-survey instrument was constructed and sent to the Class B and Class C high schools in Michigan, to obtain the specific information needed for the above description of the four types of laboratory designs. Part II of the study consisted of an evaluation of these four types of laboratory designs as to their perceived suitability for different types of instruction, namely: independent study, small group instruction, and large group instruction. The form of this evaluation was a teacher opinion survey. A survey instrument was developed and sent to a random sample of Michigan Class B and Class C high school teachers from each of the four design categories identified in the pre-survey. On this survey instrument the biology teachers rated the suitability of their laboratory design for the instructional methods of: independent study, small group instruction, and large group instruction. Of the 140 survey instruments mailed, 133 instruments were returned for a 95.0 per cent response.

This survey was followed by field visitations to discover possible explanations for laboratory design adequacy or inadequacy.

Internal consistency reliabilities were calculated for each of the survey item types and the resultant coefficients indicated a high degree of reliability for each of these categories. Optimum weights were determined for each of the items by the reciprocal averages method, so that the data would be more quantifiable.

A repeated measures analysis of covariance procedure was applied to the ratings from the survey instrument, to determine if the four types of laboratory designs differed in their instructional suitability, as perceived by the high school biology teachers currently teaching in these laboratories. The covariate used here was "recency of laboratory construction," because it was found to have a fairly high correlation with the dependent variable of perceived instructional suitability. The repeated measures were the instructional methods item categories of: independent study, small group instruction, and large group instruction. Based on this analysis, the teachers from the four laboratory design groups differed significantly in their perception of their laboratory design's suitability for the three instructional methods of independent study, samll group instruction, and large group instruction; furthermore, there was no significant interaction between the design groups and the repeated measures. Comparisons of the four design groups means indicated that: (1) the mean scores of the split design group were significantly greater than the mean scores of the perimeter, central-fixed, and central-movable design groups for the instructional methods of independent study, small group instruction, and large group instruction; (2) the mean scores of the perimeter design group were not significantly different from the mean scores of the central-fixed design group for the instructional methods of independent study, small group instruction, and large group instruction; (3) the mean scores of the perimeter design group were significantly greater than the mean scores of the central-movable design group for the instructional methods of independent study, small group instruction, and large group instruction; and (4) the mean scores of the central-fixed design group were not significantly different from the mean scores of the central-movable design group for the instructional methods of independent study, small group instruction, and large group instruction.

Categorization of the teachers' recommendations for improving the instructional adequacy of their biology laboratory designs indicated that the following categories were mentioned most frequently: (1) more functionally designed laboratory tables, ventilation system, individual student stations, and room darkening facilities; (2) more classroom space for individual and small group activities; (3) more electrical outlets, gas outlets, sinks, and faucets; and (4) more storage space.

Findings from field visitations to typical laboratories from each of the four design groups indicated that: (1) the pre-survey laboratory design drawings were accurately done; (2) the directions and the items from both the pre-survey and survey instruments were clearly understood; (3) teachers from the split and perimeter design groups were more satisfied with their laboratory design's instructional adequacy than were those from the central-fixed and central-movable design groups; and (4) the physical design variables for room lighting, leg room beneath tables, and storage space were frequently mentioned as having an affect on the instructional adequacy of the laboratory facility.

Conclusions

The conclusions drawn from this study pertain to the population of four biology laboratory design groups from which the samples were taken. Furthermore, the conclusions were based on the analyses of the opinions of the biology teachers from these various laboratory design groups, as expressed in the survey instrument.

A. The application of the human engineering approach to design provided a useful conceptual tool for the evaluation of the instructional suitability of alternative laboratory designs.

B The four biology laboratory design types of (1) split lecture-laboratory, (2) perimeter, (3) central-fixed, and (4) central-movable, differ significantly in their perceived suitability for instruction.

C. The split lecture-laboratory design was perceived to be superior to the other three biology laboratory design types for independent study, for small group instruction, and for large group instruction.

D. The perimeter design was not perceived to be significantly different from the central-fixed biology laboratory design for independent study, for small group instruction, and for large group instruction.

E. The perimeter design was perceived to be superior to the central-movable biology laboratory design for independent study, for small group instruction, and for large group instruction.

F. The central-fixed design group was not perceived to be significantly different from the central-movable biology laboratory design for independent study, for small group instruction, and for large group instruction.

Implications for Educational Practice

The finding that different biology laboratory design groups differed in their perceived suitability for instruction has major implications for future laboratory planning. Given the limitations of this study, educational planners who are faced with having to make decisions about laboratory designs will now have some data on which to base their decisions.

If independent study, small group instruction, or large group instruction is desired, then this investigation would indicate that the split lecture-laboratory design would be superior to perimeter designs, to central-fixed tables designs, and to central-movable tables designs. The remarkable homogeneity of laboratory designs indicates a limited application of creativity to design problems. Since only fourteen per cent of the biology teachers in the Class B and Class C Michigan high schools are using split laboratory designs, the strong possibility exists that the other eighty-six per cent of the teachers are using designs that are not the most productive. Each decision-making situation has unique elements, which should also be considered in the interpretation and use of this finding.

Since the human engineering approach to design was found to be useful in the conceptualization of the biology laboratory designs in this study, and the identification of criteria for evaluations, the implication would be that the human engineering approach could be useful in the planning of laboratories.

From an inspection of the four types of laboratory designs investigated in this study, one might question how adequate any of these are for independent study and for small group instruction. Hopefully, the finding that certain designs were perceived to be more suitable than others for these instructional methods will spur the development of new and more improved laboratory design types.

Another implication from this study would be that laboratory planners should consider having rooms of greater than one thousand square feet of area, as well as having more than one hundred linear feet of shelf storage space available for student projects. This implication is based on the fact that both the split and the perimeter designs investigated in this study had a majority of rooms of over one thousand square feet area, and had over one hundred linear feet of shelf storage space available for student projects. However, the central-fixed and central-movable design groups were deficient in both of these items.

Furthermore, biology laboratory planners would be wise to favor either the split or the perimeter design types since these types generally were found to have more instructional advantages than the other two design categories in both the survey and the field visitations.

Recommendations for Future Research

Some of the questions posed by this study for future research are:

1. Would the results from this survey study be supported by an experimental study, where subjects could be randomly assigned to the laboratory design types?

2. Does the type of administrative leadership in a school, affect the teacher's perception of their laboratory's instructional suitability?

3. Do laboratories of different design differ in their instructional suitability for students of different academic abilities or socio-economic backgrounds?

4. Does the laboratory planning process differ in those schools having the split lecture laboratory design from those in the other three design types?

5. What is the relative effect of variables such as, administrative style, available furniture, and curriculum type on science facility decision making?

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APPENDICES

APPENDIX A

PRE-SURVEY COVER LETTERS, INSTRUMENT, AND FOLLOW-UP LETTER

STATE OF MICHIGAN

DEPARTMENT OF EDUCATION

Lansing, Michigan 48902

IRA POLLEY
Superintendent of Public Instruction

December 16, 1968

Dear Principal:

We are asking for your assistance in helping the ESEA Title III project office of the Michigan Department of Education to study the relationship of classroom design to instructional practice. An in-depth prototype study in one specific curriculum area will be conducted by Mr. John Norman.

The study will examine secondary biology room designs and their suitability for various types of instruction. A two-part study has been devised. Part I will consist of collecting information through questionnaire regarding the types of biology facilities that exist in the State. In Part II, additional information will be gathered through a field visitation. Analyses of this information will be made concerning the instructional adequacy of various types of biology facilities. Results of the study will be made available to those schools which return questionnaires.

Your cooperation is urgently needed at this time in order to carry out Part I of the study. We are asking that you give one of the enclosed questionnaires to each teacher in your high school whose major assignment is in biology (any extra questionnaires can be kept for future reference). Upon completion of the questionnaires, would you please assume the responsibility for returning them in the large enclosed envelope by January 15, 1969, to:

ESEA Title III
State Department of Education
Lansing, Michigan 48902

Thank you for cooperating in this activity.

Sincerely yours,

Ralph E. Kellogg

Ralph E. Kellogg
Director, Curriculum Division
Bureau of Educational Services

REK:LV
Enclosure

DEPARTMENT OF EDUCATION
Lansing, Michigan

December 16, 1968

TO: The Biology Teacher

RE: The ESEA Title III Biology Facility Study

This study is being conducted by the ESEA Title III project office of the Department of Education for the purpose of investigating the relationship of biology laboratory design to instructional practice. Mr. John Norman will be the person in this office responible for conducting this study, and he may be contacting you later concerning follow-up materials.

A two-part study plan has been developed to help us achieve this overall objective. Part I will consist of collecting information through questionnaire regarding the types of biology laboratory facilities that exist in the State. In Part II, additional information will be gathered through field visitation. Analyses will be made concerning the instructional adequacy of various types of laboratory designs. Results of the study will be made available to those teachers who return questionnaires.

Your assistance in completing this questionnaire is needed at this time in order for us to carry out Part I of the study. Information obtained from this study could prove to be invaluable to educators seeking to improve their biology laboratory facilities.

Please note that this questionnaire largely pertains to the room where YOU teach biology: if you teach in several rooms, then please answer with regard to the one where biology laboratory is taught.

Upon completion of the questionnaire, it should be returned to your principal before January 15, 1969, so that he can send it to the Department along with any others from your school. Please make sure you have written your NAME and SCHOOL ADDRESS on the questionnaire, since this information is needed for Part II of the overall study plan.

Thank you for assisting us in this project.

Name of Biology Teacher ______________________________

School Address ______________________________________

I. BASIC FLOOR PLAN OF YOUR BIOLOGY LABORATORY

In this section we are interested in obtaining a verbal and graphical description of the floor plan of the room where YOU teach biology laboratory. The room of interest here should not include adjacent special purpose rooms (i.e. greenhouse, special projects room, storage room) or other more removed supplementary rooms (i.e. auditorium, library, outdoor nature center). In this description we are not only interested in the QUANTITIES and SHAPES of the major fixed and movable furniture, but also in its SPATIAL ARRANGEMENT in the room.

1. Directions: Listed below are several categories of biology laboratory floor plans. Please CIRCLE the letter of the category that best describes the floor plan of your room. The category "OTHER" is provided for those rooms that do not fit any of these categories. If the latter is true, then please give a verbal description here of your floor plan in similar terms.

A. SPLIT AREA FLOOR PLAN

Separate areas at opposite ends of the laboratory are provided for different instructional purposes. One area is for demonstration and discussion, and the other area is for laboratory activities.

B. PERIMETER LABORATORY TABLE FLOOR PLAN

Student laboratory tables and/or work counters are along two or more of the walls. In the center of the room are student desks and/or tables that are facing a demonstration table.

C. CENTRAL LABORATORY TABLE FLOOR PLAN

Student laboratory tables are located in the center of the room. There is a demonstration table in the front of the room. There is limited, if any, student work counter space along the walls.

D. MULTIPURPOSE CLASSROOM FLOOR PLAN

Student lecture desks are located in the center of the room. At the front of the room is a demonstration table. There is limited, if any student work counter space along the walls.

E. OTHER (PLEASE SPECIFY)

2. Directions: On the following page, a piece of graph paper is provided for you to sketch the floor plan of your biology laboratory. This drawing may be done freehand but should approximate the QUANTITY, SHAPE, and LOCATION of the major equipment and features of the laboratory. Listed below are the items that should be included in your drawing, if they are present in your room. Please LABEL THESE ITEMS WITH THE LETTER THAT PRECEDES THE ITEM IN THE LIST. Figure I is an example of how such a laboratory floor plan might be drawn.

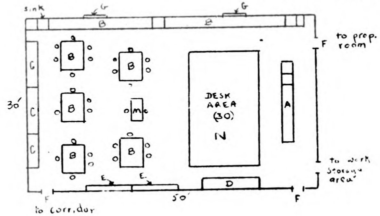
ROOM ITEMS

Fixed Installations - Furniture and other major room items that are attached to the floor and/or wall, or that are so cumbersome to move that for most instructional purposes they stay in the same place.

A. Demonstration Table
B. Student Laboratory Tables and/or Work Counters
C. Storage Cabinets
D. Display Cases
E. Book Cases
F. Doors
G. Windows
H. Other (Specify)__________
I. Other (Specify)__________
J. Other (Specify)__________
K. Other (Specify)__________

Movable Furniture - Furniture that can be easily moved from one location to another for different instructional purposes.

L. Demonstration Tables
M. Student Laboratory Tables and/or Work Counters
N. Student Lecture Desks (Give Number)
O. Student Laboratory Chairs or Stools
P. Other (Specify)______
Q. Other (Specify)______
R. Other (Specify)______
S. Other (Specify)______



II. FACILITIES AVAILABLE TO YOUR STUDENTS BOTH WITHIN YOUR LABORATORY ROOM AND/OR IN NEARBY ROOMS

In this section we are interested in the major facilities available to YOUR STUDENTS, both within your laboratory room and/or in nearby rooms.

Directions: For each item listed below, CIRCLE the category that best describes the facilities available to your students. If the item referred to is not available to your students, then circle a "zero" or "no."

1.	Shelf Storage for Student Projects (linear feet)	400	300	200	100	0
2.	Student Work Counter Space (linear feet)	90	60	30	15	0
3.	Height of Student Laboratory Tables (Measured in Inches From Floor to Work Surface)	36	34	30	29	0
4.	Number of Sinks	4	3	2	1	0
5.	Number of Electrical Outlets	7	5	3	2	0
6.	Number of Gas Outlets	7	5	3	2	0
7.	Fume Hood	Yes	No			
8.	Greenhouse	Yes	No			
9.	Life Alcove	Yes	No			
10.	Science Library	Yes	No			
11.	Student Special Projects Area or Room	Yes	No			

12. Other (Specify) ____________________

13. Other (Specify) ____________________

14. Other (Specify) ____________________

APPENDIX B

SURVEY COVER LETTERS, INSTRUMENT, AND FOLLOW-UP LETTER

DEPARTMENT OF EDUCATION

Lansing, Michigan 48902

IRA POLLEY
Superintendent of Public Instruction

April 23, 1969

Dear Principal:

Thank you for participating in the Michigan Department of Education's ESEA Title III Study of the relationship of classroom design to instructional practice.

As you may recall, a two-part study has been devised. Part I of this study consists of collecting information through several questionnaires regarding the types of biology facilities that exist in the State. In Part II, additional information will be gathered through field visitations to selected schools. Results of the entire study will be made available to those schools participating in the study.

We are now asking for your further cooperation in helping us complete the final phase of Part I of this study plan. This is the most important section of the overall study, because it deals with the instructional advantages of various room designs. We are asking that you give the enclosed questionnaire(s) to the biology teacher whose name appears on the front cover of the questionnaire, Upon completion of the questionnaire, would you please assume the responsibility for returning it in the large enclosed envelope by May 7, 1969 to:

ESEA Title III
State Department of Education
Lansing, Michigan 48902

Again we would like to thank you for your cooperation.

Sincerely yours,

Don E. Goodson

Don E. Goodson, Coordinator
ESEA Title III

John T. Norman Jr.

John T. Norman Jr., Researcher
ESEA Title III Biology Facility Study

JTN:mjn
Enclosure

STATE OF MICHIGAN

DEPARTMENT OF EDUCATION

Lansing, Michigan 48902

IRA POLLEY
Superintendent of Public Instruction

Dear Principal:

Perhaps you have already returned the ESEA Title III Biology Facility Study Questionnaires that were recently sent to you. If so, we want to thank you. However, if you have not mailed these questionnaires as yet, we request your assistance in this endeavor.

A questionnaire should be completed by each teacher in your high school whose major teaching assignment is in the area of biology. Upon completion of the questionnaires they should be returned by February 1, 1969, to ESEA Title III Biology Facility Study, Department of Education, Lansing, Michigan 48902.

Results of this study may contribute significantly to the planning of future school facilities. In order that these results will be as representative as possible of such facilities in the State, questionnaires should be returned from all high schools.

If for any reason it is impossible for you to return the questionnaire, we would appreciate it if you would complete the enclosed postcard so that we can account for as many schools as possible.

Thank you for your cooperation.

Sincerely yours,

Don E. Goodson

Don E. Goodson, Coordinator
ESEA Title III

John T. Norman Jr.

John T. Norman, Jr., Researcher
ESEA Title III Biology Facility Study

DEG:JTN:kas

ESEA Title III
DEPARTMENT OF EDUCATION
Lansing, Michigan

April 23, 1969

TO:

RE: The ESEA Title III Biology Facility Study

We appreciate your participation in the Michigan Department of Education's ESEA Title III Biology Facility Study.

As you may recall, a two-part study plan has been developed to help us study the relationship of biology laboratory design to instructional practice. Part I consists of collecting information through several questionnaires regarding the types of biology facilities that exist in the State. In Part II, additional information will be gathered through field visitations to selected schools. Results of the entire study will be made available to those schools participating in the study.

We are now asking for your assistance in completing this final questionnaire. It is the most important questionnaire of the study, because it deals with the instructional adequacy of various types of room designs. In this questionnaire the term "room design" refers not only to the quantities and shapes of the major fixed and movable furniture, but also to its spatial arrangement in the room. The room of interest here does not refer to nearby special purpose rooms (i.e. greenhouse or storage room) or other more removed supplementary rooms (i.e. auditorium, library).

Upon completion of the questionnaire, it should be sealed in the enclosed envelope and returned to your principal before May 7, 1969 so that he can send it to the Department along with any others from your school. Please make sure you have answered every question, since an unanswered question may invalidate your return.

Thank you again for assisting us in the final phase of this project.

QUESTIONNAIRE, PART I

DIRECTIONS: For each of the following instructional practices listed below please respond twice, once to the scale on the left and once to the scale on the right. In the left scale please circle the number that best indicates how FREQUENTLY you use this practice in your biology teaching. In the right scale, please circle the number that most accurately represents how SUITABLE you feel your biology room design is for this practice.

Very Infrequently Used	Infrequently Used	Neutral	Frequently Used	Very Frequently Used		Very Unsuitable	Unsuitable	Neutral	Suitable	Very Suitable
1	2	3	4	5	1. Providing the opportunity for students to come in before or after school to work on advanced projects.	1	2	3	4	5
1	2	3	4	5	2. Helping a class follow prescribed experiments in the chemistry of digestion, which might require the heating and mixing of various chemicals.	1	2	3	4	5
1	2	3	4	5	3. Assisting the students of a class in independent laboratory investigations, where each student may be doing a different investigation that may require different chemicals and equipment.	1	2	3	4	5
1	2	3	4	5	4. Meeting with a biology club of about fifteen students that is involved in various club projects and activities.	1	2	3	4	5
1	2	3	4	5	5. Assisting the class in their study of protozoa under microscopes.	1	2	3	4	5
1	2	3	4	5	6. Viewing single concept films (film loops) in groups of about eight students each.	1	2	3	4	5
1	2	3	4	5	7. Conducting relatively free and open interest group discussions where pupils may express complaints, outline procedures, or just brainstorm.	1	2	3	4	5
1	2	3	4	5	8. Providing the opportunity for a large number of your students to work on long term extra-class science fair projects, such that their projects can be left intact in the room and away from interference from other students.	1	2	3	4	5
1	2	3	4	5	9. Involving small groups of students in the planning of long term biology experiments, such as the effect of light color on the growth of seedlings.	1	2	3	4	5
1	2	3	4	5	10. Assisting a group of about three or four students in making a model or a replica that illustrates a biological phenomena (such as a model illustrating the action of the flexor and extensor muscles in humans) while other students are working at other activities.	1	2	3	4	5

Very Infrequently Used	Infrequently Used	Neutral	Frequently Used	Very Frequently Used			Very Unsuitable	Unsuitable	Neutral	Suitable	Very Suitable
1	2	3	4	5	11.	Giving assistance to a student who has asked for help.	1	2	3	4	5
1	2	3	4	5	12.	Providing the opportunity for students to engage in "discovery type" laboratory activities.	1	2	3	4	5
1	2	3	4	5	13.	Having the members of a class dissect a small animal with the aid of a prepared guide.	1	2	3	4	5
1	2	3	4	5	14.	Using the microprojector with a small number of students to demonstrate the microscopic structure of an onion root tip, while other students are working at other activities.	1	2	3	4	5
1	2	3	4	5	15.	Involving students in microscope laboratory activities where they are using programmed learning materials that enable them to work at their own speed.	1	2	3	4	5
1	2	3	4	5	16.	Giving a class demonstration to illustrate the effect of certain drugs on the heart rate of a frog or other small animal.	1	2	3	4	5
1	2	3	4	5	17.	Giving a standardized biology test to the entire class.	1	2	3	4	5
1	2	3	4	5	18.	Participating in a science seminar where various unresolved biological issues are discussed.	1	2	3	4	5
1	2	3	4	5	19.	Having a small group of students report to the class about the results of a biology investigation in which they were involved.	1	2	3	4	5
1	2	3	4	5	20.	Providing within easy reach of every student a wealth of diversified materials which lend themselves to a variety of approaches to learning.	1	2	3	4	5
1	2	3	4	5	21.	Introducing a biological concept such as mitosis through the showing of a 16mm movie to the class.	1	2	3	4	5
1	2	3	4	5	22.	Involving several classes of biology students in a seed germination experiment which requires that each student's materials be stored in the room so that they may be reexamined after a period of four days.	1	2	3	4	5
1	2	3	4	5	23.	Meeting with small groups of students for the purpose of asking questions that will better allow the teacher to measure individual student progress.	1	2	3	4	5

Very Infrequently Used	Infrequently Used	Neutral	Frequently Used	Very Frequently Used		Very Unsuitable	Unsuitable	Neutral	Suitable	Very Suitable
1	2	3	4	5	24. Having a guest speaker present a forty-five minute lecture to a class on an important biological phenomenon.	1	2	3	4	5
1	2	3	4	5	25. Allowing individual students to display the results of their independent study projects.	1	2	3	4	5
1	2	3	4	5	26. Providing the opportunity for the students of several of your classes to work on biology experiments of their choice that may require several weeks to complete.	1	2	3	4	5
1	2	3	4	5	27. Having each member of the class prepare bacterial cultures that may be incubated at room temperature for future observation.	1	2	3	4	5
1	2	3	4	5	28. Having several groupings of six to eight students working on a different laboratory experiment, with a minimum of disturbance from other groups.	1	2	3	4	5
1	2	3	4	5	29. Dividing a class of about twenty-four students into two or three interest groups so that each may do a different laboratory experiment cooperatively and discuss the results among themselves.	1	2	3	4	5
1	2	3	4	5	30. Allowing students to move at their own discretion from a group activity to that of independent reading and research.	1	2	3	4	5

PLEASE CHECK TO SEE THAT YOU
HAVE RESPONDED TO EVERY ITEM.

DIRECTIONS: List here the recommendations you have for improving the instructional adequacy of your biology laboratory design.

____

____

____

____

QUESTIONNAIRE, PART II

DIRECTIONS: Please answer each of the following questions by checking the most appropriate box.

1. When was your biology laboratory constructed?

- ☐ before the year 1950
- ☐ 1950 - 1959
- ☐ 1960 or later

2. What type of biology curriculum materials are predominately being used in your classes? (Check only one)

- ☐ Biological Science: An Inquiry into Life (BSCS Yellow Version). Harcourt, Brace & World, Inc.
- ☐ Biological Science: Molecules to man (BSCS Blue Version).
- ☐ Biological Science: Patterns and Processes (BSCS). Holt, Rinehart, and Winston, Inc.
- ☐ BSCS Green Version: High School Biology. Rand McNally Company.
- ☐ Gregory, William H. and Edward H. Goldman. Biological Science for High School.
- ☐ Kimball, John W. Biology.
- ☐ Otto, James H. and Albert Toole. Modern Biology.
- ☐ Smith, Ella Thea. Exploring Biology: The Science of Living Things.
- ☐ Trump, Richard F. and David L. Fagle. Design for Life.
- ☐ Weinberg, Stanley L. Biology: An Inquiry into the Nature of Life.
- ☐ Other (Please Specify)______

____

3. What is your average number of biology students per class?

- ☐ 24 or less
- ☐ 25 - 32
- ☐ more than 32

4. How much college biology coursework have you had?

- ☐ less than 20 semester hours (27 quarter hours)
- ☐ biology minor or about 22 semester hours (30 quarter hours)
- ☐ biology major or at least (45 quarter hours)

5. How many years have you taught high school biology?

- ☐ 3 years or less
- ☐ more than 3 years

APPENDIX C

BIOLOGY LABORATORY VISITATION GUIDE

STATE OF MICHIGAN

DEPARTMENT OF EDUCATION

Lansing, Michigan 48902

IRA POLLEY
Superintendent of Public Instruction

May 12, 1969

Dear Principal:

Perhaps you have already returned the ESEA Title III Biology Facility Study questionnaire that was recently sent to you. If so, we want to thank you. However, if you have not mailed this questionnaire as yet, we request your assistance in this endeavor.

The enclosed questionnaire(s) should be given to the biology teacher whose name appears on the front cover of the questionnaire. Upon completion of the questionnaire, would you please assume the responsibility for returning it in the large enclosed envelope by May 19, 1969, to ESEA Title III, State Department of Education, Lansing, Michigan 48902.

Results of this study may contribute significantly to the planning of future school facilities. In order that these results will be as representative as possible, questionnaires should be returned from all schools that were selected to participate in the study.

If for any reason it is impossible for you to return the questionnaire, we would appreciate it if you would complete the enclosed postcard so that we can account for as many schools as possible.

Thank you for your cooperation.

Sincerely yours,

Don E. Goodson

Don E. Goodson, Coordinator
ESEA Title III

John T. Norman Jr.

John T. Norman Jr., Researcher
ESEA Title III Biology Facility Study

DEG:JTN:mjn
Enclosure

Biology Laboratory Visitation Guide

1. Ask the teachers the following questions:
   a. What is most needed to improve your biology teaching?
   b. How could the design of your biology facility have been improved?
   c. How adequate is your biology room design for:
      (1) small group instruction (2-15 students)
      (2) large group instruction (full class)
      (3) independent study (1)
2. Take out both the pre-survey and survey instruments, and ask the teacher to comment on their clarity.
3. Take photographs of the laboratory design, and check the measurements listed on their pre-survey instrument.