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THE EFFECT OF THERMAL ENVIRONMENT ON LEARNING, A PILOT STUDY.

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DESCRIPTORS- *AIR CONDITIONING, *ENVIRONMENTAL CRITERIA, *ENVIRONMENTAL RESEARCH, *LEARNING, *THERMAL ENVIRONMENT, AIR CONDITIONING EQUIPMENT, BUILDING DESIGN, CLIMATE CONTROL, CONTROLLED ENVIRONMENT, DESIGN NEEDS, EDUCATIONAL EXPERIMENTS, ENVIRONMENTAL INFLUENCES, HEATING, PHYSICAL ENVIRONMENT, TEMPERATURE, VENTILATION,

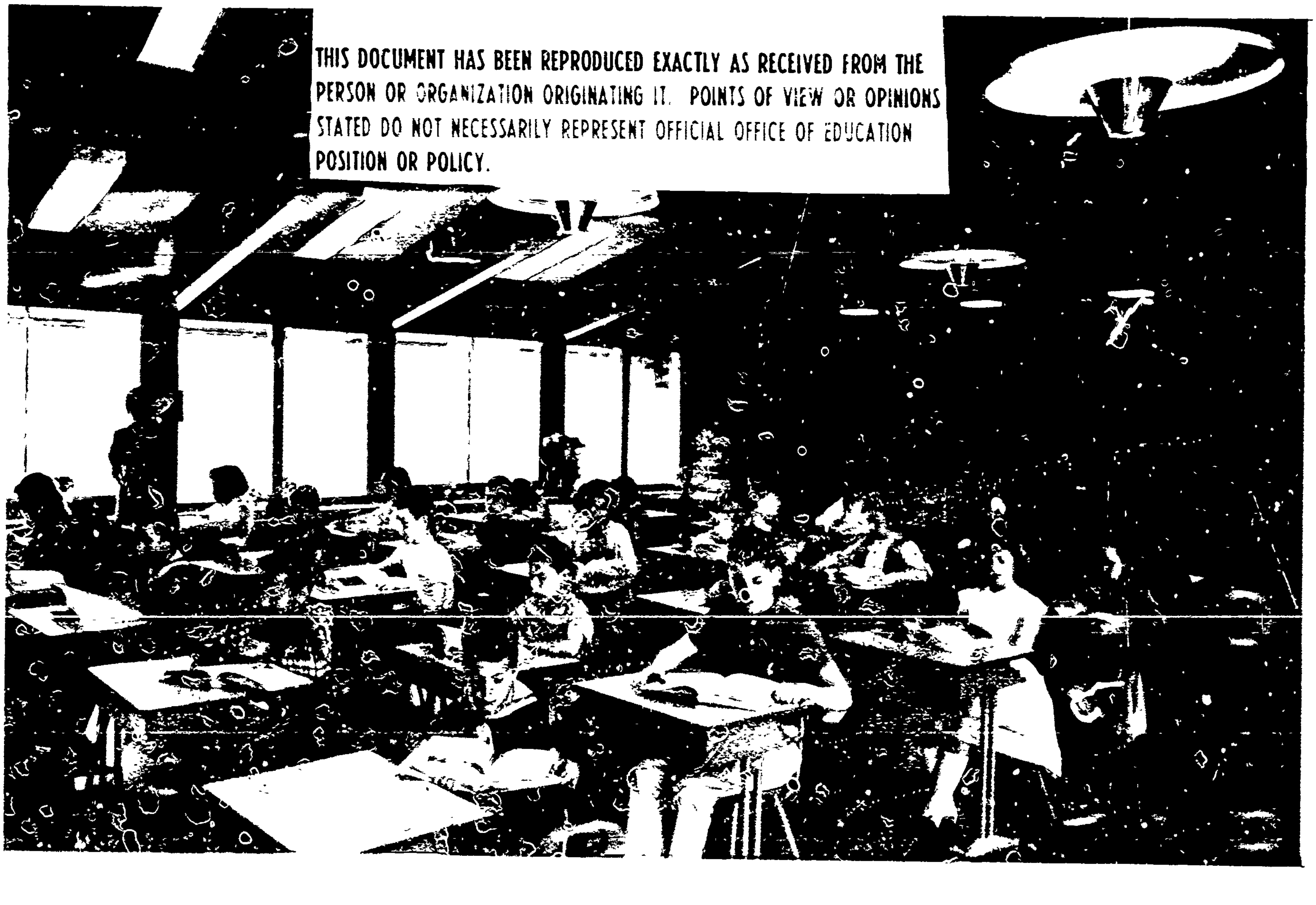
THIS IS A REPORT OF A FIRST PILOT STUDY WHICH PRECEDES A SERIES OF STUDIES BEING CONDUCTED BY THE IOWA CENTER FOR RESEARCH IN SCHOOL ADMINISTRATION AND LENNOX INDUSTRIES INC., MARSHALLTOWN, IOWA. IT IS A DIGEST OF A THESIS BY DR. CHARLES PECCOLO WHO SERVED AS RESEARCHER ON THIS FIRST STUDY. THE STUDY AIMED AT MEASURING THE EFFECTS OF THERMAL CONDITIONS ON THE LEARNING PROCESS AND ON LEARNING. THE CONCERN WAS TO STUDY THE MODEL ENVIRONMENT AS NOW ESTABLISHED BY RESEARCH AND WRITINGS AND TO COMPARE IT WITH A MARGINAL ENVIRONMENT. THE FOURTH GRADE SUBJECTS USED WERE TESTED IN VARIOUS FUNCTIONS UNDER TWO CONTRASTING THERMAL ENVIRONMENTS WHICH DIFFERED IN TEMPERATURE, HUMIDITY, AND AIR MOVEMENT. THE FIRST PIECE OF RESEARCH SHOWED DEFINITE BENEFITS FOR CHILDREN IN A CAREFULLY CONTROLLED THERMAL ENVIRONMENT. HOWEVER, SCHOOL BOARDS AND SUPERINTENDENTS SHOULD NOT EMBARK ON AMBITIOUS PROGRAMS TO AIR CONDITION SCHOOLS USING THIS RESEARCH AS THE SOLE BASIS FOR DOING SO. THIS RESEARCH ALONG WITH OTHER EVIDENCE CAN GIVE STRONG SUPPORT FOR CONSIDERATION OF THERMAL CONDITIONS IN PLANNING SCHOOLS. THIS DIGEST INCLUDES--(1) INTRODUCTION TO THE PROBLEM, (2) DEVELOPMENT OF THE THERMAL CONCEPT AND A REVIEW OF THE LITERATURE, (3) EXPERIMENTAL PROCEDURES AND CONDITIONS, (4) ANALYSIS OF THE RESULTS, AND (5) SUMMARY AND CONCLUSIONS. CHARTS, GRAPHS, AND TABLES ARE INCLUDED. (RK)

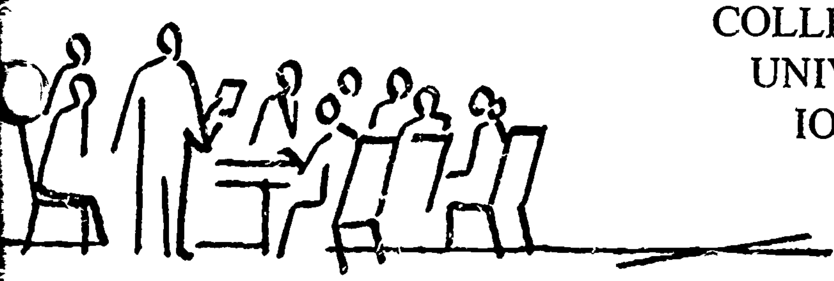
The Effect of Thermal Environment On Learning

A Pilot Study

A Digest

of a Ph.D. Dissertation by Charles Peccolo





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FOREWORD

This is the report of a first pilot study which precedes a series of studies being conducted by the *Iowa Center For Research In School Administration* and Lennox Industries Inc., Marshalltown, Iowa, led to a Ph. D. dissertation. This is a digest of a thesis by Dr. Charles Peccolo (Department of Education, Kansas State University), who served as researcher on this first study These studies are aimed at measuring the effects of the thermal conditions (a combination of temperature, humidity, and air movement) on the learning process and on learning.

In this study and in the next several to follow, no attempt was made or will be made to establish what the maximum environment should be. We are presently concerned with studying the model environment as now established by research and writings, and comparing it with a marginal environment (one in which the temperature, humidity and the air movement are all non-controlled). To establish how "bad" we could make the marginal environment we merely put instruments which measured heat, humidity and air movement in classrooms in the school building (an old one) from which the children came. We had readings from 12 different parts of the classroom every 60 seconds. The conditions in the classroom of the home school were such that it was hard to make the conditions in the experimental school room as bad.

The ideas for this research were developed by staff members in educational psychology and educational administration at the University of Iowa. The research team approached Lennox Industries Inc. with the idea, and the Lennox Industries Inc. agreed to cooperate in every way. Consequently Lennox Industries Inc. made available their model laboratory school building and all essential school equipment, the services of a research engineer, and all necessary standardized instruments for measuring thermal conditions.

Dr. William Eller, an educational psychologist and specialist in reading provided the necessary insights on how to measure learning, and ways to approach the problem. Dr. Eller is now Professor of Education at the University of Buffalo, Buffalo, New York. His part in this study and in the planning of future studies has been indispensable.

The Saydel Consolidated School District, P.O. Des Moines, Iowa was then approached by the researchers to determine whether they would be interested in cooperating in the research project. After an initial visit with the superintendent of schools, who was quick to see the possibilities, and subsequent visits with the administrative and teaching staff and the board of education, the Saydel school system joined the research team.

This research project required the cooperation of industry, a public school system, and university researchers. No one of these could have conducted this research alone. Special recognition must be given to Mr. Horace Oliver, Superintendent of the Saydel Public Schools, Mr. John Norris, President of Lennox Industries, Mr. Norman Rutgers, Marketing Manager of Lennox Industries, and Mr. Frank Nogel and Miss Elsie Grant, principals of the elementary schools involved. Mr. James Forsythe, Guidance Director, gave much aid in helping gather the data on the children involved when the experimental groups were selected. The four elementary school teachers, Lillie Elings, Annabelle Lane, Alma Smith and Marjery Fjelde, proved to be real masters in their profession. With their help the children were enthusiastic and curious participators.

A final word of warning should be offered. While this first piece of research shows definite benefits for children in a carefully controlled thermal environment no one expects school boards and superintendents to embark on ambitious programs to air condition schools using this research as the sole basis for doing so. When this research is used with other evidence available it does make a good case for careful attention to thermal conditions in school buildings which should be planned at the time of construction or extensive remodeling.

Willard R. Lane - Director
The Iowa Center For Research
In School Administration

ABBREVIATIONS

F-value — Represents a test statistic used to evaluate the statistical significance of observed differences. (Not to be confused with Fahrenheit [F]).

S.D. — Standard deviation.

S — Source.

df — Degrees of freedom.

ms — Mean square.

C — Control group in marginal environment.

E — Experimental group in model environment.

CHAPTER I — INTRODUCTION TO THE PROBLEM

Throughout the ages the problem of the thermal environment — keeping reasonably dry and warm (or cool) — has been closely related, in the mind of man, with the associated problems of food and of survival.

The phrase "thermal environment" is a relatively recent addition to the vocabulary of school administrators and teachers. However, the control of temperature, humidity, air-movement, air cleanliness and cold wall aspects of our environment which the word "thermal" implies, has long been man's concern. Primitive man was not able to control his thermal environment in any way so he was forced to adapt himself to the environment. Our present forms of shelter and clothing have evolved from this adaptation process. After the discovery of fire, man began to progress in his search for some type of positive control over the various elements of his thermal environment (28: 163). From the primitive control of external cold by heating of the air, thermal control has evolved through the ingenuity of heating and air-conditioning engineers to creating practically any indoor climate desired. Air can now be treated so as to control simultaneously its temperature, humidity, movement and cleanliness, and be distributed within a building in such a manner that the comfort, health, and efficiency of its occupants are kept at an optimum level.

The Problem

Control of the thermal environment has now reached an advanced stage. But to what extent are the thermal conditions being controlled in the classroom? What are the optimum thermal conditions needed for various kinds of learning? Is a certain type of environment more suitable to performance in skill subjects and yet another for memorization of facts? Are the established standards of comfort based on adult norms and utilized in classrooms the same for children and adults? Do public school educators recognize the many factors involved in determining and maintaining an adequate thermal environment? This study was an attempt to learn more about the area suggested by the previous questions.

More specifically the primary consideration of this study was to test the following hypothesis:

H: There is no difference in learning under recommended model conditions and marginal thermal conditions.

Historical Background and Need

Although it is true that there is no specific scientific research which establishes a definite relationship between learning and thermal environment, architects, physiologists, engineers and some educators have issued and written many positive statements concerning this relationship. They have probably taken their leads from the research findings of industry and business. The following paragraphs will illustrate the confident nature of the writings in the field of thermal environment.

In 1838, Samuel Lewis, the first State Superintendent of the Common Schools of Ohio, wrote on the need for proper ventilation by stating, "... If the house is dark and ill ventilated, the children may be expected to be dull, and careless and disorderly and perhaps unhealthy." (10)

Harmon (16) noted that for optimum learning and development the energy organizations (light, sound, and heat) of the classroom must be brought into a pattern which is in keeping with the possible realization of the full potentialities of children during the school phase of their development.

Four years later Harmon stated in very strong terms.

The heating and ventilation standards are largely concerned with keeping the child warm and comfortable with the underlying concepts of warmth and comfort derived from data secured by studying resting adults and the underlying concepts of education taken from the formal programs of the school of yesterday which looked upon learning as a passive absorption process (5:2).

Following the same line of thinking, Dean F. Smiley (23:18) in a group-session report to the American Association of School Administrators reported that teachers teach better and pupils learn better if they are provided with an atmospheric environment in which they can throw off their heat at a normal rate. Fatigue and nervous tension of both teachers and pupils are reduced by a pleasantly cool atmosphere.

There has been much written on the subject of thermal environment. The following excerpt from the Nation's Schools summarizes the bona fide research which will identify the thermal conditions conducive to learning:

> ... As yet little quantitative research has been done on the effect of changes in temperature and ventilation air on the child's alertness, attentiveness or comprehension. In recent years a growing body of statistical evidence indicates that temperature control, ventilation and other environmental factors materially affect the productivity, turnover, absenteeism and morale of office and industrial workers. ...
>
> Most school administrators and custodians have attempted to cope with the *individual* temperature preferences of teachers. Most are aware of the widely differing temperature requirements of active basketball players and their sedentary fans. A few are conscious of the surprising influence of difficult mental tasks on body temperature, particularly among elementary children. ...
>
> Such empirical evidence indicates some relationship between temperature and learning. But the school administrator requires more positive and objective criteria on which to base recommendations for expenditures on thermal control.
>
> Dr. Herrington holds that two aspects of thermal environment have not been recognized adequately. These are the relation of temperature and posture, and the effect of unfavorable thermal environments on the accuracy of human performance. He writes,
>
> "Even though the deviation from an ideal atmosphere is slight, if the tasks at hand or the pursuit of the interests and activities desired do not permit an adjustment of activity or posture consonant with the subtle change of postural tone which is thermally determined, the individual experiences distraction and a subjective sense of effort which is unpleasant and fatiguing."
>
> Granted that temperature has a measurable influence on efficiency and safety in various physical and mental tasks, one might well ask what specific temperature is best for the classroom or for any other school situation. ...
>
> While relatively little valid quantitative research has been done on the relationship of thermal environment to learning, the preponderance of available data on efficiency, safety and absenteeism in offices and industry leads to the conclusion that human performance falls off rapidly at temperatures above and below a relatively narrow comfort zone. ...
>
> Body cooling, through convection, evaporation and radiation, is the primary problem of human comfort. In fact, cooling, rather than heating, is the primary problem in all classroom heating, ventilating and air conditioning. (26: 86-90)

CHAPTER II — DEVELOPMENT OF THE THERMAL CONCEPT

A Review of Literature

Even though man has long recognized the effect of the atmosphere upon human health, comfort, and efficiency, it was only in the latter half of the eighteenth century that the first scientific theory, the carbon dioxide theory, was advanced to explain why such an influence existed. Since that time two other theories, the organic effluvia theory and the thermal concept of ventilation, have been given as explanations. (20: 1) These explanations have centered around the changes which Winslow and Herrington have shown to occur in a poorly ventilated space as a result of human occupancy: (1) a reduction in the oxygen content of the air; (2) an increase in the carbon dioxide content of the air; (3) an increase in the amount of partially oxidized organic matter to be found in the air; (4) an increase in the air temperature due to heat liberation of the human body; and (5) an increase in the humidity of the air caused by the moisture given off by the body. (28: 166-167)

Carbon Dioxide Theory

Early physiologists believed that a decrease in the oxygen supply in an inadequately ventilated room led to sensations of discomfort until the French chemist, Lavoisier, in 1777, presented the view that the presence of carbon dioxide, rather than the lack of oxygen, was the chief factor which led to deleterious effects. Claude Bernard in 1857 and Lewes in 1860 substantiated Lavoisier's views. The conclusion reached by these scientists was based on their observation of animals which were confined within a small enclosed area.

The carbon dioxide theory of ventilation was proven false by Pettenkofer, a nineteenth century experimental hygienist, as he demonstrated that the increase of carbon dioxide even in the worst ventilated room was not enough to bring about the toxic results which had been observed. Harmful physiological effects due either to an oxygen decrease or a carbon dioxide increase were found to be impossible in the worst ventilated rooms because the oxygen content was not found to decrease below 20% of the total content and the carbon dioxide content was not found to increase above 0.5% of the total content. These limits are much more conservative than those which have produced harmful physiological effects. (28: 167-168)

Organic Effluvia Theory

Not only did Pettenkofer help disprove the carbon dioxide theory but, in 1863, he advanced the belief that the harmful effects of poor ventilation were due to the presence of organic effluvia given off by the lungs and surfaces of the body. The organic substances which Pettenkofer maintained were responsible for harmful physiological effects were not easily identified. Thus Pettenkofer's theory, which was supported by the French physiologist, Brown Sequard, was not easily substantiated or rejected. Although Pettenkofer did not believe the presence of carbon dioxide in the air to be an important factor in poor ventilation, he proposed that carbon dioxide be utilized as an index to measure the unknown poisons, because the poisons and carbon dioxide were both waste products of the body and would be expected to vary together in amount produced. On the basis of the fact that the human individual produces about .06 cubic feet of carbon dioxide per hour, and that normal outdoor air contains 0.03% of carbon dioxide, advocates of the organic effluvia theory assumed that 0.06% of carbon dioxide in the atmosphere represented a permissible maximum figure. Thus, by dividing 0.6 cubic foot by .0006-.0003 (or .0003) the figure of 2000 cubic feet of air per person per hour was obtained as a desirable figure. Roughly, this corresponds to 30 cfm per person and on the equally unsound assumption that ventilation could not be effected without undesirable drafts at a rate above three air changes per hour (standards of minimum space allowances per person were found by dividing 2000 by three). A minimum outside air figure as well as a minimum space allowance per person for schools and other crowded places of assembly became the object of legislation in many states in the country. Some states still have laws based on the thirty cubic feet formula which was intended to rid enclosed areas of volatile substances emanating from human bodies. (28: 168-169)

Several proponents of the organic effluvia theory discussed and investigated their theory for several years, but none were ever able to prove that human beings emit any organic poisons into the air. Even though the theory was discredited, Winslow and Herrington reported that the resulting "well-meant but misguided standards cost millions of dollars in the aggregate and greatly retarded the development of adequate and efficient methods of air conditioning." (28: 169) Meredith also stated that "as relics of that generation, we still have a few fresh air fiends who believe they should live in a gale." (17: 551)

Thermal Concept of Ventilation

Doubt of the validity of the theory of organic effluvia was confirmed by Hermans of Amsterdam in 1883 when he was able to demonstrate that the air of a chamber containing only 15% of oxygen and as much as 2 to 4% of carbon dioxide was not toxic, and the ill effects experienced in crowded, inadequately ventilated rooms were not due to any chemical poisons but to heat and humidity. This new theory was accepted very slowly. (28: 169)

The thermal concept of ventilation received a great impetus from Flugge at Breslau in 1905 when he and his pupils performed the following experiments:

1. A subject was kept in a poorly ventilated room until the carbon dioxide content of the air became quite high and symptoms of discomfort became very great. Fresh, outside air was then piped to the subject's nostrils so that he was breathing fresh air while being surrounded by bad air. There was no relief from the symptoms of discomfort. Neither did any relief come when air of the same temperature and humidity as the room air, but with the correct amount of oxygen and carbon dioxide, was allowed to enter the room. Immediate relief came when an electric fan was started in the "bad air." (17)
2. Air with a low oxygen and high carbon dioxide content but of low temperature and low humidity was blown into a room containing foul air. The uncomfortable subject immediately began to experience greater comfort even though the oxygen and carbon dioxide content remained the same. Flugge concluded that cool, dry, moving air was needed rather than air containing an increased amount of oxygen and a decreased amount of carbon dioxide. He also concluded that the subject needed the air around his body. (17)
3. A subject was placed in a chamber with a content of 1.1% carbon dioxide, a temperature of 86F, and a relative humidity of 87%. Symptoms of discomfort were recorded and these symptoms were not relieved by breathing fresh air from outside the chamber through a tube. Complete relief came when the chamber was cooled to 63F, although the carbon dioxide content had risen to 1.6%. (28)
4. As a final experiment, the subject was taken into fresh air and asked to breathe bad air with a low oxygen and high carbon dioxide content through a tube. As long as the subject's body was in good air, he was able to breathe the air which contained a low percentage of oxygen and a high percentage of carbon dioxide without any ill effects. (17)

Flugge's work was soon confirmed by Haldane and his associates in England; by Benedict in the United States; and by the New York Commission on Ventilation. (17)

Winslow and Herrington state that the following conclusions reached 30 years before by Flugge and his associates have been proved correct. (28)

1. Chemical changes in the air produced by any type of gaseous excreta of human beings do not exercise any deleterious effect on the health of the occupants of the space involved. This is true for both normal and diseased subjects.
2. When detrimental health conditions such as fatigue, headache, dizziness, and nausea are observed in closed or

crowded rooms, these conditions are to be attributed entirely to inadequate heat loss.
3. The thermal properties of our atmospheric environment —temperature, moisture, air movement—are of far greater significance for our well-being than the chemical properties of the air.

As a result of the establishment of the thermal theory of ventilation, the New York Commission on Ventilation stated that "the major objective of ventilation, is, therefore, to remove the excess of heat given off by the human body to maintain an atmosphere which will be comfortably cool but not too cold." (20)

The Human Body as a Heat Producing Machine

Comparison of the human body with a machine is an analogy that is hard for some people to accept. Although the human body is extremely complex, it is subject to some of the same laws that govern the operation of simple machines. Significant progress in the field of physiology did not come until scientists were able to recognize that complete combustion of foodstuff in a bomb calorimeter and in the human body produced the same amount of heat. (28) This simple analogy assumes a role of importance in dealing with the complete picture of thermal control.

ROLE OF METABOLISM

The physiological process called "metabolism" provides for the energy needs of the body by the combustion of foods. All movement of living organisms along with the growth and repair of the various tissues require energy. Food is converted into energy in very much the same manner as fuel is burned in a machine. Like other forms of combustion, the process of metabolism liberates the energy contained in food, thus permitting work to be done and heat to be produced. There is a quantitative relationship between the intake of fuel, or food, and oxygen on the one hand and work done and heat liberated on the other. The human body is slightly more efficient than the steam engine by comparison, being able to convert 20% of the energy value of food into physical work as compared with 14% efficiency for the steam engine. (28)

In discussing the effects of various factors upon the metabolism rate for an individual, Best and Taylor (4: 611) enumerated the following physiological conditions which stimulate metabolism: (1) muscular work, (2) food, (3) a rise in body temperature, or (4) a fall in environmental temperature. They then go on to list the seven physiological conditions which influence the basal metabolic rate: (1) age and sex; (2) race and climate; (3) habits; (4) pregnancy; (5) diet; (6) variations in barometric pressures; (7) chemical substances. (4)

The physiological concept of heat production is of great concern to engineers who plan heating and ventilating systems for classroom use. The engineer must convert human heat production into a term which is compatible with his heat measurements. For such a measurement engineers use the term, British Thermal Unit (Btu). One Btu is roughly equivalent to the amount of heat released in burning a kitchen match.

It is interesting to note that the average sedentary adult or active school child generates as much heat as a 100 watt electric light bulb. Expressed in terms of Btu's a school child will produce from 260 to 560 Btuh (Btu per hour) during normal classrooom activities, depending on age, sex and the specific activity. Simple arithmetic enables one to estimate the heat production of 25 to 30 school children. A teacher walking slowly will dissipate from 400 to 500 Btuh's. Light factory work will raise the Btu output to around 750 Btuh and heavier factory work will cause a heat production of 1,000 to 1,450 Btuh. (26)

Body Temperature

The normal temperature of a healthy human body as determined by placing a thermometer in the mouth is around 98.6F. This reading refers to the temperature of the interior of the body as most skin temperatures are lower than 98.6F. The 98.6F figure represents a mean figure as there is a slight variation from this reading in the body temperature of some people and measurement proves that variations also occur in the same individual throughout the day. Kleitman (12) has demonstrated that man's bodily temperature regularly goes up and down each day on a fairly smooth, wave-like curve, with a peak or plateau in the middle of the waking period and a minimum at night during sleep.

From the discussion of metabolism the conclusion might be drawn that the body is capable of overheating itself. However, the body is also capable of cooling itself in such a way that a compensating effect for the overheating may be reached.

A large per cent of the body heat is lost through the skin, while most of the remainder is given off through the lungs. Specifically, heat is lost from the body through: (1) radiation, convection and conduction; (2) evaporation of water from the lungs and skin; (3) raising the inspired air to body temperature, and (4) urine and feces. (21: 720)

The means of losing heat from the body mentioned in the preceding paragraph can become effective only if three heat regulating functions of the body are functioning to bring heat to the skin's surface. These functions are :(1) vaso-motion in the skin; (2) sweat secretion; and (3) respiration. (21: 721-725)

Elements of the Thermal Environment

The Housing Commission of the Health Organization of the League of Nations (11:505) and the National Council on School House Construction (19:170) urged that, in careful studies of thermal influences upon the body, a knowledge of the four factors of air temperature, air movement, relative humidity and mean radiant temperature is needed.

Winslow and Herrington stated that ideal thermal comfort is experienced when three conditions are maintained: A skin temperature of 91.5F; a minimum heat change in the body tissues; and a minimum evaporative rate. (28) The following discussion of the thermal factors that are partially responsible either for the presence or absence of these conditions is considered essential to a better understanding of the subject.

AIR TEMPERATURE

Because body functions produce from 250 Btuh at rest to over 1200 Btuh at hard physical labor, the temperature of the air must be such that these quantities of heat may be lost to the surroundings if body temperature is to remain constant. This fact probably prompted the British physiologist, Thomas Bedford, to state, "A room should be as cool as is compatible with comfort." (3: 127)

Even though all factors are interwoven, the effect of air temperature on human activity is perhaps the most important single thermal factor. The importance of air temperature was stressed by Dr. Herrington when he declared, "Ambient temperature alone has been found to have a large effect on the precision of skilled muscular tasks as well as the execution of practiced logic." (9: 64)

American dress customs are somewhat standardized; however, the fact remains that different people dress differently. Because of dress differences, differences in metabolic rates, and reactions of different people to various air temperatures, these differences occur. There are sometimes differences of opinion among the occupants of a room concerning desirable temperatures. (30: 72) In a classroom this situation is complicated because older people generally prefer warmer rooms, thus often creating an overheated situation for the children.

Taking the above factors into consideration, one might safely say that optimum air temperatures, or any other thermal factor, depend upon the activity experienced in a given space.

MEAN RADIANT TEMPERATURE

Every classroom has two temperatures—the air temperature, and the mean temperature of the surrounding surfaces and objects in proportion to the position in which they are located in reference to the body's surface. If excessive air movement is absent, air temperature and mean radiant temperature have nearly the same effect on comfort. (2: 66) The 1959 *Heating, Ventilating, Air Conditioning Guide* points out that different authorities give 0.3 to 1 degree increase of room temperature to compensate for one degree depression of the mean radiant temperature. (2) This would indicate that for every degree the radiant temperature is raised or lowered above or below the air temperature, an opposite air temperature adjustment must be made to produce equal sensations of comfort.

RELATIVE HUMIDITY

Both extremes of relative humidity of the air are capable of influencing comfort. Since people lose about one pound of moisture per hour by perspiration while at rest and much more while engaged in strenuous activities, skin clamminess must be prevented by evaporation to air dry enough to pick up the moisture rapidly, but not so rapidly that the skin, nostrils, and lips re left dry.

Henry Wright (31: 209) and Winslow and Herrington (29: 187-188) are among those who dispute the importance of relative humidity on the comfort of the heated rooms in the wintertime. The three agree that relative humidity has a great influence on comfort in hot, humid atmospheres but stated that the influence is practically non-existent at otherwise favorable temperature conditions. Wright stated: "The humidity problem is actually physical rather than physiological, and a matter of protecting the building more than one of protecting the pupils." (31: 209) Despite the minimum influence of humidity at comfortable temperature levels, an optimum relative humidity range does seem to exist.

AIR MOVEMENT

Most heating and ventilating authorities are in agreement that some air movement is needed in the classroom. Herrington attached more importance to air movement than to relative humidity and considered air movement an important factor in comparing radiant and convective heating systems. (8: 372)

Herrick pointed out that air movement is necessary by stating:

> The human body will not be comfortable in a pool of stagnant air. Air movement will prevent pockets of excessive humidity, equalize temperature throughout a given space, and remove odors and stale air. (7: 442)

Under most classroom conditions, air in the classroom is in motion. Reasons for air motion include natural differences in temperature, infiltration, ventilation, motion of people, and the heating and cooling systems.

OTHER FACTORS

Some other factors that may influence the thermal environment of the classroom are: (a) microclimatology, (b) solar control, fenestration, illumination, and insulation, and (c) classroom size, occupancy, and socio-economic status of the occupants. (26: 91)

Effects of an Inadequate Thermal Environment

The New York Commission on Ventilation in studies on heating and ventilation found that overheating was responsible for two physiological ills. Extreme overheating was found to increase body temperature, pulse rate, respiration and metabolism. A room temperature as low as 75F with 50% relative humidity and no air movement was found to cause a definite increase in body temperature and pulse rate. The second ill, an anemic condition of the nasal mucosa which makes it highly receptive to microbic infection, was shown to be caused by exposure to high temperature followed by exposure to chill. (20: 43-45)

McConnell and Yaglou (15: 167) reported experiments done in Pittsburg in which effective temperature was varied. The increase in pulse rate almost doubled as the effective temperature rose from 60F to 80F and total work in foot pounds decreased almost 10%. Above 85F effective temperature the heart rate increased and total work in foot pounds decreased rapidly.

Dr. Frances Ilg, of the Gesell Institute of Child Development, has observed the instability of internal temperature of children in first grade (ages 5½ to 6) and in the sixth grade (about 11). Dr. Ilg says:

> Everything is rapidly shifting, blowing hot and cold, expressing extremes. In the first grade you can observe this with the sudden pulling off of sweaters especially with the girls during an arithmetic period. I have known their body temperature to rise to 102F during the intense intellectual demands of the arithmetic process. . . . (16:190)

Benedict and Talbot (8:369) compared the basal metabolic rate of children from kindergarten through high school with that of adults who were present in the same environment. They found a wide range of resting heat production in school populations; this justifies some research on the regulation of heating systems They found that the livelier activity of the kindergarten child at 67F produces the same sensory and physiological effect for the child as does 75F for the older person. They maintain that while this is an extreme comparison it is rare indeed that the comfort levels of the student and the teacher are not separated by at least 5F.

Kugelmass, (5: 31) working with the caloric requirements of children and adults, maintains that in a thermal environment regulated for adults not only is the child more subject to erratic chemical body temperature control because of the immaturity and imperfection of his regulatory mechanisms, but by virtue of his proportionately smaller mass area, he is denied the opportunity to lose a corresponding amount of heat through skin surface channels.

Kleitman (13: 211-234) maintains that rapport with school tasks goes up as the internal temperature goes up above the average but within the daily differences range. The converse is also true.

Discomfort and health deficiencies due to an inadequate thermal environment are accompanied by a loss in work efficiency. Considerable data regarding accidents and errors in heavy manual work, light assembly work and complex mental tasks are available. So many of the data relate to mine workers and textile workers that they are not elaborated upon herein.

Research (3: 11-15) has shown that heavy tasks such as coal mining are done most efficiently in situations where the temperature is held around 60F and that accidents increase two to three fold when the temperature approaches 80F.

Light assembly work seems to be more void of accidents at 67F while accidents increase both above and below that point. Accidents seem to be related to the involuntary postural conditions created both at the higher and lower temperature levels.

Most research in connection with skilled work or complex mental tasks has been done with wireless code reception, typing and office work. Most of these data are in terms of effective temperature readings, readings which take into consideration both dry and wet bulb headings. All data show that errors increase as temperature stress increases.

RELATED STUDIES

A great amount of work has been done in the production of literature relating to the thermal environment. A large portion of the literature is filled with individual opinions, however, and there seems to be a lack of agreement among workers in the various fields which have an interest in control of the thermal environment.

Some research has been done regarding the influence of the classroom environment on learning, but that research has quite often been characterized by the use of adult-aged subjects with the data obtained being applied to children of school age. At the present time many manufacturers of heating and ventilating equipment are conducting experimental studies concerned with the effects of various types of heating and ventilating equipment on the classroom environment.

One of the first organizations in the United States to conduct studies in the area of classroom thermal control was the New York Commission on Ventilation. (20: V-VI)

The experimental work was conducted between 1913 and 1917 but was not published until 1923. Two types of studies were conducted during this period with one type involving studies of physiological and psychological reactions to various atmospheric conditions, which were produced in the experimental chambers at the City College and the other type involving observation of the effect of various atmospheric conditions on school children in actual classroom situations.

Some of the results of the City College studies were:
1. The conclusion that overheating is the primary factor in bad ventilation was confirmed.
2. With a given thermal condition, the presence of chemical vitiation produced no physiological or psychological reaction except a slight decrease in physical work and in appetite.
3. Overheating produced (a) fundamental physiological changes, (b) marked decrease in physical work performed and (c) abnormal reactions to the mucous membranes of the nose and throat which interfered with their adaptation to outdoor atmospheres.
4. High moisture content aggravated the effect of high atmospheric temperatures, but low humidities had no noticeable influence and could not be subjectively detected by the subject exposed to them. (20: 16-17)

The studies conducted in actual classroom situations produced the following conclusions:
1. The ventilation of classrooms by windows alone was found to be highly unsatisfactory.
2. A system of window-gravity ventilation with air admitted over slanted window boards and tempered by radiation below the windows and with gravity exhaust ducts for removing vitiated air from near the ceiling proved highly satisfactory.
3. The conditions necessary for satisfactory utilization of the window-gravity system of ventilation were considered to be as follows:
   a) Radiators should be located beneath the windows and should extend the full width of the windows.
   b) Deflecting boards should be placed at the bottom of the windows which open from the bottom.
   c) Two window shades should be attached to each window frame, one to be pulled upward and the other downward.
   d) Exhaust ducts should be placed on the wall opposite the windows.
   e) Classrooms should not be overcrowded.
   f) A large thermometer with 68F clearly marked should be displayed in a prominent position on the teacher's desk.
4. Careful observations in the classroom showed no difference whatever in the health, physical condition, or mental performance of pupils in unhumidified as compared with humidified rooms.
5. Recirculation of classroom air had no harmful effect upon the health of the pupils, but elimination of objectionable odors was difficult.
6. The choice for suitable school ventilation method to be between plenum ventilation and window gravity ventilation. The atmosphere, as measured by subjective impressions, was more agreeable in a room ventilated by the window-gravity system. Respiratory illnesses were also less pronounced in rooms employing window-gravity ventilation. (20: 17-22)

During the years 1926 to 1929, the Commission investigated, under actual classroom conditions, school ventilation, relation of atmospheric temperature to health and efficiency, and the hygienic values of various systems of school ventilation. Some of the conclusions derived from the latter series of studies were:

1. The major objective of classroom ventilation is the provision of such atmospheric conditions as will facilitate the elimination of heat from the body surface without the production of objectionable drafts. An objective of a minor nature should be the elimination of unwanted body odors by sufficient air change.
2. Comfort, efficiency, and resistance against disease are sustained by avoiding overheating.
3. Desirable thermal conditions may be obtained by (a) plenum ventilation, (b) by local unit ventilation or (3) window-gravity ventilation with window-gravity ventilation found to be the most comfortable and economical.
4. The physiological effects of radiation and convection of heat and of vertical variation in temperature need further investigation.
5. Laws requiring a supply of thirty cubic feet of air per minute per pupil have no justification and should be replaced by laws which outline the major objective of school ventilation. (20: 65-67)

In 1957, Shupp (22) set up a proposed study on the effects of air-conditioning on classroom learning activities. Shupp was concerned primarily with reviewing related literature and outlining a plan for actually determining the effects of air-conditioning on learning. After reviewing related literature, Shupp set up a study which included the description of the equipment needed, the method of selecting subjects, the selection of school tasks, the method, and the testing procedure to be utilized in the study. The proposed study has never been carried out.

Mincy (18) studied the factors involved in establishing a satisfactory thermal environment in the classroom and concluded that although control of humidity and air movement is essential, the control of air temperature is the critical issue in maintaining an optimum thermal environment.

The purpose of a Texas study by Captain Nolan (21) was to determine the effect of temperature on learning. He concluded that the physical discomfort resulting from high temperature conditions does have an adverse influence on academic learning.

A three year project by the Pinellas County School System (25) in Florida in cooperation with the United States Office of Education entitled "An Evaluation of Climate Control As a Contributing Factor To an Effective Education Program," is now underway. One of the phases of this project is a comparison of gains in achievement in mathematics, science, social studies and language arts during the 1961 summer session and the 1961-62 academic year.

CHAPTER III — EXPERIMENTAL PROCEDURES AND CONDITIONS

The object of this research was to investigate the effect of thermal environment upon mental efficiency and learning. For this purpose the subjects used were tested in various functions under two contrasting thermal environments which differed in temperature, humidity and air movement.

The evidence from the research literature and from the writer's experience suggested the desirability of a rigorously controlled human experiment to determine the effect of temperature, humidity and air movement upon learning ability. While it is recognized that other physical factors in the school classroom environment play a part in affecting learning ability, it seemed wise to put this experiment upon as specific a basis as possible by confining the inquiry to the thermal environment factors.

It was desirable to have elementary school students as subjects (students in the fourth grade) because they are old enough to accept responsibility and follow directions. Yet they are young enough that they are not sufficiently concerned with the thermal conditions to want to alter them. It was necessary to secure the cooperation of a school district with a large enough student population. It was held desirable to have subjects matched in as many respects as possible.

During the period of the experiment the two groups would receive exactly the same treatment, perform the same tasks at the same time of day, with the exception that one group would be occupying a classroom with a model thermal environment and the other group a classroom with a marginal thermal environment. To equate motivational factors among the children no child would know whether he would occupy the classroom with the model or marginal thermal environment. During the inquiry the children of both groups would receive the same periodic training in a number of different tasks. A comparison could then be made between the amount of improvement shown by the control group of children who were exposed to the marginal thermal environment and by the experimental group in the model thermal environment.

Selection of Schools and Students

For the purpose of carrying out the proposed plan the investigators were fortunate in securing the cooperation of the Lennox Industries, Inc., and the Saydel School District in Des Moines, Iowa.

LENNOX RESEARCH SCHOOL

In 1956, Lennox Industries Inc. with headquarters in Marshalltown, Iowa constructed the Lennox Research School in Des Moines for the express purpose of probing new, improved and economical methods of heating, ventilating and air-conditioning school classrooms. The school is located on a separate four-acre plot which has been attractively landscaped. The architectural firm of Perkins and Will, Chicago, Illinois, designed the building with R. C. Oversat, AIA, doing the actual design work. The exterior of the school is finished in brick, glass and a small amount of wood (See Figure 1).

FIGURE 1 Lennox Research School

One classroom was designed for elementary grade children and the other for junior high school children. The complete two-classroom project was intended to represent typical classroom construction and be within the budget of the average school district. The school was designed to represent two typical classrooms and not to portray a perfect design.

Figure 2 is a floor plan of the school. The elementary classroom (No. 2) is 930 square feet and is equipped with book-shelf ducts for ample book storage. At five locations in the classroom floor thermocouples have been located to provide a means of recording temperatures at any desired height. Automatic control of heating, ventilating and air-conditioning is provided.

The junior high classroom (No. 1) is eighteen inches below the level of the elementary classroom (No. 2) although it has water heating and cooling equipment, electrical panels and various instruments for testing and measuring.

Complete facilities have been provided for automatically recording temperature at desired heights; for checking movement and direction of air; and for recording humidity.

As is evident from the description, this school is actually a research laboratory completely equipped to allow a normal teaching program to be carried out as a part of a research program to determine the effects of various conditions on the student occupants.

SAYDEL SCHOOL DISTRICT

At the time of the experiment (March 19 to May 1, 1962) the Saydel School District had a school population of 2,393. Of

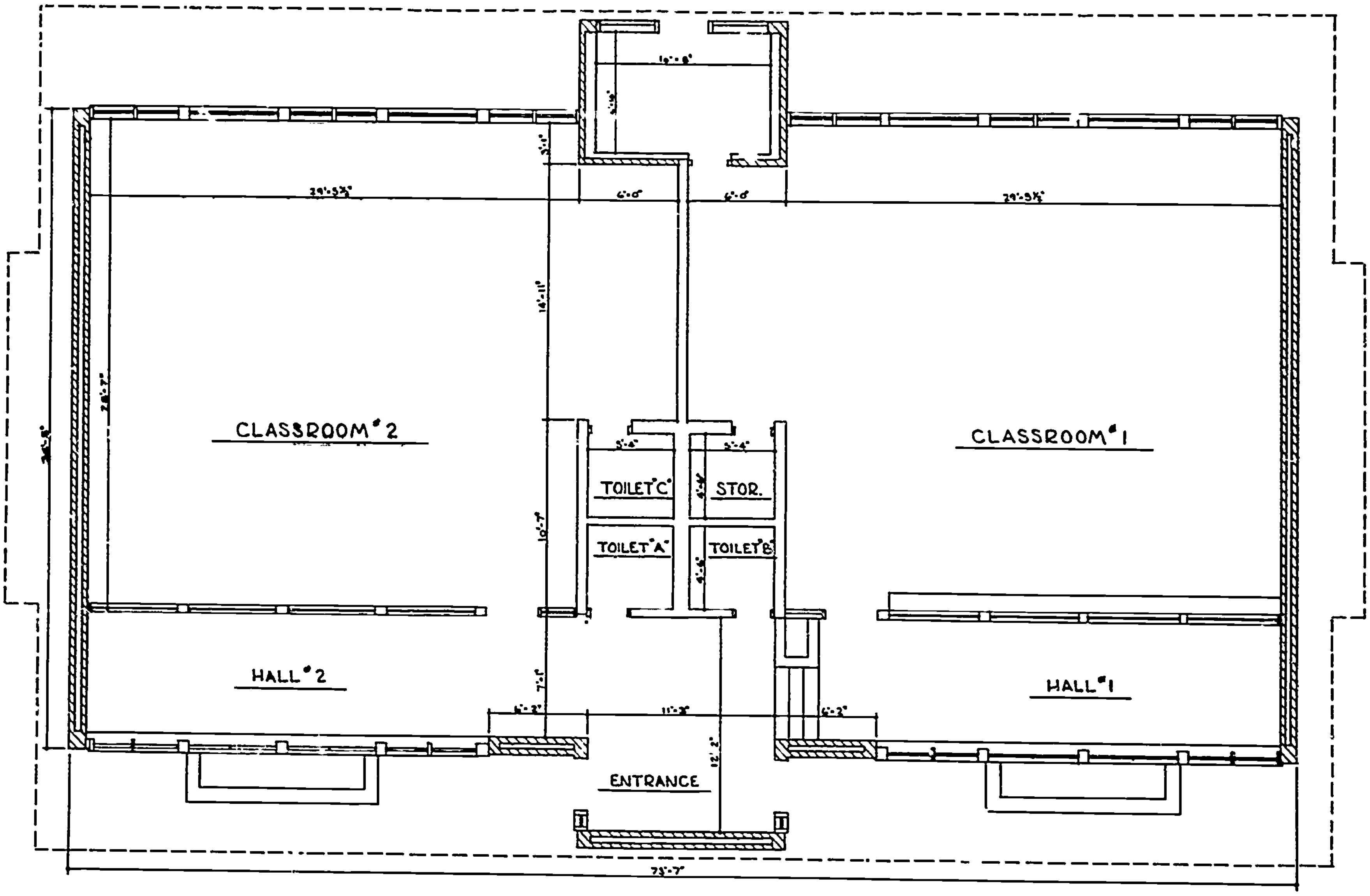

FIGURE 2 Floor Plan of Lennox Research School

the same number of square feet of floor area. This was done by the architect to provide a greater floor to ceiling dimension for a larger occupant of a typical junior high classroom. A system of wall ducts in place of book shelf ducts was used in this room. Normally this age student changes classes every hour and the book storage requirement is greatly minimized. However, portable book-shelves on casters are located in the room for the storage of books if so desired. This room also has its five separate thermocouple locations and separate automatic controls for heating, ventilating and air conditioning.

At the rear of the school and located between the two classrooms is a heater room. This area houses the gas-fired heater, these, 1,894 were in elementary school and 499 in secondary schools. These students were housed in six elementary schools, one junior high school and one senior high school. In addition the district operates a kindergarten and a school for the trainable mentally handicapped. All students in the district are transported and the district operates a hot lunch program in each school.

At a joint meeting of representatives of the state University of Iowa, officials of Lennox Industries Inc. the Saydel administrative staff, and cooperating fourth grade teachers, all major arrangements were made to carry out the experiment. The researcher met with the principals and teachers of the schools involved after the general meeting in order to work out the final details.

CANARY LAKE SCHOOL

The subjects for the experiment were the two fourth grades in the Canary Lake School. The two classes were heterogenously grouped so that both classes had covered the same amount of instructional material at the time the experiment began. There were 29 students enrolled in one class and 28 students in the other. It was possible to select 22 matched pairs of students from the classes.

The two classes had occupied similar rooms, the same size, adjacent to each other, on the same side of the building and on the same floor since the beginning of school. The thermal conditions in the two rooms were the same so that the children had been exposed to similar thermal environments since the beginning of the school year.

The school was heated by a central warm air heating system and the heated air was discharged into the rooms through a grill located at a height of seven feet on an interior wall. The heated air was discharged at a rate of 400 cfm. The velocity of the air across the desks was from 5 to 10 feet per minute depending upon the location of the desk in the room.

The rooms were ventilated by the raising or lowering of windows and by opening the door. If the door was not opened there was a discharge grill (11 inches by 23 inches) with 20 louvers to let air into the halls. This provided an open free area of 120 square inches for letting air into the halls. The opening between the bottom of the door and the floor provided an additional 13-½ square inches of free area.

Experiment Duplicated

The experiment was repeated, the only differences in procedures being:

(1) A second set of fourth grade children. (The 22 matched pairs who initially participated in the experiment are characterized as *low* only because the mean achievement score for the group was lower than the mean achievement score for the 22 matched pairs, labeled *high*, who were used to duplicate the experiment. (See Tables I and II).

(2) This second set occupied opposite rooms at the research school from the first set.

(3) The morning tasks were changed to afternoon and afternoon tasks changed to morning.

SAYLOR CENTER SCHOOL

The second group of subjects came from the two fourth grades from the Saylor Center School. The two classes were heterogenously grouped and both classes had covered the same amount of instructional material at the time of the experiment. There were 27 students in one class and 26 students in the other. Twenty-two match pairs were selected from the classes.

The thermal conditions in both rooms were the same as those described for the Canary Lake School.

Equating the Groups

The children were aware that an experiment was in progress and were eager to participate in a scientific undertaking. They were given as full an explanation of the investigation as could be understood by them. However, they were not told which group would occupy the room with model thermal conditions. The explanation stressed the possible importance to education, the need for rigorous accuracy and the possible benefits of the results to the welfare of other school children. Their appreciation of the situation was shown by the fact that the test periods were characterized by rapt attention and great effort on the part of every subject. Frequently, while the experiment was in progress, one child or anther would ask for information on the findings and question the teacher about opening the door or moving about the room. Members of the classes and the teachers gave or sent letters of appreciation for having been selected to participate in the experiment. Although every child in the fourth grade classes of both schools was included in the experimental routine, only the information on 44 matched pairs is reported.

On the basis of the preliminary data, the children were separated into two equal groups, the personnel of one being as nearly like the personnel of the other as possible. The first consideration upon which the assignments to the groups were made was their achievement as measured by their composite score on the Iowa Test of Basic Skills (I. T. B. S.), taken the latter part of January, 1962.

All subjects were ranked in sequence according to test scores and paired in order. They were then assigned to the groups, one member of each pair to the control group and the other to the experimental group.

Because the composite Basic Skills Test scores were closely similar it was possible by shifting equal-scoring children from one group to the other to obtain a good balance between the groups in other factors and to allow as many as possible to remain with their own teachers.

After the children had been assigned in secret to two quite well-matched groups the principal of the school determined which group would occupy the control room and which would occupy the experimental room.

That the achievement and ability to learn was very nearly equal in the groups at the beginning of the investigation is attested by their scores on the standardized measures used. (Iowa Test of Basic Skills—Composite Score and Arithmetic Composite and Otis Quick-Scoring Mental Ability Tests, Beta, Form A)

By referring to the data in Tables I and II the similarity of the two groups can be verified.

The overall level of achievement and intelligence for both groups was exactly the same (See mean I.T.B.S. score and mean Otis Intelligence score in Tables I and II). The mean Arithmetic Composite score for the control was slightly higher than that of the experimental group.

How these factors were equated by proportioning them as equally as possible between the matched groups can be seen in Tables I and II. Further reference to the tables will reveal the similarity of the standard deviations for each of the preliminary measures, indicating that the variation in the two groups was very much the same.

For the control and experimental groups respectively, the mean I. T. B. S. Composite scores were 4.6 and 4.6 with standard deviations of .83 and .81; the mean Quotient on the Otis Quick-Scoring Mental Ability, Beta, Form A, were 110 and 110 with standard deviations of 13.8 and 10.8; the mean I. T. B. S. Arithmetic Composite scores were 4.4 and 4.2 with standard deviations of .82 and .73; the mean ages were 10 and 10 with standard deviations of .30 and .33; the mean heights were 54 and 54 inches with standard deviations of 2.5 and 2.4; the mean weights were 73 and 73 with standard deviations of 13.2 and 12.9. The control group had 22 boys and 22 girls, and the experimental group had 21 boys and 23 girls.

Program of Tasks

Several considerations governed the choice of material to be utilized in the measurement of specific learning by the children. It was held desirable to tap as wide a range of types of activity as possible. It was necessary, however, to use for the tasks, material of the kind and level occurring in public school curricula and tests that called for fairly short, quick reaction. It was important, of course, to use for every task such material as would lend itself to objective measurement. Further it was distinctly desirable, since the experiment was to deal with healthy, active, energetic boys and girls for a three weeks period. that all tasks should hold as much intrinsic interest as possible and be so well within the range of the children's ability as to call out their best efforts.

The program of regularly practiced tasks consisted of 10 paper and pencil activities performed in the Lennox Research School classrooms. The tasks were intended to measure three types of activities which take place in the classroom:

(1) Clerical and Routine Activities—The tasks selected to measure gain in this type of an activity were (a) Checking Names, (b) Checking Numbers, (c) Finding and Canceling Letters, and (d) Finding and Canceling Digits. Every task was performed once a week for three weeks.

TABLE I
GENERAL DATA FOR CONTROL GROUP
(**Low** Students 1-22; **High** Students 23-44)

Student	Achievement Score Comp.	Achievement Score Arith. C.	I. Q. Score	Age	Height	Weight	Father's Occupation	Sex
1	2.8	2.8	89	10	53	67	Truck Driver	M
2	2.9	3.4	98	10	54	74	Carpenter	M
3	3.0	3.3	91	11	57	77	Painter	M
4	3.0	3.2	88	10	57	86	Carpenter	M
5	3.4	3.0	105	10	54	73	Laborer	F
6	3.6	4.2	101	10	57	91	Trucker	M
7	3.8	3.2	103	10	53	60	Checker	M
8	3.8	3.2	114	10	54	68	Supervisor	F
9	3.9	4.2	105	10	54	70	Salesman	M
10	4.1	3.9	104	10	53	74	Sheet Metal	M
11	4.3	3.9	108	10	53	64	Inspector	M
12	4.4	3.6	90	10	56	76	Proprietor	M
13	4.4	4.6	114	10	52	63	Machinist	F
14	4.5	4.8	109	10	51	62	Foreman	F
15	4.7	4.6	105	10	53	63	Plumber	F
16	4.7	5.0	104	10	52	80	Mechanic	M
17	4.8	4.6	125	10	54	71	Checker	F
18	5.0	5.1	127	10	50	54	Truck Driver	F
19	5.0	4.7	115	10	60	87	Mechanic	F
20	5.1	4.0	117	10	56	87	Supervisor	F
21	5.8	4.7	140	10	49	50	Bookkeeper	F
22	6.4	5.6	131	10	51	68	Proprietor	F
Students 1-22								
Sum	93.4	89.6	2383	221	1183	1565		M-11
Mean	4.2	4.1	108	10	54	71		F-11
S. D.	.92	.76	13.54	0.0	2.5	10.5		
23	3.8	3.6	85	11	54	72	Supervisor	M
24	4.1	4.0	114	10	52	76	Roofer	F
25	4.4	4.3	111	10	52	66	Army	M
26	4.4	4.3	122	10	59	100	Carpenter	M
27	4.4	4.8	105	10	55	86	Machinist	F
28	4.6	5.3	112	11	51	60	Laborer	M
29	4.7	4.6	112	10	54	66	Engineer	F
30	4.7	3.9	104	10	52	70	Salesman	F
31	4.7	4.8	105	10	56	75	Salesman	M
32	4.8	4.0	112	10	54	55	Mechanic	M
33	4.8	5.2	107	10	58	82	Salesman	M
34	4.9	4.2	107	10	55	75	Salesman	F
35	5.0	4.4	114	11	57	110	Salesman	M
36	5.1	4.4	133	10	53	69	Driver	F
37	5.2	5.0	143	10	55	71	Laborer	F
38	5.2	5.0	96	10	53	65	Mechanic	F
39	5.3	5.2	141	10	55	71	Car Dealer	F
40	5.4	5.6	96	10	58	103	Salesman	F
41	5.6	5.8	122	10	51	54	Warehouseman	M
42	5.8	6.2	112	10	58	100	Realtor	M
43	5.8	5.6	114	10	52	65	Proprietor	F
44	6.0	5.9	92	10	58	69	Mechanic	M
Students 23-44								
Sum	108.7	106.3	2459	223	1202	1660		M-11
Mean	4.9	4.8	112	10	54	75		F-11
S. D.	.55	.70	14.13	.37	2.57	15.07		
Overall Control Group								
Sum	202.1	195.7	4842	444	2385	3225		M-22
Mean	4.6	4.4	110	10	54	73		F-22
S. D.	.83	.82	13.8	.30	2.54	13.2		

TABLE II
GENERAL DATA FOR EXPERIMENTAL GROUP
(**Low** Students 1-22; **High** Students 23-44)

Student	Achievement Score Comp.	Achievement Score Arith. C.	I. Q. Score	Age	Height	Weight	Father's Occupation	Sex
1	2.8	2.7	103	10	56	64	Bulldozer Op.	M
2	2.9	2.5	103	10	54	74	Sign Painter	M
3	3.0	3.2	97	10	54	69	Proprietor	M
4	3.1	3.6	98	10	50	55	Carpenter	M
5	3.6	2.8	103	10	53	61	Painter	M
6	3.6	4.2	105	10	54	86	Const. Driver	M
7	3.8	3.6	105	10	59	110	Inspector	F
8	3.8	3.2	105	10	49	54	Inspector	F
9	4.1	4.5	103	11	53	64	Salesman	M
10	4.2	4.6	105	10	51	83	Machinist	F
11	4.2	4.2	108	10	53	62	Inspector	M
12	4.4	3.7	90	10	54	62	Proprietor	F
13	4.4	3.8	98	11	53	64	Machinist	F
14	4.6	3.6	109	10	53	60	Salesman	F
15	4.8	4.8	112	10	55	90	Warehouseman	M
16	4.9	3.6	109	10	56	75	Painter	M
17	4.9	4.6	111	10	54	65	Civil Service	F
18	4.9	5.0	115	10	52	68	Driver	F
19	5.0	5.1	110	11	54	85	Laborer	F
20	5.2	4.6	111	10	53	69	Teacher	F
21	5.6	4.6	141	10	56	82	Salesman	M
22	5.8	5.2	137	10	54	57	Press Operator	F
Students 1-22								
Sum	93.6	87.7	2378	223	1180	1559		M-10
Mean	4.2	4.0	108	10	54	71		F-12
S. D.	.84	.78	11.32	.37	2.11	13.34		
23	3.8	3.8	108	10	52	61	Foreman	M
24	3.9	4.0	101	10	54	74	Carpenter	M
25	4.3	4.6	100	10	54	72	Plumber	F
26	4.3	4.2	109	11	58	88	Repairman	M
27	4.4	4.4	103	10	51	70	Salesman	M
28	4.6	4.5	111	11	56	73	Trucker	F
29	4.6	4.9	100	10	54	72	Draftsman	F
30	4.7	4.0	119	10	54	91	Salesman	F
31	4.8	3.4	108	10	56	76	Manager	M
32	4.8	4.6	112	10	55	67	Repairman	F
33	4.8	4.2	131	10	53	67	Supervisor	M
34	4.9	4.0	108	10	56	86	Plasterer	F
35	4.9	4.2	114	10	50	54	Salesman	M
36	5.0	4.4	124	10	56	65	Manager	M
37	5.2	4.4	116	10	52	65	Disabled	F
38	5.3	5.1	119	10	62	108	Mechanic	F
39	5.5	4.6	126	10	54	63	Manager	M
40	5.6	5.2	129	10	55	78	Repairman	F
41	5.7	5.3	119	10	55	71	Warehouseman	M
42	5.7	5.0	111	10	55	82	Serviceman	F
43	5.8	4.7	114	10	55	92	Machinist	F
44	6.0	5.6	92	10	58	81	Plumber	M
Students 23-44								
Sum	108.6	99.1	2474	222	1205	1656		M-11
Mean	4.9	4.5	112	10	54	75		F-11
S. D.	.60	.52	9.79	.30	2.62	12.04		
Overall Experimental Group								
Sum	202.2	186.8	4852	445	2385	3215		M-21
Mean	4.6	4.2	110	10	54	73		F-23
S. D.	.81	.73	10.8	.33	2.38	12.9		

(2) Reasoning Activities The tasks selected to measure gain in this type of activity were (a) Mazes, (b) Design Completion, (c) Analogies, (d) Addition, and (e) Solving Problems. The Mazes, Design Completion and Analogies tasks were performed once a week for the three weeks. The Addition and Solving Problems tasks were daily tasks.

(3) Activities involving new concepts in a content field—e.g., scientific information was presented on films. The subject studied was "The Earth: Its Atmosphere; Changes In Its Surface; Resources In Its Crust; and Its Oceans." One film was shown the first week, two were shown the second week; and one was shown the last week. The students watched the film and then took a test over the information presented.

The tasks selected for use in this experimental program were:

1. Mazes—After the Porteus Test, Vineland Revision and Non-Language Section of California Test of Mental Maturity five forms. The time allowed for each of the trials was two minutes.

2. Design Completion—After the Detroit Alpha Intelligence Test, five forms. The time allowed for each of the trials was five minutes.

3. Analogies—After the Dominion Tests of Learning Capacity, five forms. The time allowed for each of the trials was five minutes.

4. Checking Names—After the Minnesota Clerical Test, five forms. The time allowed for each of the trials was 30 seconds.

5. Checking Numbers—After the Minnesota Clerical Test, five forms. The time allowed for each of the trials was 30 seconds.

6. Canceling letters on a page of pirnted letters—After the Thorndike Clerical Test, five forms. The time allowed for each of the trials was two minutes.

7. Canceling numbers on a page of printed numbers—After the Thorndike Clerical Test, five forms. The time allowed for each of the trials was two minutes.

8. Addition of simple numbers—A sheet of addition problems made up of two and three digit numbers which had to be added, 15 forms. This was a daily task. The digits were different in each trial. The time allowed for each of the trials was five minutes.

9. Solving Problems—After Monroe's Standardized Reasoning Tests in Arithmetic, the Los Angeles Diagnostic Tests and Iowa Tests of Basic Arithmetic Skills, 15 forms. This was a daily task. The time allowed for each of the trials was 20 minutes.

10. Films—The Coronet Films series on "The Earth: Its Atmosphere; Changes in its Surface; Resources in its Crust; Its Oceans" was used. The time allowed for each of the trials was 15 minutes with an additional 13 minutes for the showing of the film.

The 10 tasks were administered by the researcher to the children of both groups in their own rooms at the home school a week before the experiment began and again as a post test one week following the end of the experiment. Figure 3 denotes the time schedule of the tasks at the Lennox Research School. During the experiment the tasks were performed at the same time with the researcher being with the control group in the morning on the first day and with the experimental group in the afternoon of the first day and then changing to the experimental group in the morning of the second day and with the control group in the afternoon of the second day. The researcher alternated with each group each day throughout the experiment. The regular teacher administered the tasks to the group not with the researcher. When a film was scheduled the researcher showed the film to both groups and the teachers administered the tests. The printed directions accompanying each task were employed as a matter of group instruction, there being no private or individual help. The timing as set was followed exactly using stop watches. On every school day about 20 minutes was spent both morning and afternoons by every subject in performing these pencil-and-paper tasks, two, three or four in number. Some tasks were repeated each day and some once each week. Thus, each complete repetition required one week.

Figure 3

Program Task Schedule for Initial Experiment

(Pre-Test and Follow-Up Test in own room in home school, one week before start and one week after conclusion of the experiment.)

Task	Time (Min.)	No. of Forms	March 12-16 Pre-Test Form	April 9-13 Follow-Up Form
Mazes	2	5	C	D
Design Completion	5	5	C	D
Checking Names	30 sec.	5	C	D
Checking Numbers	30 sec.	5	C	D
Cancelling Letters	2	5	C	D
Cancelling Numbers	2	5	C	D
Analogies	5	5	C	D
Film	15	4	ABCD	
Addition	5	15	G	I
Problem Solving	20	15	G	I

Task Schedule at Lennox Research School

3-19-62 First Day	3-20-62 Second Day	3-21-62 Third Day
Prob. Solv.—A *Addition—A *Design—A Ck. Names—A	Prob. Solv.—B *Addition—B *Maze—A *Can. Let.—A	Prob. Solv.—C *Addition—C *Film—A
3-22-62 Fourth Day	**3-23-62 Fifth Day**	**3-26-62 Sixth Day**
Prob. Solv.—D *Addition—D *Ck. No.'s—A *Can. No.'s—A	Prob. Solv.—E *Addition—E *Analogies—A	Prob. Solv.—F *Addition—F *Design—B *Ck. Names—B
3-27-62 Seventh Day	**3-28-62 Eighth Day**	**3-29-62 Ninth Day**
Film—B *Maze—B *Can. Let.—B	Prob. Solv.—H *Addition—H	Film—C *Ck. No.'s—B *Can. No.'s—B
3-30-62 Tenth Day	**4-2-62 Eleventh Day**	**4-3-62 Twelfth Day**
Prob. Solv.—J *Addition—J *Analogies—B	Prob. Solv.—K *Addition—K *Design—F *Ck. Names—E	Prob. Solv.—L *Addition—L *Maze—E *Can. Let.—E
4-4-62 Thirteenth Day	**4-5-62 Fourteenth Day**	**4-6-62 Fifteenth Day**
Prob. Solv.—M *Addition—M *Film—D	Prob. Solv.—N *Addition—N *Ck. No.'s—E *Can. No.'s—E	Prob. Solv.—O *Addition—O *Analogies—E

*—Tasks performed in the afternoons.

The tasks were presented to the children in every period throughout the experiment in a folio prepared in advance with the same tasks in the same order face down on their desks. Thus until instructions were ended, questions answered, and the signal to turn over tasks and begin work was given, no child could see the material upon which he was to work.

During the second three-week period the various tasks were reversed in order as illustrated in Figure 4. The tasks which were performed in the morning session during the first three weeks were performed in the afternoon the second three weeks and vice versa.

All tasks were scored on the day they were administered so that minor items which needed additional checking, such as failure to sign or date a test blank, could be cleared up immediately.

The schedules of recitation followed by the classes during the first and second three-week periods are found in Appendix, Form E.

Description of the Instruments Used to Measure Thermal Conditions

Several instruments had to be used in order to obtain the thermal data needed for this study. These instruments are known to be highly accurate in measuring air temperature, relative humidity and air movement. The instruments used are identified under the condition measures. The Research Engineer for Lennox Industries, Inc., selected and set up the instruments. He was assigned to the experiment by Lennox Industries Inc. He was familiar with the school and the equipment in the school, having conducted many experiments on the thermal conditions which could be maintained. He had a vast amount of recorded information on heat gains, and heat losses of both rooms under various conditions. He carried out all of the thermal tests and maintained the thermal conditions prescribed for this study.

Two Taylor mercurial thermometers with a range of 20F to 120F were used throughout the study as calibration instruments.

Figure 4

Program Task Schedule for Duplicate Experiment

(Pre Test and Follow Up Test in own room in home school one week before start and one week after conclusion of the experiment)

Task	Time (Min.)	No. of Forms	April 2-6 Pre-Test Form	May 7-11 Follow-Up Form
Mazes	2	5	C	D
Design Completion	5	5	C	D
Checking Names	30 sec.	5	C	D
Checking Numbers	30 sec.	5	C	D
Canceling Letters	2	5	C	D
Canceling Numbers	2	5	C	D
Film	15	4	ABCD	
Addition	5	15	G	I
Problem Solving	20	15	G	I

Task Schedule at Lennox Research School

4-9-62 First Day	4-10-62 Second Day	4-11-62 Third Day
Addition—A Design—A Ck. Names—A *Prob. Solv.—A	Addition—B Maze—A Can. Let.—A *Prob. Solv.—B	Addition—C Film—A *Prob. Solv.—C
4-12-62 Fourth Day	**4-13-62 Fifth Day**	**4-16-62 Sixth Day**
Addition—D Ck. No.'s—A Can. No.'s—A Prob. Solv.—D	Addition—E Analogies—A *Prob. Solv.—E	Addition—F Design—B Ck. Names—B *Prob. Solv.—F
4-17-62 Seventh Day	**4-18-62 Eighth Day**	**4-19-62 Ninth Day**
Maze—B Can. Let.—B *Film—B	Addition—H *Prob. Solv.—H	Ck. No.'s—B Can. No.'s—B *Film—C
4-24-62 Tenth Day	**4-25-62 Eleventh Day**	**4-26-62 Twelfth Day**
Addition—J Analogies—B *Prob. Solv.—J	Addition—K Design—E Ck. Names—E *Prob. Solv.—K	Addition—L Maze—E Can. Let.—E *Prob. Solv.—L
4-27-62 Thirteenth Day	**4-30-62 Fourteenth Day**	**5-1-62 Fifteenth Day**
Addition—M Film—D *Prob. Solv.—M	Addition—N Ck. No.'s—E Can. No.'s—E *Prob. Solv.—N	Addition—O Analogies—E *Prob. Solv.—O

*—Tasks performed in the afternoons.

A 12 point Type 153 Electronik Recorder, Model No. 153X72P12-X-26 with type J thermocouples was used for a continuous printed record of temperatures, dry bulb and wet bulb readings. A thermocouple is an electrical device used for measuring differences in temperature. The recorder was capable of recording thermocouple readings from −50F to 200F with the recorder calibrated to an accuracy of one-half of one degree. The recorder printed the thermocouple readings in multicolor in a cycle of one reading every five seconds or all 12 points within a minute. The chart speed was 24 inches per hour. On the chart there were four air temperature readings at desk level, one for each quadrant of the room. Also recorded on the chart was a dry and wet bulb reading for the mechanical psychrometer to be described later. Thus, for every minute of the school day the chart contained 12 readings, six for each room. Inasmuch as the readings commenced one hour before school began and continued for one hour after school was dismissed, there was a total of 172,000 readings for the six week period.

To insure maximum accuracy of the thermocouple readings, the cooperating research engineer checked the recorder two times daily with the Taylor mercurial thermometer.

The Brown Instruments Thermo Humidigraph was an instrument used to record temperature and humidity continuously on a 24 hour chart. The instrument was equipped to sample room air over the temperature sensing device and hair-type humidistat. The range of temperatures that the instrument was capable of recording was 0F to 100F with the range of relative humidity from 0 to 100%. This was a Model 612X21KL-X-86 instrument manufactured by the Brown Instruments Division of Minneapolis-Honeywell Regulator Company.

The sling psychrometer was used to measure the humidity of the air along with the mechanical psychrometer which gave the wet and dry bulb readings on the thermocouple chart.

In the sling psychrometer, the two thermometers are mounted on a frame, side by side, fitted with a handle by which the device can be whirled through the air after the cloth wick is wetted. The whirling motion is stopped for reading the thermomters and then continued until the thermomter readings become steady. Because of evaporation of the moisture in the wick, the wet-bulb thermometer will indicate a lower temperature than the dry-bulb thermometer. The difference between the two is known as the wet-bulb depression.

The 1959 Heating, Ventilating and Air Conditioning Guide of the American Society of Heating and Air-Conditioning Engineers, Inc., has charts and tables for determining relative humidity from the dry-bulb and wet-bulb readings.

The mechanical psychrometer used to measure humidity at task level had a standard wick and gave wet and dry bulb readings every minute. One of these was located in each room. The readings were checked twice daily for calibration with the sling psychrometer.

A vane-type anenometer was used to measure the velocity of the air discharged into the rooms by the equipment. The air movement at task level was measured with an Anemotherm-Model 60 hot wire anemometer. This is a thermal-type anemometer, self-powered and a direct reading of temperature, velocity and static pressure can be obtained. It has an accuracy acceptable for most laboratory work. It is another application of the thermocouple principle.

The readings were made several times each day to make certain that the thermal conditions to be described later were being met. The readings at task level were taken for each of the four quadrants in each room.

Thermal Conditions

Since this study was concerned primarily with the effect of thermal environment on mental efficiency it was necessary to create two different thermal environments. As described earlier in the study every attempt was made to make all conditions equal except for air temperature, humidity and air movement.

The thermal environment created for one of the rooms was a model thermal environment based upon the recommended standards found in standard reference works; physiological and medical texts; graduate studies in education, engineering and psychology; educational texts and periodicals; reports of organizations such as the School Facilities Laboratories and publications of the American Society of Heating, Refrigerating and Air-Conditioning Engineers.

The marginal thermal environment created for the other room was based on thermal conditions found in the children's own schoolroom and one to which they were accustomed. It was deemed desirable to do this so that the children would not be exposed to worse thermal conditions than they would have encountered if they had occupied their original room in their own school. In other words, the conditions were controlled to the extent that they were not allowed to get worse than those to which the children had been accustomed.

MODEL THERMAL CONDITIONS

The ideal conditions of the air and surrounding surfaces which affect the physical and mental comfort of the students are given by Winslow and Herrington (28: 189-197) as 75F-76F for moderate activity and for considerable activity as 69F-70F. These air temperatures assume the effects of a cold wall and the individual wearing ordinary winter clothing. With summer clothing the readings may be several degrees higher. The temperature readings just given assume air movement of 20 to 30 fpm and a range in relative humidity of from 30 to 60%. However, Winslow and Herrington feel that the influence of relative humidity is slight at otherwise favorable temperature conditions.

The Commissioner of Education of the State of New York (24: 16-17) gives the following figures for the thermal environment during the heating season: A room air temperature of 68F-72F for sedentary activities. and air movement in the zone of occupancy not to exceed 25 fpm (relative humidity plays an insignificant role in thermal comfort during the heating season).

The American Society of Heating and Air-Conditioning Engineers (2:69) states that most healthy, sedentary, and slightly active men and women, normally clothed and in uniform environments with air velocities of the order of 25 fpm, are thermally comfortable the year around when the dry-bulb air temperature is in the range of 73F to 77F and the relative humidity in the range of 25 to 60%.

On the basis of information presented in Chapter II and on the basis of the above recommendations, an environment was created which was considered model for most classroom activities (excluding physical education) in the lower grades. It was characterized by an air temperature in the range of 70F to 74F; a relative humidity of between 40 and 60%; air movement in the range of 20 to 40 fpm.

No attempt was made to establish these criteria as the ultimate in thermal environment. However, at present they seem to be representative of the most acceptable ideas in the literature.

MARGINAL THERMAL ENVIRONMENT

Conditions for the marginal thermal environment in the one room was determined by assessing the thermal conditions found at the Canary Lake School and the Saylor Center School. As was mentioned before, this was deemed necessary so that the children would not be exposed to thermal conditions which were worse than those they would have ordinarily experienced. The air temperature at the home school ranged from 70F to 92F. At the research school the temperatures varied from 72F to 81F.

The humidity at the home schools ranged from 33 to 75% relative humidity. At the research school the relative humidity varied from 35 to 67%.

The air movement at desk level in the home school was from 5 to 10 fpm depending upon the location of the desk in the room. The air was recirculated room air with no fresh air introduced except by the opening of windows. The 10 fpm recirculated room air was maintained at the research school.

It must be stressed that the teacher in charge of this room was free to adjust conditions in the room by opening windows and adjusting the thermostat as she saw fit just as she would if she were in her own room at her home school. The readings given for the conditions under which the control group worked are the result of the adjustments which the teacher made.

The brightness of the lighting at desk level was 50 to 55 foot candles in both rooms.

As mentioned before both rooms were identical except for cubic footage. This factor was taken into consideration by the counterbalancing. The experimental group occupied Room No. 1 the first three weeks and Room No. 2 the second three weeks with the control group occupying Room No. 2 the first three weeks and Room No. 1 the second three weeks. Of course, the thermal environments were changed when the groups changed.

Actual Thermal Conditions Maintained

The mechanical equipment in the Lennox Research School was capable of supplying at desired rates, air of required temperature and humidity. There were also chilling units capable of cooling the rooms in very short periods. The circulation of the air was controlled by the room units which could be set for any desired amount of air movement—either fresh or recirculated air.

Table III gives a detailed account of the conditions actually realized hour by hour (8:00 A.M. to 4:00 P.M.) and day by day. Outside temperature and humidity as well as the temperature and humidity in the rooms occupied by the control and experimental groups are given. Of extreme interest is the fact that as the outside temperature rose above 50F the air had to be cooled by the chilling or refrigeration units. It should be noted that even with full introduction of outside fresh air the air temperature in the room occupied by the experimental group could not be maintained within the range specified (72F to 74F) and refrigerated cool air had to be introduced on those days. Refrigerated cool air had to be used as early as March 27th and 28th. After April 17th, refrigerated cool air was used continuously until the end of the experiment.

The data in Table III reveal that the conditions specified for the room occupied by the experimental group were maintained throughout the experiment. The variations in the conditions of the room occupied by the control group were as expected when provisions for cooling are not made.

Analysis of Data

All of the measures in this study lend themselves to statistical analysis. The writer was able to obtain data of an objective nature which could be handled by analysis of variance and trend analysis.

A level of significance had to be chosen which represented a compromise between a Type I error (rejecting a true hypothesis) and a Type II error (retaining a false hypothesis). The consequences of a Type I error in this experiment would result in a waste of time and effort in further experimentation. In order to reduce the danger of following a false lead a high level of significance is usually set to control Type I errors. The consequences of a Type II error in this experiment would result in not following up a true lead with more experimentation. Probably this type of error is not too serious because other leads would eventually have to be tried out anyway.

The literature indicates that a .01 level of significance is ordinarily considered a high level of control over a Type I error, and that .10 is so low a level of control that it is seldom used in educational research. As a compromise between these two levels a .05 level of significance was used.

TABLE III
TEMPERATURE AND HUMIDITY READINGS—March 19-May 1, 1962
(Outdoor, Control and Experimental Rooms)

Date	Place	800 T	800 H	900 T	900 H	1000 T	1000 H	1100 T	1100 H	1200 T	1200 H	1300 T	1300 H	1400 T	1400 H	1500 T	1500 H	1600 T	1600 H
March 19	Outdoor	33	89	37	82	38	79	38	79	38	79	40	79	40	79	41	79	41	76
	Control	72	55	77	46	76	44	75	47	75	48	77	47	77	47	79	47	77	46
	Exper.	68	45	75	47	73	45	72	43	72	42	73	45	72	48	71	50	72	47
March 20	Outdoor	29	100	29	87	31	82	32	92	32	89	33	85	33	85	34	82	35	79
	Control	73	60	73	55	74	40	75	54	74	40	74	58	75	50	76	52	75	48
	Exper.	72	47	72	50	72	53	72	52	72	52	72	51	72	50	72	49	72	48
March 21	Outdoor	33	75	34	72	36	70	37	64	39	62	40	59	40	60	40	65	40	65
	Control	73	50	75	41	78	38	79	34	78	34	75	41	77	40	77	38	77	36
	Exper.	72	50	72	40	72	40	72	41	72	42	72	40	72	40	72	40	71	42
March 22	Outdoor	30	89	34	82	36	75	37	76	38	73	39	67	40	70	41	65	42	68
	Control	71	45	73	54	74	46	75	45	75	51	75	48	78	44	78	41	76	42
	Exper.	71	45	72	41	71	41	72	42	73	41	72	40	72	40	72	40	72	40
March 23	Outdoor	33	82	34	82	37	82	38	62	40	76	43	76	47	68	48	68	48	74
	Control	73	46	74	46	77	46	78	46	79	47	79	47	78	44	78	41	75	40
	Exper.	71	43	71	47	72	43	72	41	72	42	72	41	72	40	72	40	72	40
March 26	Outdoor	33	89	37	85	44	73	47	68	50	68	52	71	53	64	55	64	56	61
	Control	74	43	76	37	77	40	78	45	80	48	79	50	78	57	78	56	80	41
	Exper.	71	45	71	42	72	40	72	40	73	40	73	42	73	38	73	40	73	47
March 27*	Outdoor	38	82	46	76	57	59	63	48	66	47	69	42	71	41	72	38	72	38
	Control	74	57	74	40	77	44	78	46	80	44	80	44	81	47	82	52	79	57
	Exper.	70	67	72	45	71	47	72	50	74	51	74	50	74	52	74	52	74	48
March 28*	Outdoor	56	62	60	58	64	56	69	47	71	42	73	43	73	41	76	38	76	35
	Control	73	47	75	41	76	45	77	47	78	40	79	38	81	41	82	42	82	38
	Exper.	72	48	73	47	74	47	72	47	74	55	74	55	74	60	74	60	74	55
March 29	Outdoor	38	73	37	76	35	85	34	89	35	85	39	79	40	73	43	60	43	60
	Control	72	36	73	33	76	35	77	36	78	37	78	37	78	38	78	39	78	34
	Exper.	72	37	72	40	72	41	72	42	72	42	72	45	72	43	72	42	72	42
March 30	Outdoor	35	69	36	67	39	62	41	57	43	55	44	51	45	55	47	40	47	44
	Control	73	30	74	31	78	34	78	31	78	39	78	29	78	39	80	35	79	36
	Exper.	72	28	73	40	72	42	73	42	73	42	73	42	73	42	73	43	73	42
April 2	Outdoor	32	72	31	78	33	72	35	69	35	69	36	59	38	54	39	50	39	46
	Control	72	38	74	37	77	37	78	37	79	37	78	36	79	38	79	38	78	36
	Exper.	72	30	72	44	72	40	71	41	71	43	71	43	72	42	72	41	72	41
April 3	Outdoor	33	69	38	66	41	57	44	50	46	45	46	43	46	44	43	44	43	67
	Control	74	37	77	36	78	38	79	39	81	38	74	35	77	38	78	39	80	38
	Exper.	71	28	71	40	72	40	72	40	72	46	71	46	72	46	72	46	72	47
April 4	Outdoor	44	76	43	82	44	82	44	79	45	79	45	76	48	76	50	66	52	58
	Control	75	43	75	43	77	45	79	47	80	48	78	43	79	43	79	47	79	47
	Exper.	72	34	72	40	72	41	71	45	71	51	72	51	71	49	71	48	71	46
April 5	Outdoor	40	79	42	79	43	70	45	70	47	63	47	60	49	54	50	50	52	45
	Control	74	50	75	54	77	60	78	62	80	58	75	62	76	50	77	48	77	46
	Exper.	71	35	71	40	72	40	72	40	72	41	72	41	72	40	72	40	72	40
April 6	Outdoor	43	79	51	66	56	51	58	53	56	57	54	64	50	77	51	66	52	63
	Control	76	48	77	64	77	68	78	70	81	68	78	65	78	65	78	60	76	60
	Exper.	72	35	72	44	72	44	71	40	72	40	72	40	72	40	72	40	72	40
April 9	Outdoor	37	59	40	50	44	45	47	37	50	36	52	35	53	35	54	34	55	35
	Control	72	35	74	35	75	38	77	38	78	37	76	38	77	38	78	38	76	37
	Exper.	72	33	73	40	72	40	72	40	72	40	72	40	72	42	72	43	72	40
April 10	Outdoor	37	62	40	60	42	56	45	60	50	48	52	46	53	46	54	47	54	47
	Control	73	36	75	37	75	40	77	40	78	39	76	41	77	42	78	40	77	39
	Exper.	73	36	73	40	73	40	73	41	73	43	72	42	72	44	73	47	71	40
April 11	Outdoor	42	73	43	76	46	71	48	63	48	63	47	63	46	80	45	83	45	82
	Control	72	38	72	39	77	39	78	39	78	39	77	39	78	40	78	40	75	38
	Exper.	73	33	73	40	73	42	73	43	72	42	71	40	72	42	72	50	73	40

(Continued on following Page)

TABLE III (Cont'd)

Date	Place	Time 800 T	800 H	900 T	900 H	1000 T	1000 H	1100 T	1100 H	1200 T	1200 H	1300 T	1300 H	1400 T	1400 H	1500 T	1500 H	1600 T	1600 H
April 12	Outdoor	38	89	38	89	34	92	34	92	34	89	34	92	32	92	34	89	34	82
	Control	72	35	73	39	74	37	75	39	73	40	78	34	78	35	78	34	76	34
	Exper.	73	33	72	40	72	40	72	44	72	53	72	40	72	40	72	40	72	40
April 13	Outdoor	32	69	35	59	37	54	40	52	41	53	44	51	45	47	47	46	48	42
	Control	72	28	74	28	75	35	76	34	77	33	78	33	78	34	77	34	76	33
	Exper.	72	24	72	39	72	40	72	40	73	40	72	40	72	40	72	42	71	46
April 16	Outdoor	36	70	41	51	46	45	50	39	51	36	50	38	47	39	49	46	50	37
	Control	72	28	75	28	79	28	78	32	78	34	78	30	78	31	78	31	78	27
	Exper.	73	36	73	39	72	42	72	45	72	47	71	50	72	51	73	54	73	54
April 17*	Outdoor	41	85	46	71	52	54	57	44	62	32	64	27	65	26	67	23	67	23
	Control	72	30	73	32	76	35	78	36	78	34	77	51	79	51	79	48	78	56
	Exper.	72	33	72	40	73	42	72	41	72	40	72	50	73	52	73	54	72	57
April 18*	Outdoor	51	52	57	39	61	26	64	27	66	26	66	26	68	25	70	23	69	18
	Control	77	25	75	28	78	33	78	34	78	31	78	33	78	33	78	31	78	28
	Exper.	74	43	72	45	73	54	72	57	72	60	71	53	72	55	72	57	72	57
April 19*	Outdoor	45	53	49	41	52	35	54	31	58	26	59	23	62	21	63	19	64	18
	Control	71	28	74	25	75	32	77	31	77	31	77	52	78	30	78	31	78	31
	Exper.	73	25	73	39	73	40	72	40	72	40	72	40	72	40	73	40	73	40
April 24*	Outdoor	63	41	68	36	72	31	76	26	78	24	80	23	82	20	82	21	82	20
	Control	73	33	76	32	78	36	78	37	79	38	79	37	78	40	78	47	80	29
	Exper.	73	47	73	47	73	50	73	51	73	50	73	53	73	55	73	58	73	50
April 25*	Outdoor	64	46	68	40	72	35	77	31	79	28	81	27	82	26	83	27	83	30
	Control	74	40	76	39	77	43	78	43	79	37	78	43	80	43	81	39	81	42
	Exper.	73	43	73	43	72	42	73	42	74	43	74	47	74	47	74	50	74	55
April 26*	Outdoor	68	63	73	53	77	47	79	44	81	41	83	38	83	37	84	36	83	34
	Control	71	50	76	52	79	53	80	53	81	52	79	49	80	50	82	50	79	42
	Exper.	71	61	73	50	74	51	74	53	74	58	74	52	74	58	74	57	74	43
April 27*	Outdoor	71	68	74	62	75	60	73	64	66	87	69	81	69	87	68	20	66	90
	Control	75	46	77	47	80	52	80	54	81	56	70	61	80	62	80	65	77	60
	Exper.	72	57	73	57	73	57	73	57	73	57	73	58	73	60	74	60	73	58
April 30*	Outdoor	56	96	57	90	58	87	58	83	58	80	59	75	58	72	58	67	57	67
	Control	72	56	74	51	75	55	76	51	77	48	73	47	75	47	76	48	74	51
	Exper.	72	47	73	50	73	50	73	50	73	50	72	56	73	58	73	36	73	43
May 1*	Outdoor	56	59	59	55	63	48	65	40	66	39	67	36	68	33	69	30	68	30
	Control	72	42	75	43	75	44	76	45	78	43	76	41	77	43	77	40	77	36
	Exper.	73	37	72	40	73	40	73	42	73	40	71	40	72	40	72	43	71	40

Air Movement:
Control Room—10 fpm recirculated air
Experimental Room—25 fpm outside air
*Air Conditioning

CHAPTER IV — ANALYSIS OF THE RESULTS

The test of the hypothesis—that there is no difference in learning under model and marginal classroom thermal environment—lies, as far as this investigation is concerned, in the comparison of the performance of two groups of individuals who differed only in the thermal environment they occupied each day. The other known factors were equated as much as most human experimentation permits.

Comparison of Achievement of Control and Experimental Groups

Learning in this experimental situation was represented by the number of correct responses made by the subjects to each task in a series of repetitions of the tasks. The tasks were chosen for this program primarily because they represented performance in reasoning ability, clerical ability and ability to recognize new concepts. It was possible to objectively score every performance on every task.

The complete set of data lists the number of correct responses made by each child taking part in this study in each of his practice periods, as he progressed in the 10 tasks from the first through the last trial. All of the tasks were practiced once a week with the exception of the addition and problem solving tasks. These latter tasks were practiced daily during the first week, three times the second week and daily the third week. Tasks based on concepts presented via motion pictures were given twice during the second week. However, for the uniformity of treatment and reporting, the mean weekly averages of the addition and problem solving tasks are reported as are the mean performances on all four film tasks. Since the data in their entirety are not printed in this report, a summary of these mean scores as made by the control and experimental groups on each of the trials is presented in Table IV.

TABLE IV

MEAN SCORES MADE BY CONTROL AND EXPERIMENTAL GROUPS IN FIVE TRIALS OF TEN TASKS

Task	Group	Home School Trial 1	Research School Trial 2	Research School Trial 3	Research School Trial 4	Home School Trial 5
Mazes	C	3.61	4.23	4.75	5.66	5.25
	E	3.84	4.20	5.07	6.23	5.70
Design Completion	C	30.59	58.55	66.73	75.70	72.52
	E	26.48	53.16	69.25	80.59	79.02
Checking Names	C	2.84	2.86	4.23	4.20	3.89
	E	2.57	3.89	4.48	5.16	5.14
Checking Numbers	C	3.82	4.45	5.25	5.89	5.93
	E	3.64	5.09	6.23	7.20	6.84
Canceling Letters	C	25.32	32.48	31.18	39.84	38.82
	E	23.64	30.59	33.73	42.25	41.61
Canceling Numbers	C	45.73	46.89	52.93	55.07	53.23
	E	40.61	48.36	54.77	57.43	56.34
Analogies	C	10.05	14.18	17.70	17.50	16.48
	E	11.34	16.09	18.95	19.55	19.32
Addition	C	23.66	27.09	28.45	31.75	31.59
	E	21.48	27.45	32.11	36.02	35.30
Solving Problems	C	10.52	11.77	14.02	14.93	13.41
	E	11.05	12.89	15.82	17.98	17.84
Films	C	8.00			11.09	
	E	7.73			11.80	

Although it seems clear from Table IV that there are differences in the performance of the control and experimental groups on the trials, it is necessary to look more closely at these differences.

Analysis of variance procedures were used to analyze the data from the experiment. The specific statistical design employed to determine what happened to both levels of each treatment group as they proceeded from trial 2 through trial 4 in the research school in their respective thermal environments, was a three-factor Type VI design. (14. 292-297) To determine if the observed differences on Trial 5 at the end of the experiment were significant, a two-factor Type I design (14.267-273) was utilized. All significance tests were conducted at the .05 level.

Analysis of Variance by Type VI Design

The performance of the two groups in the research school on Trials 2, 3, and 4 are considered first. Since some of the tasks were similar in nature, they are grouped into three broad categories. (1) Reasoning Tasks—Mazes, Design Completion, Analogies, Addition and Solving Problems, (2) Clerical Routine Tasks—Checking Names, Checking Numbers, Canceling Letters and Canceling Numbers, and (3) Tasks Involving New Concepts—Science Films.

TABLE V

GROUP MEANS FOR MAZE TASK ON TRIALS 2, 3 AND 4

	Low Level Trials 2	Low Level Trials 3	Low Level Trials 4	Low Level Average		High Level Trials 2	High Level Trials 3	High Level Trials 4	High Level Average
Con.	4.91	5.09	5.55	5.18	Con.	3.55	4.41	5.77	4.58
Exp.	4.55	4.91	6.14	5.20	Exp.	3.86	5.23	6.32	5.14
Ave.	4.73	5.00	5.84	5.19	Ave.	3.70	4.82	6.05	4.86

	Trials x Treatment Trials 2	Trials 3	Trials 4	Average		Levels x Treatment Low	High	Average
Con.	4.23	4.75	5.66	4.88	Con.	5.18	4.58	4.88
Exp.	4.20	5.07	6.23	5.17	Exp	5.20	5.14	5.17

TABLE Va

ANALYSIS OF VARIANCE SUMMARY

Source	df	ms	F	(df)
Between S	43	1.183		
Levels	1	7.333	7.0759*	1,42
error (b)	42	1.036		
Within S	220	1.350		
Trials	2	66.489		
Treat.	1	5.470	4.1551*	1,42
Trials x Treat.	2	1.936	4.8821*	2,84
Trials x Levels	2	8.663		
Treat. x Levels	1	4.909	3.7290	1,42
Trials x Treat. x Levels	2	1.580	3.9839*	2,84
Error (w)	210	0.616		
$Error_1$ (w)	84	0.485		
$Error_2$ (w)	42	1.316		
$Error_3$ (w)	84	0.396		
Totals	263			

F .05 = 4.08 df = 1,42 * F significant
F .05 = 3.12 df = 2,84

Reasoning Tasks

MAZES

Table V shows the performance on the maze task of each level of the control and experimental groups on each of three trials at the research school. The overall means for the *low* and *high* level groups were 5.19 and 4.86 respectively. The overall means for the control and experimental groups were 4.88 and 5.17 respectively. The differences in the means in both cases were statistically significant. These significance tests are summarized in Table Va. The respective F-values are 7.0759 and 4.1551. Also given in this summary table are the significance tests for the interaction effects of interest. The trials x treatments interaction over levels with an F. of 4.8821 and trials x treatments x levels interaction (F-3.9839) were both statistically significant. The treatments x levels interaction (F-3.7290) was not.

Figure 5 illustrates the nature of the observed interaction effects graphically. The trials x treatments graph shows that the control and experimental groups were at about the same point on trial 2 and that in subsequent trials the rate of gain for the experimental group was significantly greater than than that of the control group. While there was hardly any difference (.02) in the overall mean performance of the *low* level control and experimental groups (see treatment x level graph) there was a difference of .5 between the *high* level control and experimental groups. However, this treatments by levels interaction (i.e., the difference between these two differences) was not statistically significant. In analyzing the trials x treatments x levels triple interaction the graph for the *low* level shows why there was no overall mean difference between the treatment groups for this level (see also treatments x levels graph). The experimental group started at a lower point and had to gain more before any difference could be realized. The *high* level experimental group on the other hand started higher than the *high* level control group, increased more rapidly on trial 3 and maintained this difference on trial 4. This triple interaction (i.e., the difference between the treatments x trials interaction as observed for the *low* and *high* levels) was statistically significant.

DESIGN COMPLETION

It may be noted from Table VI that the overall means on the design completion task for the *low* and *high* levels were 65.60 and 69.16 respectively. The overall means for the control and experimental groups were 66.99 and 67.67 respectively. Neither of these pairs of means differed significantly. These significance tests are summarized in Table VIa. The respective F-values are 1.8062 and 0.0581. The significance tests for the interaction effects of interest are also given in this summary table. The trials x treatments interaction over levels was statistically significant (F-11.2433) as was the triple interaction for trials x treatments x levels (F-4.4528). The treatments x levels interaction was non-significant (F-0.1003).

The nature of the observed interaction effects are illustrated graphically in Figure 6. As the trials x treatments graph shows the experimental group mean was below that of the control group on trial 2. However, by trial 3 the mean performance of

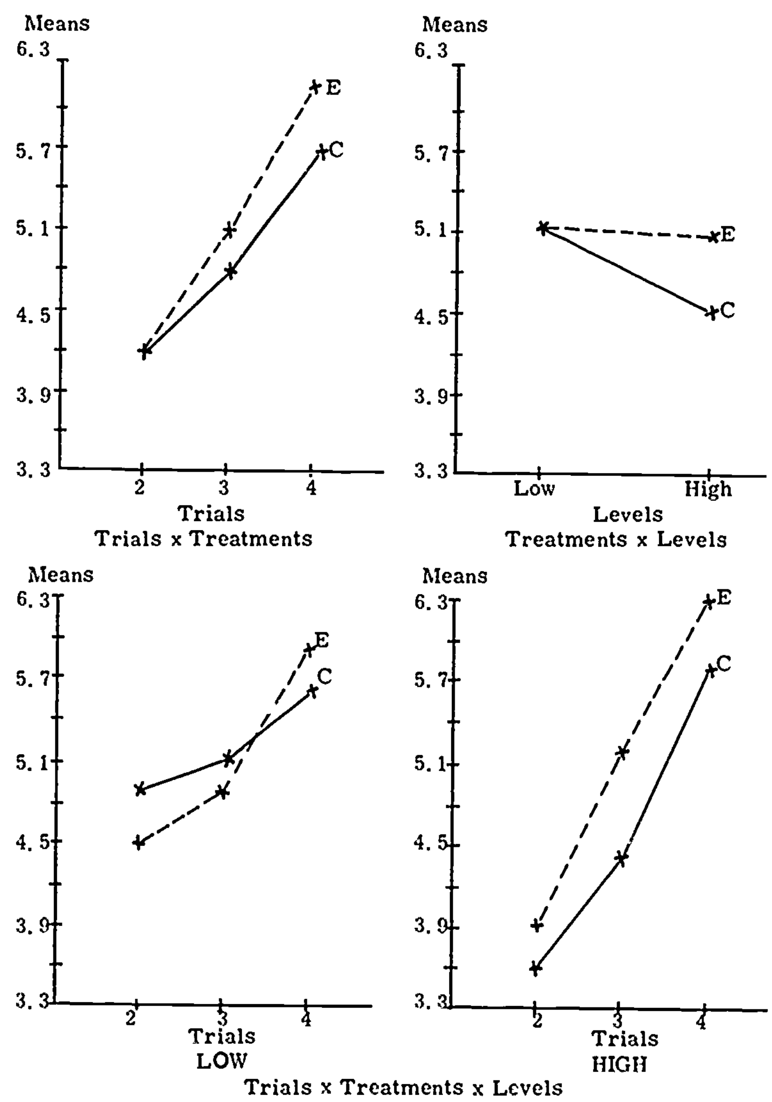

Figure 5 Interaction for Maze Task on Triels 2, 3 and 4

TABLE VI
GROUP MEANS FOR DESIGN COMPLETION TASK ON TRIALS 2, 3 and 4

Low Level

	Trials 2	Trials 3	Trials 4	Average
Con.	53.59	65.73	77.50	65.61
Exp.	49.95	63.55	82.68	65.39
Ave.	51.77	64.64	80.09	65.50

High Level

	Trials 2	Trials 3	Trials 4	Average
Con.	63.50	67.73	73.91	68.38
Exp.	56.36	74.95	78.50	69.94
Ave.	59.93	71.34	76.20	69.16

Trials x Treatment

	Trials 2	Trials 3	Trials 4	Average
Con.	58.55	66.73	75.70	66.99
Exp.	53 16	69.25	80.59	67.67

Levels x Treatment

	Low	High	Average
Con.	65.61	68.38	66.99
Exp.	65.39	69.94	67.67

TABLE VIa
ANALYSIS OF VARIANCE SUMMARY

Source	df	ms	F	(df)
Between S	43	498.435		
Levels	1	883.700	1.8062	1,42
error (b)	42	489.262		
Within S	220	263.353		
Trials	2	10964.600		
Treat.	1	30.000	0.0581	1,42
Trials x Treat.	2	636.800	11.2433*	2,84
Trials x Levels	2	951.000		
Treat. x Levels	1	51.800	0.1003	1,42
Trials x Treat. x Levels	2	252.200	4.4538*	2,84
Error (w)	210	153.556		
Error₁ (w)	84	68.940		
Error₂ (w)	42	516.621		
Error₃ (w)	84	56.638		
Totals	263			

F .05 = 4.08 df = 1,42 *F significant
F .05 = 3.12 df = 2,84

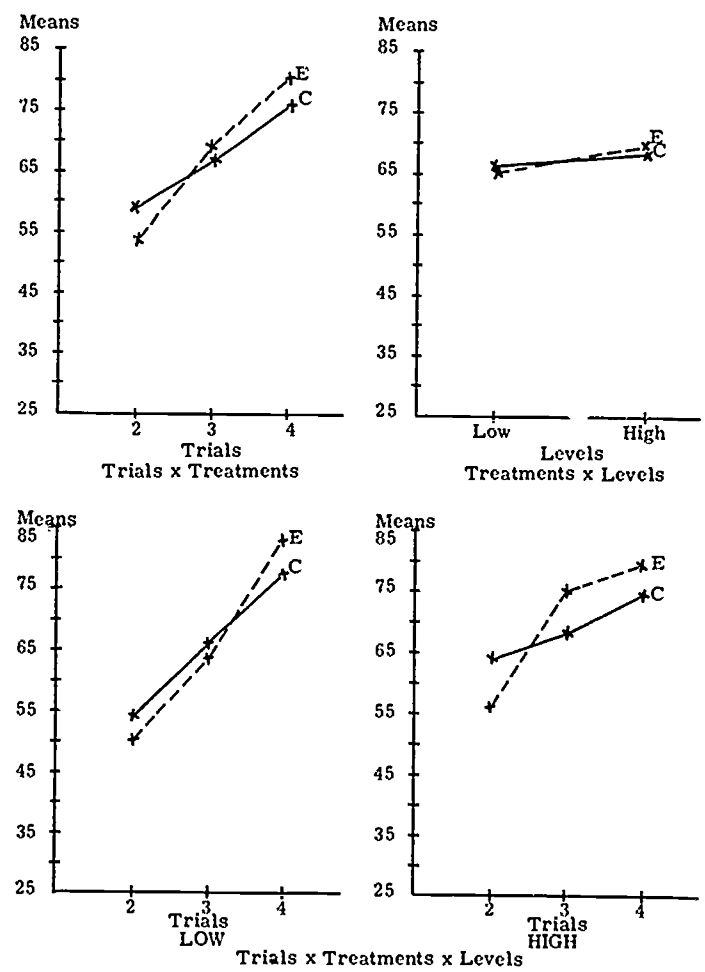

Figure 6 Interaction for Design Completion Task on Trials 2, 3 and 4

the experimental group surpassed that of the control group. This advantage was maintained on trial 4. This cross-over effect explains why the mean for the experimental group over all trials was not significantly larger than that for the control group.

Since the treatments x levels interaction was not significant attention is next directed to the trials x treatments x levels graphs. It may be noted that the *low* level experimental group was lower on trials 2 and 3 than the *low* level control group but was higher on trial 4. The *high* level experimental group was also lower on trial 2 but was higher on trial 3 and maintained that advantage on 4. As has already been noted this difference in trials x treatments interaction from level to level was statistically significant.

TABLE VII
GROUP MEANS FOR ANALOGIES TASK ON TRIALS 2, 3 AND 4

	Low Level					High Level			
	Trials 2	3	4	Average		Trials 2	3	4	Average
Con.	14.27	18.86	19.50	17.55	Con.	14.09	16.55	15.50	15.38
Exp.	15.68	19.68	20.45	18.61	Exp.	16.50	18.23	18.64	17.79
Ave.	14.98	19.27	19.98	18.08	Ave.	15.30	17.39	17.07	16.58

	Trials x Treatment					Levels x Treatment		
	Trials 2	3	4	Average		Low	High	Average
Con.	14.18	17.70	17.50	16.46	Con.	17.55	15.38	16.46
Exp.	16.09	18.95	19.55	18.20	Exp.	18.61	17.79	18.20

TABLE VIIa
ANALYSIS OF VARIANCE SUMMARY

Source	df	ms	F	(df)
Between S	43	116.073		
Levels	1	147.005	1.2746	1,42
error (b)	42	115.337		
Within S	220	24.260		
Trials	2	318.285		
Treat.	1	198.642	2.7713	1,42
Trials x Treat.	2	3.979	0.4882	2,84
Trials x Levels	2	59.842		
Treat. x Levels	1	29.997	0.4185	1,42
Trials x Treat. x Levels	2	2.896	0.3553	2,84
Error (w)	210	20.660		
Error₁ (w)	84	7.660		
Error₂ (w)	42	71.679		
Error₃ (w)	84	8.150		
Totals	263			

$F_{.05} = 4.08$ df = 1,42
$F_{.05} = 3.12$ df = 2,84

ANALOGIES

The various means for the analogies task are shown in Table VII. The overall means for the *low* and *high* levels were 18.08 and 16.58 respectively. The overall means of 16.46 and 18.20 were for the control and experimental groups respectively. As may be noted from the summary Table VIIa neither of these pairs of means differed significantly. The respective F-values were 1.27 and 2.77. Moreover none of the interaction effects of interest was statistically significant.

Figure 7, which graphically illustrates the nature of the observed interaction effects has been included for the sake of completeness. However, since none of the observed effects is statistically significant no comment on the nature of these effects is called for.

ADDITION

It may be noted from Table VIII that the overall means on the addition task for the *low* and *high* levels were 29.31 and 31.64 respectively and that the overall means for the control and experimental groups were 29.10 and 31.85 respectively. Neither

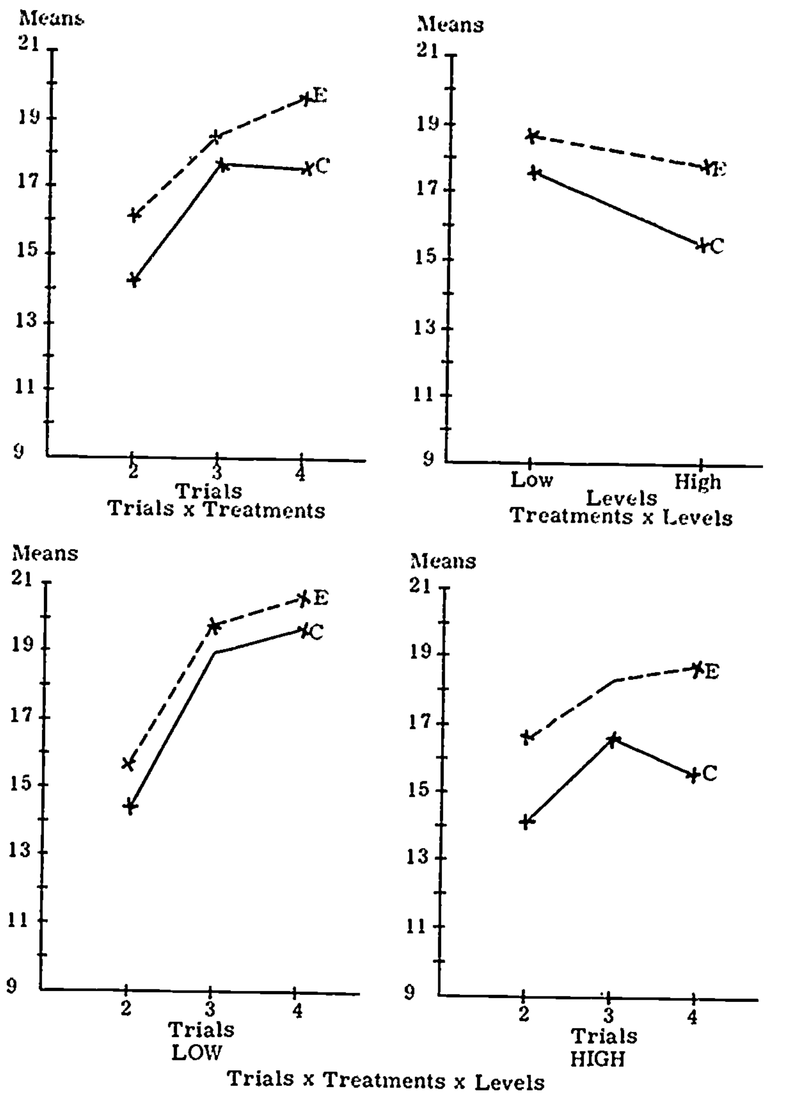

Figure 7 Interaction for Analogies Task on Trials 2, 3 and 4

of these pairs of means differed significantly. The significance tests are summarized in Table VIIIa. The respective F-values for these pairs of means are 2.4485 and 3.6821. The significance tests for the interaction effects of interest are also given in this summary table. The trials x treatments interaction was statistically significant (F-8.9240) as was the triple interaction for trials x treatments x levels (F-10.4245). The treatments x levels interaction was non-significant (F-1.1971).

The nature of the observed interaction effects is illustrated graphically in Figure 8. As the trials x treatments graph shows, the experimental and control groups were at about the same point on trial 2, but in subsequent trials the rate of gain for the experimental group was significantly greater than that of the control group.

Since the treatments x levels interaction was not significant, attention is next directed to the trials x treatments x levels graphs. It may be noted that the *low* level experimental group was higher on trial 2 than the *low* level control group, increased that difference considerably on trial 3 but did not maintain that difference on trial 4. On the other hand the *high* level experimental group was lower than the *high* level control group on trial 2, but was slightly higher on trial 3 and increased that advantage on trial 4. As has already been noted this difference in trials x treatments interaction from level to level was statistically significant.

SOLVING PROBLEMS

Table IX shows the mean performance on the problem solving task of each level of the control and experimental group on each of three trials. The overall means for the *low* and *high* level groups were 13.61 and 15.52 respectively. The overall means for the control and experimental groups were 13.58 and 15.56 respectively. The difference in overall means for the *low* and *high* level groups was not statistically significant (F-2.4151). The difference in overall means for the control and experimental groups was significant (F-14.5090). These significance tests are summarized in Table IXa. Also given in this summary table are

TABLE VIII
GROUP MEANS FOR ADDITION TASK ON TRIALS 2, 3 AND 4

Low Level					High Level				
	Trials 2	3	4	Average		Trials 2	3	4	Average
Con.	24.45	24.91	32.09	27.15	Con.	29.73	32.00	31.41	31.05
Exp.	26.91	32.05	35.45	31.47	Exp.	28.00	32.09	36.59	32.23
Ave.	25.68	28.48	33.77	29.31	Ave.	28.86	32.05	34.00	31.64

Trials x Treatment					Levels x Treatment			
	Trials 2	3	4	Average		Low	High	Average
Con.	27.09	28.45	31.75	29.10	Con.	27.15	31.05	29.10
Exp.	27.45	32.07	36.02	31.85	Exp.	31.47	32.23	31.85

TABLE VIIIa
ANALYSIS OF VARIANCE SUMMARY

Source	df	ms	F	(df)
Between S	43	150.718		
Levels	1	357.010	2.4485	1,42
error (b	42	145.806		
Within S	220	48.941		
Trials	2	965.255		
Treat.	1	499.140	3.6821	1,42
Trials x Treat.	2	96.345	8.9240*	2,84
Trials x Levels	2	73.475		
Treat. x Levels	1	162.280	1.1971	1,42
Trials x Treat. x Levels	2	112.545	10.4245*	2,84
Error (w)	210	36.240		
$Error_1$ (w)	84	12.024		
$Error_2$ (w)	42	135.558		
$Error_3$ (w)	84	10.796		
Totals	263			

F .05 = 4.08 df = 1,42 *F significant
F .05 = 3.12 df = 2,84

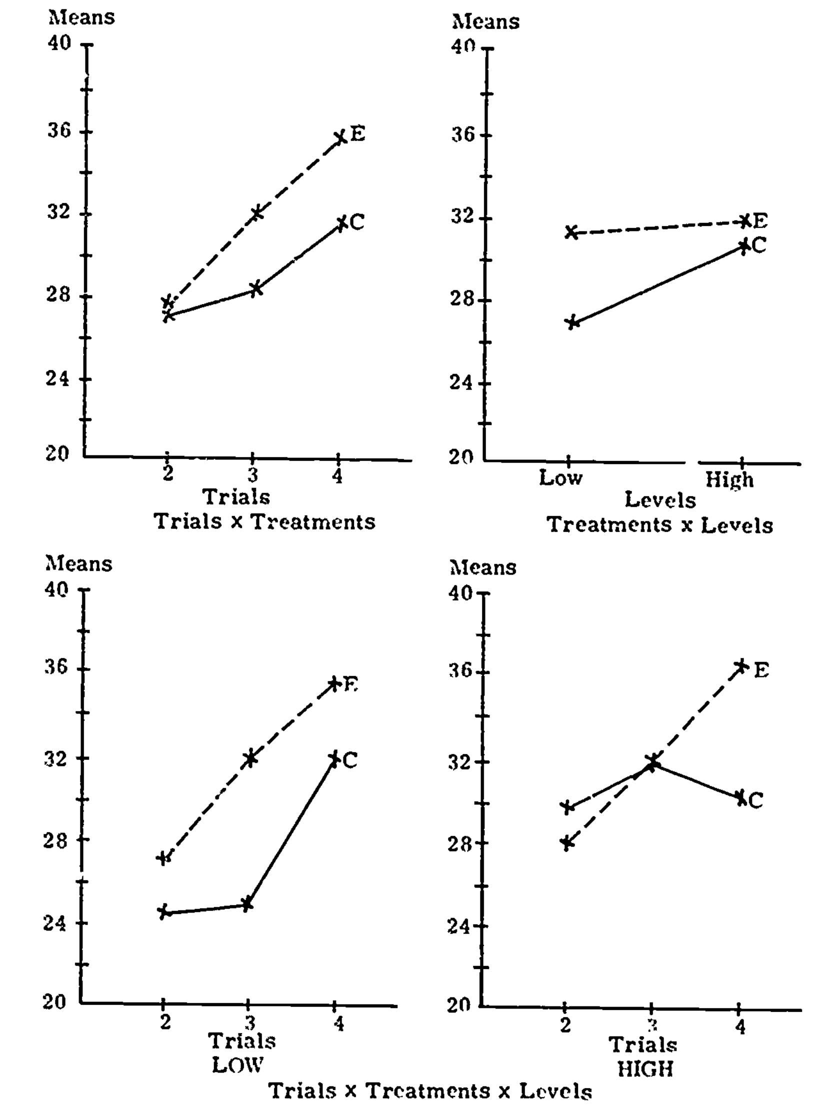

Figure 8 Interaction for Addition Task on Trials 2, 3 and 4

the significance tests for the interaction effects of interest. The trials x treatments interaction with an F of 5.4721 and trials x treatments x levels interaction (F-5.0926) were both statistically significant. The treatment x levels interaction (F-0.7606) was not.

Figure 9 illustrates the nature of the observed interaction effects graphically. The trials x treatments graph shows that the experimental group started at a higher point on trial 2 than the control group, maintained that difference on trial 3 and substantially increased that difference on trial 4. This interaction was statistically significant. The treatments x levels interaction was not statistically significant. In analyzing the trials x treatments x levels the graph for the *low* level shows that there was almost parallel gain for the two groups on trials 2, 3 and 4. However, for the *high* level the experimental group was only slightly above the control group on trial 2, but increased the difference on trial 3. Even though the *high* level experimental group did not show a marked increase on trial 4, the *high* level control group had a lower mean on this trial than on the preceding one which resulted in greater overall difference in the two groups on trial 4. As already noted this difference in trials x treatments interaction from level to level was statistically significant.

Summary of Analysis for Reasoning Tasks Type VI Design

The difference between the overall means for the *low* and *high* level groups was significant and in favor of the low group for the mazes task. The difference in overall means for the control and experimental groups was significant for two tasks—mazes and solving problems. In both cases the differences favored the experimental group.

TABLE IX
GROUP MEANS FOR SOLVING PROBLEMS TASK ON TRIALS 2, 3 AND 4

Low Level					High Level				
	Trials 2	3	4	Average		Trials 2	3	4	Average
Con.	9.82	12.82	15.91	12.85	Con.	13.73	15.23	13.95	14.30
Exp.	11.55	13.82	17.77	14.38	Exp.	14.23	17.82	18.18	16.74
Ave.	10.68	13.32	16.84	13.61	Ave.	13.98	16.52	16.07	15.52

Trials x Treatment					Levels x Treatment			
	Trials 2	3	4	Average		Low	High	Average
Con.	11.77	14.02	14.93	13.58	Con.	12.85	14.30	13.58
Exp.	12.89	15.82	17.98	15.56	Exp.	14.38	16.74	15.56

TABLE IXa
ANALYSIS OF VARIANCE SUMMARY

Source	df	ms	F	(df)
Between S	43	102.878		
Levels	1	240.548	2.4151	1,42
error (b)	42	99.600		
Within S	220	12.605		
Trials	2	362.535		
Treat.	1	260.017	14.5090*	1,42
Trials x Treat.	2	21.116	5.4721*	2,84
Trials x Levels	2	118.714		
Treat. x Levels	1	13.631	0.7606	1,42
Trials x Treat. x Levels	2	19.651	5.0926*	2,84
Error (w)	210	6.740		
$Error_1$ (w)	84	4.030		
$Error_2$ (w)	42	17.921		
$Error_3$ (w)	84	3.859		
Total	263			

F .05 = 4.08 df = 1,42 *F significant
F .05 = 3.12 df = 2,84

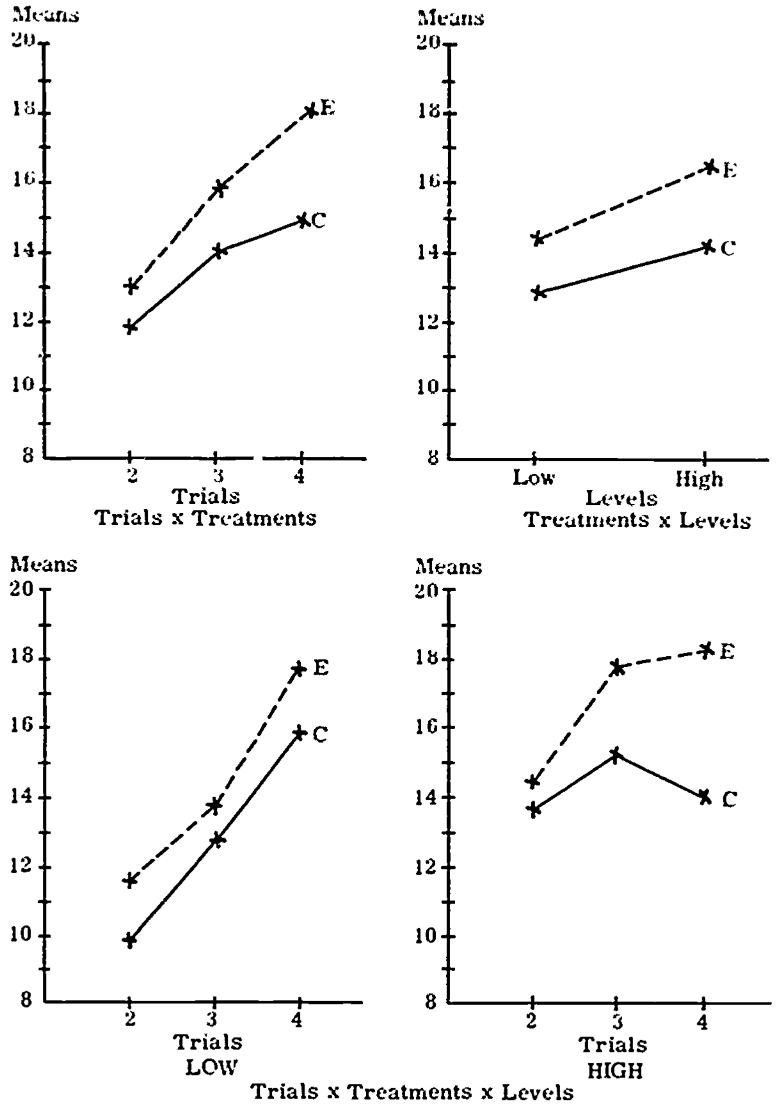

Figure 9 Interaction for Solving Problems Task on Trials 2, 3 and 4

The trials x treatments interaction effects were significant for mazes, design completion, addition and problem solving tasks. The nature of these significant interactions was in each instance characterized by a more rapid rate of gain for the experimental than for the control group from trial to trial.

The trials x treatments x levels interactions were significant for the same four tasks. While the treatments x trials interaction did thus differ from level to level it was again true that at each level the trial to trial improvement of the experimental group was either at least as rapid or more rapid than that of the control group.

Clerical Routine Tasks

CHECKING NAMES

Table X shows the mean performance on the checking names task for each level of the control and experimental groups on each of three trials at the research school. The overall means were 3.45 for the *low* level group and 4.81 for the *high* level group. The overall means were 3.77 for the control group and 4.49 for the experimental group. The difference in the means in both cases were statistically significant. These significance tests are summarized in Table Xa. The respective F-values are 32.2376 and 7.3038. Also given in this summary table are the significance tests for the interaction effects. The trials x treatments interaction with an F of 2.3462 and the treatments x levels interaction with an F of 1.6769 were both non-significant. The trials x treatments x levels interaction (F-5.9707) was statistically significant.

The nature of the observed interaction is illustrated graphically in Figure 10. The trials x treatments graph and the treatments x levels graphs are included for completeness even though, in view of the non-significance of these effects, no comment is made about them. The trials x treatments x levels graphs show that the *low* level experimental group increased steadily from trial to trial as did the *low* level control group. However, the control group exhibited a more rapid rate of improvement. The *high* level experimental group also made a continuous growth from trial to trial but the pattern for the *high* level control group was erratic. The *high* level control group was below the *high* level experimental group on trial 2, above on trial 3 and considerably below on trial 4. As has already been noted this difference in trials x treatments interaction from level to level was statistically significant.

TABLE X
GROUP MEANS FOR CHECKING NAMES ON TRIALS 2, 3 AND 4

	Low Level					High Level			
	Trials 2	Trials 3	Trials 4	Average		Trials 2	Trials 3	Trials 4	Average
Con.	1.86	3.05	3.82	2.91	Con.	3.86	5.41	4.59	4.62
Exp.	3.64	3.95	4.36	3.98	Exp.	4.05	5.00	5.95	5.00
Ave.	2.75	3.50	4.09	3.45	Ave.	3.95	5.20	5.27	4.81

	Trials x Treatment					Levels x Treatment		
	Trials 2	Trials 3	Trials 4	Average		Low	High	Average
Con.	2.86	4.23	4.20	3.77	Con.	2.91	4.62	3.77
Exp.	3.84	4.48	5.16	4.49	Exp.	3.98	5.00	4.49

TABLE Xa
ANALYSIS OF VARIANCE SUMMARY

Source	df	ms	F	(df)
Between S	43	6.573		
Levels	1	122.727	32.2376*	1,42
error (b)	42	3.807		
Within S	220	2.859		
Trials	2	42.186		
Treat.	1	34.909	7.3038*	1,42
Trials x Treat.	2	3.761	2.3462	2,84
Trials x Levels	2	1.920		
Treat x Levels	1	8.015	1.6769	1,42
Trials x Treat. x Levels	2	9.572	5.9707*	2,84
Error (w)	210	2.244		
Error₁ (w)	84	1.617		
Error₂ (w)	42	4.780		
Error₃ (w)	84	1.603		
Total	263			

F .05 = 4.08 df = 1,42 *F significant
F .05 = 3.12 df = 2,84

CHECKING NUMBERS

Table XI shows the mean performance of each level of each group for the checking numbers task. The overall means for the *low* and *high* levels were 6.36 and 5.04 respectively. The overall means were 5.20 for the control group and 6.20 for the experimental group. The differences between these pairs of means were both statistically significant. These significance tests are summarized in Table XIa. The F-values are 25.0041 and 9.9866 respectively. The significance tests for the interaction effects are also given in this summary table. The trials x treatments (F-2.0714), trials x levels (F-1.2471) and trials x treatments x levels (F-0.3809) interactions were not statistically significant.

Figure 11 illustrates the nature of the observed interaction. As before, when the interaction effects on a task were not significant, the graphs were included for the sake of completeness but no comment is called for.

CANCELING LETTERS

It may be noted from Table XII that the overall mean on the canceling letters task for the *low* level was 36.27 and for the *high* level 34.09. The overall means were 34.83 for the control group and 35.52 for the experimental group. No significant difference in overall means was found between the *low* and *high* levels. The same was true for the difference between the overall means of the control and experimental groups. The results of these tests are summarized in Table XIIa. The respective F-values are 1.9307 and .0988. The interaction effects of interest are also given in this summary table. The trials x treatments interaction with an F of 3.2624 was statistically significant. The

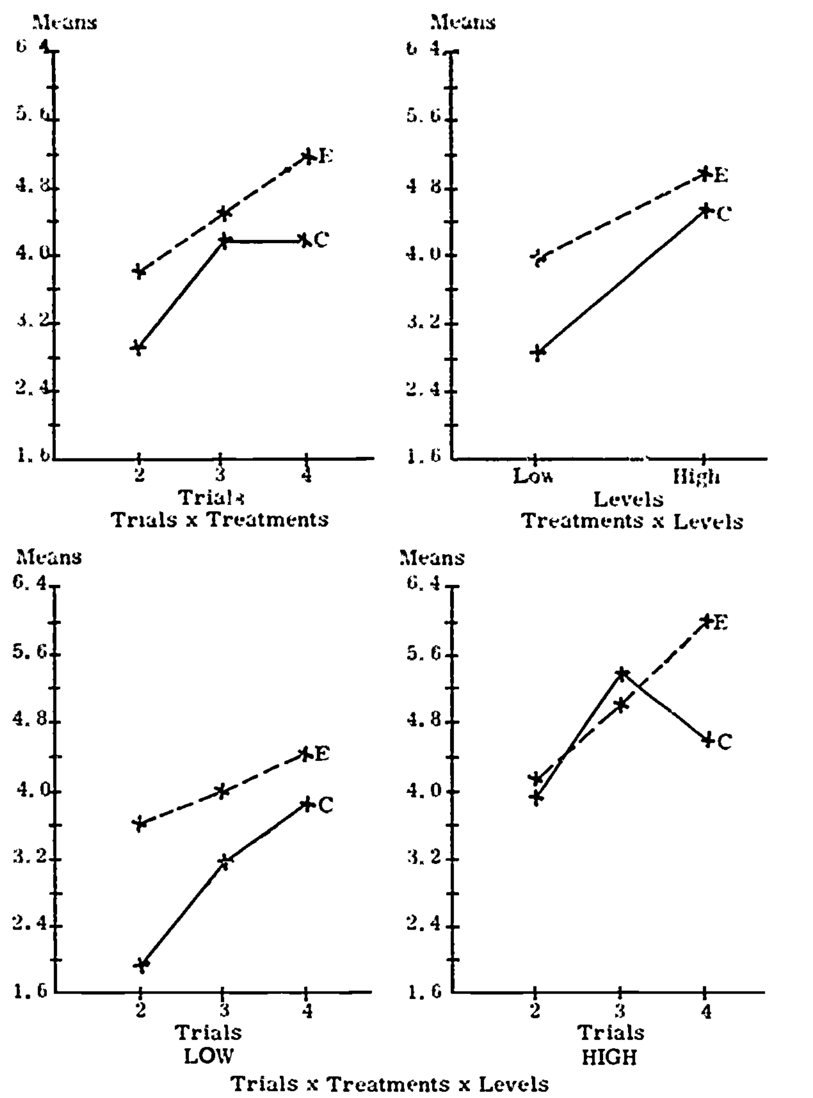

Figure 10 Interaction for Checking Names Task on Trials 2, 3 and 4

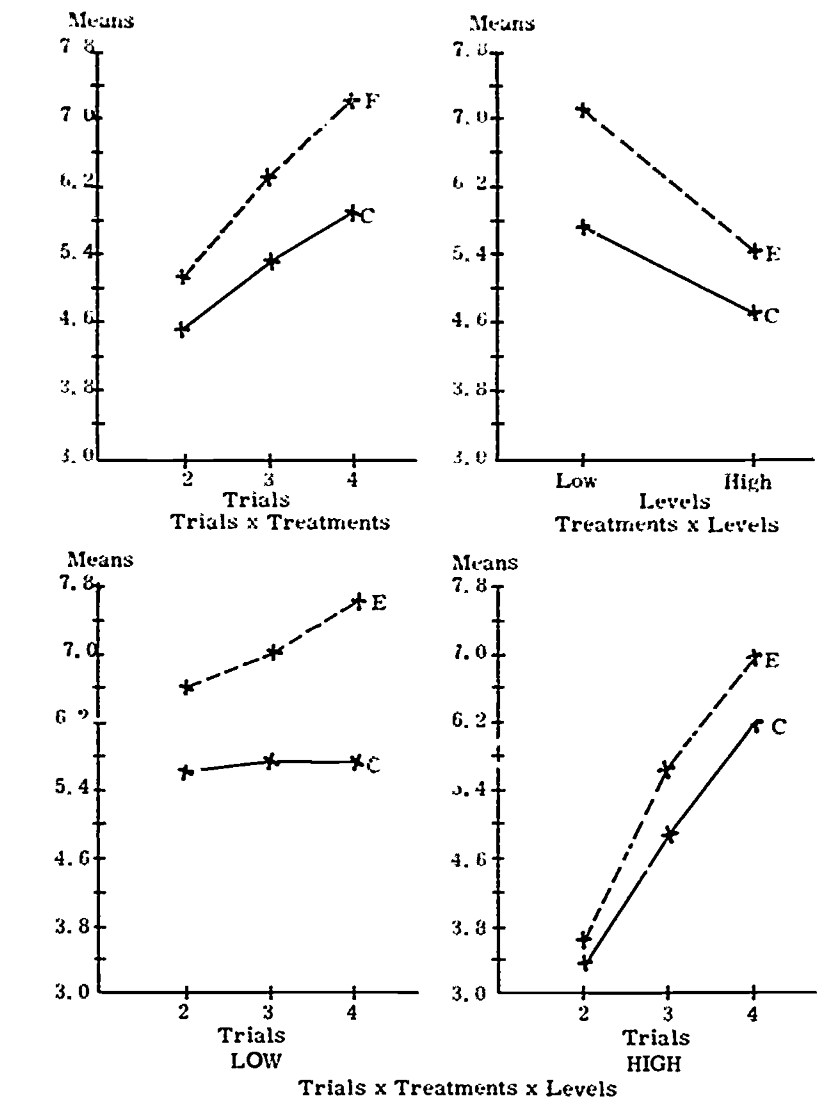

Figure 11 Interaction for Checking Numbers Task on Trials 2, 3 and 4

TABLE XI
GROUP MEANS FOR CHECKING NUMBERS TASK ON TRIALS 2, 3 AND 4

Low Level

	Trials 2	Trials 3	Trials 4	Average
Con.	5.59	5.73	5.73	5.68
Exp.	6.59	7.00	7.55	7.05
Ave.	6.09	6.36	6.64	6.36

High Level

	Trials 2	Trials 3	Trials 4	Average
Con.	3.32	4.77	6.05	4.71
Exp.	3.59	5.64	6.68	5.36
Ave.	3.45	5.20	6.45	5.04

Trials x Treatment

	Trials 2	Trials 3	Trials 4	Average
Con.	4.45	5.25	5.89	5.20
Exp.	5.09	6.32	7.20	6.20

Levels x Treatment

	Low	High	Average
Con.	5.68	4.71	5.20
Exp.	7.05	5.36	6.20

TABLE XIa
ANALYSIS OF VARIANCE SUMMARY

Source	df	ms	F	(df)
Between S	43	7.229		
Levels	1	116.004	25.0041*	1,42
error (b)	42	4.639		
Within S	220	3.475		
Trials	2	69.595		
Treat.	1	67.004	9.9866*	1,42
Trials x Treat.	2	2.617	2.0714	2,84
Trials x Levels	2	33.595		
Treat. x Levels	1	8.367	1.2471	1,42
Trials x Treat. x Levels	2	0.481	0.3809	2,84
Error (w)	210	2.269		
Error₁ (w)	84	1.055		
Error₂ (w)	42	6.709		
Error₃ (w)	84	1.264		
Total	263			

F .05 = 4.08 df = 1,42 *F significant
F .05 = 3.12 df = 2,84

TABLE XII
GROUP MEANS FOR CANCELING LETTERS TASK ON TRIALS 2, 3 AND 4

Low Level

	Trials 2	Trials 3	Trials 4	Average
Con.	36.59	32.41	41.32	36.77
Exp.	31.09	32.95	43.23	35.76
Ave.	33.84	32.68	42.27	36.27

High Level

	Trials 2	Trials 3	Trials 4	Average
Con.	28.36	31.95	38.36	32.89
Exp.	30.09	34.50	41.27	35.29
Ave.	29.23	33.23	39.82	34.09

Trials x Treatment

	Trials 2	Trials 3	Trials 4	Average
Con.	32.48	32.18	39.84	34.83
Exp.	30.59	33.73	42.25	35.52

Levels x Treatment

	Low	High	Average
Con.	36.77	32.89	34.83
Exp.	35.76	35.29	35.52

TABLE XIIa
ANALYSIS OF VARIANCE SUMMARY

Source	df	ms	F	(df)
Between S	43	165.100		
Levels	1	312.010	1.9307	1,42
error (b)	42	161.602		
Within S	220	112.188		
Trials	2	2316.550		
Treat.	1	31.360	0.0988	1,42
Trials x Treat.	2	113.570	3.2624*	2,84
Trials x Levels	2	147.675		
Treat. x Levels	1	191.750	0.6039	1,42
Trials x Treat. x Levels	2	61.505	1.7668	2,84
Error (w)	210	91.332		
Error₁ (w)	84	34.755		
Error₂ (w)	42	317.526		
Error₃ (w)	84	34.811		
Total	263			

F .05 = 4.08 df = 1,42 *F significant
F .05 = 3.12 df = 2,84

treatments x levels and the trials x treatments x levels interaction with F values of 0.6039 and 1.7668 respectively were not significant.

Figure 12 shows the nature of the observed interaction graphically. The trials x treatment graph shows that the experimental group was lower than the control group on trial 2, was higher on trial 3 and increased that difference on trial 4. As in the case of the design completion task, this cross-over effect explains why the mean for the experimental group over all trials was not significantly larger than that for the control group. This difference in rate of gain was significant. Although the interaction effects for treatments x levels and trials x treatments x levels were not significant, the graphs illustrating the interaction are included for completeness.

CANCELING NUMBERS

The various means for the canceling-numbers task are shown in Table XIII. The overall means for the *low* and *high* levels were 53.70 and 51.45 respectively. The overall means of 51.63 and 53.32 apply respectively to the control and experimental groups. As may be noted from the summary Table XIIIa neither of these pairs of means differ significantly. The respective F-values are 1.7012 and 0.5529. Moreover, only one of the interaction effects of interest was statistically significant. This one was the trials x treatments x levels interaction with an F of 8.8986.

The nature of the observed interaction effects are illustrated graphically in Figure 13. The trials x treatments and treatments x levels interaction graphs are included for completeness. In the case of the trials x treatments x levels triple interaction the graph for the *low* level shows the experimental group to be at a lower point on trial 2, a higher point on trial 3 and a lower point again on trial 4. The *high* level experimental group, on the other hand, started higher than the *high* level control group, was still above, though not by as much, on trial 3 but again increased the difference on trial 4. This triple interaction as observed for the *low* and *high* levels was significant.

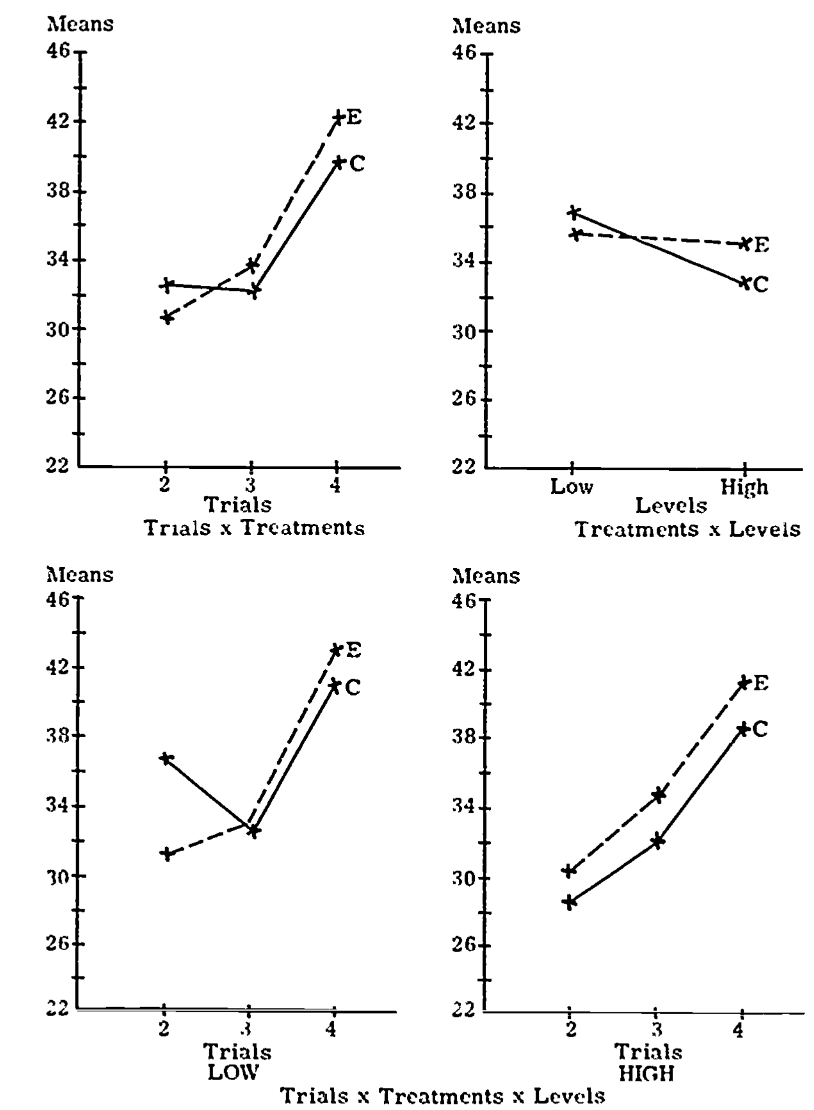

Figure 12 Interaction for Canceling Letters Task on Trials 2, 3 and 4

Summary of Analysis for Clerical Routine Tasks—Type VI Design

The difference between the overall means for the *low* and *high* level groups was significant and in favor of the *high* level for the checking-names task and significant but in favor of the *low* level group on the checking numbers task. The difference in the overall means of the control and experimental groups was also significant for the same tasks. In both instances the advantage favored the experimental group.

TABLE XIII
GROUP MEANS FOR CANCELING NUMBERS TASK ON TRIALS 2, 3 AND 4

	Low Level					High Level			
	Trials 2	3	4	Average		Trials 2	3	4	Average
Con.	46.82	52.59	62.45	53.95	Con.	46.95	53.27	47.68	49.30
Exp.	45.86	55.59	58.91	53.45	Exp.	50.86	53.95	55.95	53.59
Ave.	46.34	54.09	60.68	53.70	Ave.	48.91	53.61	51.82	51.45

	Trials x Treatment					Levels x Treatment		
	Trials 2	3	4	Average		Low	High	Average
Con.	46.89	52.93	55.07	51.63	Con.	53.95	49.30	51.63
Exp.	48.36	54.77	57.43	53.52	Exp.	53.45	53.59	53.52

TABLE XIIIa
ANALYSIS OF VARIANCE SUMMARY

Source	df	ms	F	(df)
Between S	43	200.962		
Levels	1	336.390	1.7012	1,42
error	42	197.737		
Within S	220	133.542		
Trials	2	1744.145		
Treat.	1	236.740	0.5529	1,42
Trials x Treat.	2	4.355	0.1410	2,84
Trials x Levels	2	771.055		
Treat. x Levels	1	378.220	0.8834	1,42
Trials x Treat. x Levels	2	274.805	8,8986*	2,84
Error (w)	210	110.359		
$Error_1$ (w)	84	30.938		
$Error_2$ (w)	42	428.158		
$Error_3$ (w)	84	30.882		
Total	263			

F .05 = 4.08 df = 1,42 *F significant
F .05 = 3.12 df = 2,84

The trials x treatments interaction effect was significant for the canceling letters task. The nature of this significant interaction was characterized by a more rapid rate of gain from trial to trial for the experimental group than for the control group.

The trials x treatments x levels interaction effects were significant for the checking names and canceling numbers tasks. On the checking names task the *low* level control group appeared to be making more rapid trial to trial progress than the *low* level experimental group. Though the pattern was erratic, this did not seem to be true of the *high* level groups. However, on the whole, the experimental group tended to be superior to the control group on all trials at both levels, a fact consistent with the previously mentioned overall superiority of the experimental group. On the canceling numbers task there was not much basis for choice between the two treatments for the *low* level group, but the experimental treatment appeared to have the advantage in the case of the *high* level group.

Analysis of Variance by Type I Design

Consideration is now given to the statistical significance of the difference between the overall means of the control and ex-

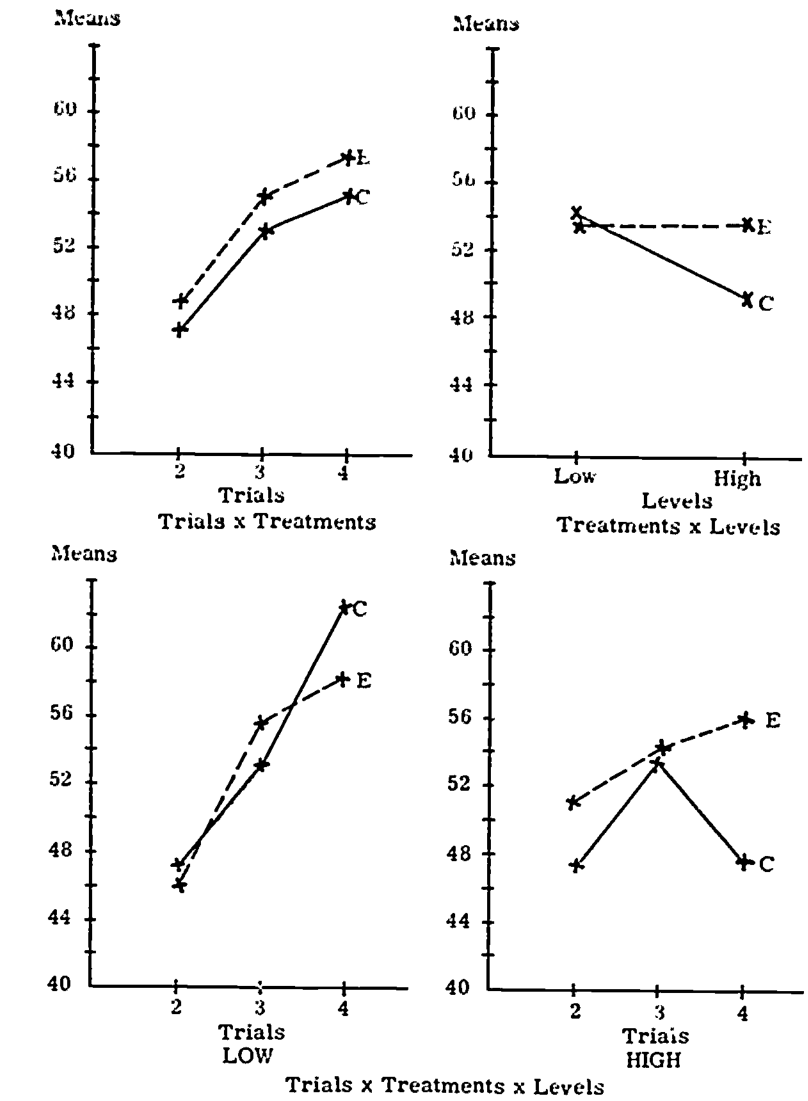

Figure 13 Interaction for Canceling Numbers Task on Trials 2, 3 and 4

perimental groups on trial 5. The test for significance, using F as the test statistic and .05 as the significance level was carried out for each of the criterion measures.

Reasoning Tasks

MAZES

As shown in Table XIV the means on this fifth trial for the mazes task were 5.25 for the control group and 5.70 for the experimental group. The difference between these means was statistically significant. The significance test is summarized in Table XIVa. The F-value for the difference between these two means is 6.6307. Also summarized in Table XIVa is the significance test for the treatments x levels interaction effect. This interaction was statistically significant (F-9.5095).

The nature of this observed interaction is illustrated graphically in Figure 14. There was little difference between the *low* level experimental and control groups but a considerable difference between the *high* level experimental and control groups.

DESIGN COMPLETION

On the design completion task the means on the fifth trial were 72.52 for the control group and 79.00 for the experimental group (see Table XV). The difference between these means was statistically significant (F-4.1477). The significance test is summarized in Table XVa. The test for the treatments x levels interaction effect was not significant (F-.0943).

ANALOGIES

The means for the analogies task are shown in Table XVI. The control group mean was 16.48 and the experimental group mean was 19.32. The F-test (see Table XVIa) indicated that the difference between these two means was significant (F-7.3906). The treatments x levels interaction effect was not significant (F-0.0800).

TABLE XIV

GROUP MEANS FOR MAZES TASK ON TRIAL 5

Levels x Treatment

	Low	High	Average
Con.	5.41	5.09	5.25
Exp.	5.32	6.09	5.70

TABLE XIVa

ANALYSIS OF VARIANCE SUMMARY

Source	df	ms	F	(df)
Between S	43	0.790		
Levels	1	1.136		
error (b)	42	0.781		
Within S	44	0.909		
Treat.	1	4.545	6.6307*	1,42
Treat. x Levels	1	6.546	9.5095*	1,42
error (w)	42	0.688		
Total	87			

F .05 = 4.08 df = 1,42 *F significant

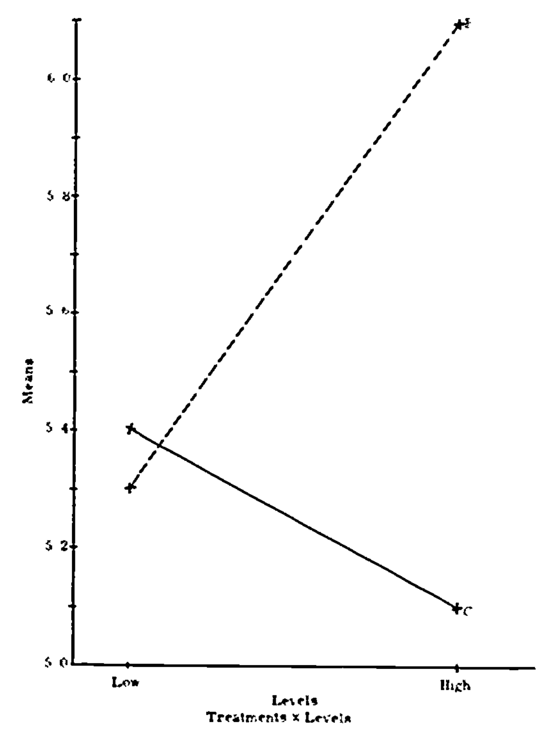

Figure 14 Interaction for Mazes Task on Last Trial

TABLE XV

GROUP MEANS FOR DESIGN COMPLETION TASK ON TRAIL 5

Levels x Treatment

	Low	High	Average
Con.	79.86	65.18	72.52
Exp.	85.36	72.64	79.00

TABLE XVa

ANALYSIS OF VARIANCE SUMMARY

Source	df	ms	F	(df)
Between S	43	342.733		
Levels	1	4131.920		
error (b)	42	252.514		
Within S	44	233.875		
Treat.	1	923.020	4.1477*	1,42
Treat. x Levels	1	20.980	0.0943	1,42
error (w)	42	222.536		
Total	87			

F .05 = 4.08 df = 1,42 *F significant

ADDITION

The means on the addition task were 31.59 for the control group and 35.30 for the experimental group as shown in Table XVII. The difference between these two means was significant (F-7.2049, see Table XVIIa). The treatments x levels interaction effect was not significant (F-.9439).

SOLVING PROBLEMS

The means for the problem solving task are given in Table XVIII. The means for the control and experimental groups were 13.41 and 17.84 respectively. The difference between these two means was statistically significant (F-34.3466, see Table XVIIIa). There was no significant treatments x levels interaction effect for this task (F-1.8292).

Summary of Analysis for Reasoning Tasks—Type I Design

The difference between the experimental and control groups means on trial 5 were statistically significant for all of the reasoning tasks at the .05 level. In every case the advantage lay with the experimental group.

A significant treatments x levels interaction was observed only in the case of the mazes task. For all practical purposes there was no difference between the means of the *low* level control and experimental groups on this task. However, the mean performance of the *high* level experimental group was markedly superior to that of the *high* level control group.

Clerical Routine Tasks

CHECKING NAMES

The means for the two groups on the checking names tasks are shown in Table XIX. The mean for the control group was 3.89. The mean for the experimental group was 5.14. The difference between these means was found to be significant (F-13.5476). This significance test is summarized in Table XIXa. Again, there was no significant treatments x levels interaction effect (F-0.2195).

TABLE XVI

GROUP MEANS FOR ANALOGIES TASK ON TRIAL 5

Levels x Treatment

	Low	High	Average
Con.	16.73	16.26	16.48
Exp.	19.86	18.77	19.32

TABLE XVIa

ANALYSIS OF VARIANCE SUMMARY

Source	df	ms	F	(df)
Between S	43	61.572		
Levels	1	13.920		
error	42	62.706		
Within S	44	27.011		
Treat.	1	177.555	7.3906*	1,42
Treat. x Levels	1	1.922	0.0800	1,42
error (w)	42	24.024		
Total	87			

F .05 = 4.08 df = 1,42 *F significant

TABLE XVII

GROUP MEANS FOR ADDITION TASK ON TRIAL 5

Levels x Treatment

	Low	High	Average
Con.	28.23	34.95	31.59
Exp.	33.27	37.32	35.30

TABLE XVIIa

ANALYSIS OF VARIANCE SUMMARY

Source	df	ms	F	(df)
Between S	43	63.168		
Levels	1	638.286		
error (b)	42	49.475		
Within S	44	47.761		
Treat.	1	301.922	7.2049*	1,42
Treat. x Levels	1	39.555	0.9439	1,42
error (w)	42	41.905		
Total	87			

F .05 = 4.08 df = 1,42 *F significant

TABLE XVIII

GROUP MEANS FOR SOLVING PROBLEMS TASK ON TRIAL 5

Levels x Treatment

	Low	High	Average
Con.	14.00	12.82	13.41
Exp.	17.41	18.27	17.84

TABLE XVIIIa

ANALYSIS OF VARIANCE SUMMARY

Source	df	ms	F	(df)
Between S	43	37.933		
Levels	1	0.555		
error (b)	42	38.823		
Within S	44	22.352		
Treat.	1	432.101	34.3466*	1,42
Treat. x Levels	1	23.013	1.8292	1,42
error (w)	42	12.581		
Total	87			

F .05 = 4.08 df = 1,42 *F significant

CHECKING NUMBERS

The means for the checking numbers task are given in Table XX. The difference between the mean of 5.93 for the control group and 6.84 for the experimental group was statistically significant (F-4.7098, see Table XXa). The F of 0.9537 for the interaction effect was not significant.

CANCELING LETTERS

The means for the control and experimental groups on the canceling letters task are shown in Table XXI. They are 38.82 and 41.61 respectively. The difference between these two means

TABLE XIX

GROUP MEANS FOR CHECKING TASK ON TRIAL 5

Levels x Treatment

	Low	High	Average
Con.	3.41	4.36	3.89
Exp.	4.50	5.77	5.14

TABLE XIXa

ANALYSIS OF VARIANCE SUMMARY

Source	df	ms	F	(df)
Between S	43	2.988		
Levels	1	27.284		
error (b)	42	2.410		
Within S	44	3.216		
Treat.	1	34.375	13.5476*	1,42
Treat. x Levels	1	0.557	0.2195	1,42
error (w)	42	2.537		
Total	87			

F .05 = 4.08 df = 1,42 *F significant

was not significant (F-1.2220). The treatment x levels interaction effect was also non-significant (F-.2269). These significance tests are summarized in Table XXIa.

CANCELING NUMBERS

The means for the fifth trial on the canceling numbers task were 53.23 for the control group and 56.34 for the experimental group. These means are given in Table XXII. The difference between these two means was not significant (F-.8818). However, the treatments x levels interaction was found to be significant (F-4.4856). These significance tests are summarized in Table XXIIa.

Figure 15 illustrates the nature of this observed interaction graphically. The graph shows that the *low* level experimental group had a much higher mean than the *low* level control group, but the *high* level experimental group had a lower mean than the *high* level control group. This difference in levels was significant.

Summary of Analysis for Clerical Routine Tasks—Type I Design

The difference between the means of the control and experimental groups was significant and in favor of the latter group for two of the tasks (checking names and checking numbers).

The only significant treatments x levels interaction was observed in the case of the canceling numbers task. The nature of this observed interaction was such as to suggest that the experimental treatment was the better when used with *low* level groups and that the reverse is true in the case of *high* level groups

New Concepts

FILMS

The means for the two groups on the films task are given in Table XXIII. The mean for the control group was 11.09. The mean for the experimental group was 11.80. The difference between these means was not significant (F-3.7702, see Table XXIIIa). The treatments x levels interaction was significant (F-4.8056).

TABLE XX

GROUP MEANS FOR CHECKING NUMBERS TASK ON TRIAL 5

Levels x Treatment

	Low	High	Average
Con.	5.82	6.05	5.93
Exp	7.14	6.35	6.84

TABLE XXa

ANALYSIS OF VARIANCE SUMMARY

Source	df	ms	F	(df)
Between S	43	2.392		
Levels	1	0.727		
error (b)	42	2.432		
Within S	44	4.182		
Treat.	1	18.182	4.7098*	1,42
Treat. x Levels	1	3.682	0.9537	1,42
error (w)	42	3.860		
Total	87			

F .05 = 4.08 df = 1,42 *F significant

Figure 16 illustrates the nature of the observed interaction graphically. This treatments x levels graph shows that there was very little difference between the means of the *low* level control and experimental groups. However, there was considerable difference between the means of the *high* level control and experimental groups. The difference in levels was significant.

TABLE XXI

GROUP MEANS FOR CANCELING LETTERS TASK ON TRIAL 5

Levels x Treatment

	Low	High	Average
Con.	43.55	34.09	38.82
Exp.	45.14	38.09	41.61

TABLE XXIa

ANALYSIS OF VARIANCE SUMMARY

Source	df	ms	F	(df)
Between S	43	124.660		
Levels	1	1497.370		
error (b)	42	91.977		
Within S	44	138.920		
Treat.	1	171.920	1.2220	1,42
Treat. x Levels	1	31.920	0.2269	1,42
error (w)	42	140.682		
Total	87			

F .05 = 4.08 df = 1,42 *F significant

TABLE XXII

GROUP MEANS FOR CANCELING NUMBERS TASK ON TRIAL 5

Levels x Treatment

	Low	High	Average
Con.	50.32	56.14	53.23
Exp.	60.45	52.23	56.34

TABLE XXIIa

ANALYSIS OF VARIANCE SUMMARY

Source	df	ms	F	(df)
Between S	43	145.707		
Levels	1	31.920		
error (b)	42	148.416		
Within S	44	260.398		
Treat.	1	213.290	0.8818	1,42
Treat. x Levels	1	1085.000	4.4856*	1,42
error (w)	42	241.886		
Total	87			

F .05 = 4.08 df = 1,42 *F significant

Figure 15 Interaction for Canceling Numbers Task on Last Trial

TABLE XXIII
GROUP MEANS FOR FILMS TASK ON LAST TRIAL

Levels x Treatment

	Low	High	Aver-age
Con.	11.64	10.55	11.09
Exp.	11.55	12.05	11.80

TABLE XXIIIa
ANALYSIS OF VARIANCE SUMMARY

Source	df	ms	F	(df)
Between S	43	3.796		
Levels	1	1.921		
error (b)	42	3.840		
Within S	44	3.330		
Treat.	1	10.921	3.7702	1,42
Treat. x Levels	1	13.920	4.8056*	1,42
erro⁻ (w)	42	2.897		
Total	87			

F .05 = 4.08 df = 1,42 *F significant

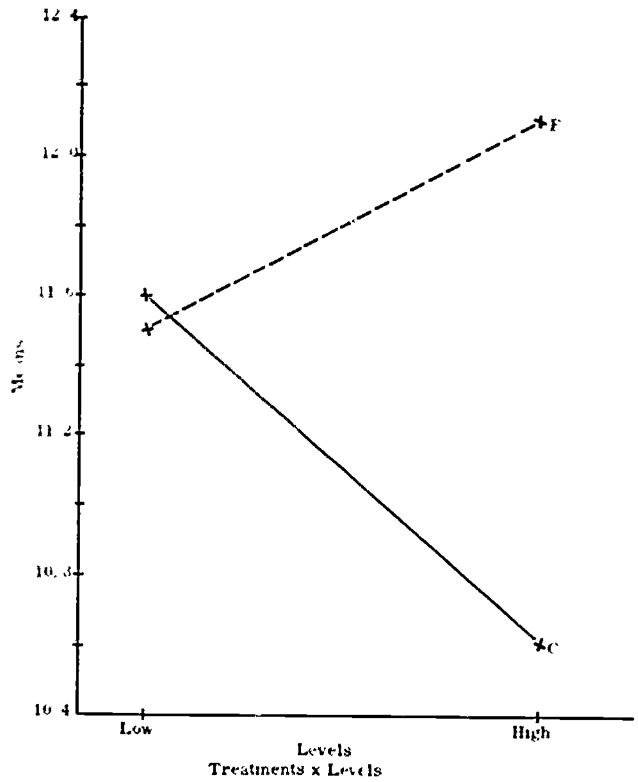

Figure 16 Interaction for Films Task on Last Trial

CHAPTER V — SUMMARY AND CONCLUSIONS

Purpose of the Study

The purpose of this study was to investigate and obtain objective evidence on the effect that thermal environments (temperature, air movement and humidity) in school classrooms on the learning that takes place in those environments.

Procedures

The Lennox Industries, Inc., made available a two room school plant in which the thermal environment was completely controlled. A model thermal environment (based on recommended standards by authorities in the field) was created and maintained in one classroom and a marginal classroom environment (based on conditions to which the subjects were accustomed) was created in the other classroom. This marginal classroom thermal environment was always under the control of the teacher, to alter as she saw fit. The rooms were identical except that the number of cubic feet in one was greater than in the other. Lennox Industries assigned their resident research engineer to create, maintain and measure the desired thermal conditions.

Two classrooms of fourth grade children were matched so as to insure no significant differences between the classes as to achievement, intelligence, home background, age and sex. The matched fourth grade children were from the Saydel School District in Des Moines.

During the period of the experiment the two groups received exactly the same treatment, performed the same tasks at the same time of day, with the exception that they occupied rooms with different thermal environments. The children did not know which room was designated as ideal until after the whole experiment was completed.

In addition to their regular classroom activities the groups in each room spent approximately a half hour in the morning and a half hour in the afternoon performing various paper and pencil tasks. These tasks were classified into three broad categories—Reasoning Tasks, Clerical Routine Tasks and Tasks involving knowledge of content material obtained by watching science films. Seven tasks were performed once a week—Mazes, Design Completion, Analogies, Checking Names, Checking Numbers, Canceling Letters and Canceling Numbers. The Addition and Solving Problems Tasks were performed daily during the first and third weeks but only three times during the second week. There was one film shown the first week, two the second and one the third week.

The tasks were presented to the children throughout the experiment in a folio prepared in advance with the same tasks in the same order face down on their desks. No child saw the material to be worked on until the signal to start work was given. They all stopped when the signal to stop work was given. All tasks were scored the day they were administered so that minor items which needed additional checking were cleared.

The experiment was duplicated by a second set of fourth grade children matched in the same factors as the first set. This second set (*high*) was differentiated from the first set (*low*) only because their mean achievement score (I. T. B. S.) was higher. This second set of children used opposite rooms at the research school from the first set for the experimental and control group to counterbalance the physical size factor of the

TABLE XXIV

OVERALL LEVEL MEANS — OVERALL TREATMENT MEANS AND INTERACTION FOR TASKS — TRIALS 2, 3 AND 4

	Group Levels			Treatment Groups			Interaction F-Values		
Tasks	Low	High	F-Value	Con.	Exp.	F-Value	Trials x Treat.	Treat. x Levels	Trials x Treat. x Levels
Reasoning									
Mazes	5.19	4.86	7.0759*	4.88	5.17	4.1551*	4.8821*	3.7290	3.9839*
Design Comp.	65.60	69.16	1.8062	66.99	67.67	.0581	11.2433*	.1003	4.4528*
Analogies	18.08	16.58	1.2746	16.46	18.20	2.7713	.4882	.4185	.3553
Addition	29.31	31.64	2.4485	29.10	31.85	3.6821	8.9240*	1.1971	10.4245*
Solving Problems	13.61	15.52	2.4151	13.58	15.56	14.5090*	5.4721*	.7606	5.0926*
Clerical									
Checking Names	3.45	4.81	32.2376*	3.77	4.49	7.3038*	2.3462	1.6769	5.9707*
Checking Numbers	6.36	5.04	25.0041*	5.20	6.20	9.9866*	2.0714	1.2471	0.3809
Cancel. Letters	36.27	34.09	1.9307	34.83	35.52	.0988	3.2624*	.6039	1.7668
Cancel. Numbers	53.70	51.45	1.7012	51.63	53.52	.5529	.1410	.8834	8.8986

*F — Value is significant.

TABLE XXV
TREATMENT GROUP MEANS AND INTERACTION FOR TASKS — LAST TRIAL

Tasks	Treatment Groups Con.	Exp.	F-Values	Interaction F-Values Treatments x Levels
Reasoning				
Mazes	5.25	5.70	6.6307*	9.5095*
Design Completion	72.52	79.00	4.1477*	.0943
Analogies	16.48	19.32	7.3906*	.0800
Addition	31.59	35.30	7.2049*	.9439
Solving Problems	13.41	17.84	34.3466*	1.8292
Clerical				
Checking Names	3.89	5.14	13.5476*	.2195
Checking Numbers	5.93	6.84	4.7098*	.9537
Canceling Letters	38.82	41.61	1.2220	.2269
Canceling Numbers	43.23	56.34	.8818	4.4855*
New Concepts				
Films	11.09	11.80	3.7702	4.8056*

*F-Value is significant.

room. Morning and afternoon tasks were interchanged for the second set of subjects to counterbalance time of day when the tasks were performed.

The data evaluated consisted of scores representing the number of correct responses to the 10 tasks each subject practiced at least once a week. A null hypothesis was tested concerning the differences among means using analysis of variance. Two different designs were used—Type VI to determine the differences in the groups on subsequent trials during the period they were at the research school and a Type I to determine the differences in the two groups on the last trial as a result of the treatment.

Summary of the Results

The summary of findings is presented in tabular form. The overall level means, overall treatment means and interactions over trials for each criterion measure are shown in Table XXIV. The treatment group means and interaction for each criterion measure on the last trial are shown in Table XXV.

REASONING CRITERION MEASURES

The difference between the overall *low* and *high* level group means was significant for one reasoning task—mazes (See Table XXIV). This difference was in favor of the *low* level group.

The difference in the overall means for the control and experimental group was significant for mazes and problem solving for the experimental period. On the last trial (Table XXV) the differences in means between these two groups were significant for all of the reasoning criterion measures. In all cases the differences favored the experimental group.

For mazes, design completion, addition and problem solving tasks the trials x treatments interaction effects were significant (Table XXIV). In each case the nature of those significant interactions was characterized by a faster rate of gain from trial to trial for the experimental group than for the control group.

The treatments x levels interaction on the last trial (Table XXV) for mazes was of such a nature that there was very little difference between the means of the *low* level control and experimental groups. On the other hand the mean performance of the *high* level experimental group was considerably higher than that of the *high* level control group.

The trials x treatments x levels interactions were significant for the mazes, design completion, addition and problem solving tasks (Table XXIV). Even though the trials x treatments interaction differed from level to level the improvement of the experimental group from trial to trial was at least as great as or greater than that of the control group.

The hypothesis of no difference in learning under a model thermal environment and a marginal classroom thermal environment as measured by the performance of the groups in the experimental situation was rejected for two tasks (mazes and problem solving) and accepted for three (design completion, analogies, and addition). When the last trial differences were used the hypothesis was repected for all five tasks.

CLERICAL CRITERION MEASURES

For the checking names and checking numbers tasks the difference between the overall level means for the *low* and *high* level groups was significant. This difference favored the *low* level groups for the checking numbers task and the *high* level group for the checking names task (Table XXIV).

The difference between the overall means for the control and experimental groups was significant for the checking names and checking numbers task in the experimental situation. The difference between the means of the two groups on the last trial for the same two tasks was also significant. In the experimental situation and one the last trial the difference favored the experimental group (Tables XXIV and XXV).

The significant trials x treatments interaction was for the canceling letters task. This significant interaction was characterized by a more rapid rate of growth from trial to trial for the experimental group (Table XXIV).

The treatments x levels interaction which was significant was observed in the case of the canceling numbers task. The nature of this interaction was such that the experimental treatment favored the *low* level group (Table XXV).

For the checking names and canceling numbers task the trials x treatments x levels interaction effects were significant. The *low* level control group appeared to make more rapid trial to trial gain than the *low* level experimental group. Though the pattern was erratic, this did not seem to be true for the *high* level group. However, the overall effect was such that the experimental group was superior on all trials at both levels. On the canceling numbers task the two treatments appeared to have the same effect on the *low* level group but with the *high* level group the experimental treatment was effective (Table XXIV).

In two of the four tasks (checking names and checking numbers) the hypothesis of no difference in learning under a recommended ideal thermal environment and a regular classroom environment as measured by the performance of the two groups in the experimental situation and on the last trial was rejected. The hypothesis was retained for the canceling letters and canceling numbers tasks in both cases.

NEW CONCEPTS CRITERION MEASURE

The difference between the means of the control and experimental groups was not significant for the films task (Table XXV).

The treatments x levels interaction observed was of such a nature that the experimental treatment did not have much effect on the *low* level group but was effective with the *high* level group. However, when the low and high level groups were combined the experimental group outperformed the control group.

The hypothesis of no difference in learning under model thermal conditions and marginal classroom conditions was retained.

Conclusions

This study was designed to determine the difference, if any, in learning between a group of students in a model thermal environment and another group in a marginal thermal environment. Learning in this experiment was measured by the number of correct responses to a repeated series of 10 paper and pencil tasks. Within the limitations of this experiment, using the selected tasks, using fourth grade students, and using thermal conditions prescribed, the following conclusions seem justified.

On the whole, the experiment showed large improvement on the part of every child taking part in 10 types of work. In every task, however, the experimental group which occupied the room with model thermal conditions, improved more than the control group.

1. The significantly higher gains made by pupils in the experimental group indicated the prescribed model environment was superior to the marginal thermal environment for all reasoning and some clerical tasks.

2. The superiority of the experimental group on the new concepts task was not significant and may have been a chance difference.

3. The interaction between trials and levels and treatments indicated the model environment favored the experimental group in all of the tasks, although the experimental effect varied in some tasks from level to level.

REASONING TASKS

When learning in reasoning tasks is measured by the number of correct responses on: completing mazes and designs; adding columns of numbers, determining the relationship of words; and solving word problems involving mathematical processes, the result was a progression in gain for both the control and experimental groups. The rate of gain for the experimental group was greater than that of the control group, and the difference between the two groups increased with each trial while in the experimental situation.

In all of the reasoning tasks the differences between the means was significant by trial 5 at the .05 level. On the whole the interaction effects observed favored the experimental group in all of the tasks.

CLERICAL ROUTINE TASKS

When mental efficiency is measured by the gain made in the number of correct responses on successive trials in such tasks as: checking similar names and numbers on a page of names and numbers; and canceling designated letters and numbers on a page containing rows and columns of letters and numbers, the results indicate that both the experimental and control group gained in efficiency through practice. For all of the tasks the overall observed interaction effects were of such a nature that they favored the experimental group. The overall results in the differences in performance between the two groups indicate that the thermal environment does have an effect on mental efficiency when students are performing clerical tasks calling for quick recognition and response. The effect is not nearly as pronounced when the clerical tasks are more routine and monotonous in nature.

TASKS INVOLVING NEW CONCEPTS

When learning new concepts (presented via films) is measured by the difference in the number of correct responses made by the two groups on written tests, the results showed little difference for *low* level control and experimental groups. However, the difference was much greater for *high* level control and experimental groups. While the overall difference between means was not statistically significant the amount of difference increased from trial to trial.

Implications

Rejection of the null hypothesis, (H: there is no difference in learning under model thermal conditions and marginal thermal conditions) reveals that there is apparently a tenable relationship between the thermal environment in which children work and study and their effectiveness in accomplishing their goals. The knowledge of this relationship affords us increased control over our mental functions. It adds to our understanding, gives us the power to increase efficiency in learning, and places on us the responsibility to provide the necessary environment for learning.

Never before has so much been expected of teachers and children. With the advent of the age of space and automation teachers and children are expected to teach and learn more, and do it better than ever before. The results of this first study would suggest that for increased mental efficiency teachers and children should be exposed to a well controlled thermal environment if they are to meet the demands placed upon them by a rapidly changing society.

Further, school administrators, boards of education and architects who are responsible for designing and constructing school buildings have a new dimension to consider in determining economy. This dimension is "economy in learning." The relationship accepted in this study suggests that school buildings in which the thermal environment is not adequately controlled bring about inefficiency in learning. While this study must be construed as only a beginning, it does open up several pertinent questions about school buildings. First, the literature reveals that when economies must be effected in school buildings, adequate heating, ventilating and control systems are often among the first features to be compromised. Second, the use of large amounts of glass areas in buildings is questionable. Large expanses of glass make it extremely difficult to control the thermal environment. (In this study refrigerated air had to be used to keep the experimental room at 72F-74F when the outside temperature was above 50F.)

Some areas suggested for further research and study include:

1. Will narrower ranges in the control of the elements of the thermal environment mean proportionately greater gains in learning?

2. Is there an inter-relationship between temperature, humidity and air movement? Will learning be affected if one or two of these factors are at an optimum level and the third not at an optimum level?

3. Would the superiority of the group in an ideal thermal environment become even greater if the experiment were extended over a greater length of time or would it become asymptotic, suggestive of a plateau of successful utilization? (Study now underway)

4. What role, if any, does the thermal environment play in partially neutral functions like hearing and vision, in pure memory, in the learning of vocabulary, in reaction time of responses, uses of automated teaching devices, in fine muscle work and the creative arts? (Study now underway)

5. Is there any relationship between pupil and teacher morale and thermal environment?

6. Is there any relationship between learning and environment when one or both groups are in an ideal thermal environment, but one group is in a well-lighted, windowless room?

7. Is there a fatigue factor present which can be overcome in a model environment? Do children tend to tire more by the middle of the afternoon in a poor thermal environment than in a model environment? (Study now underway)

8. Further analysis should be given to the phenomena disproved in this study in regard to individual intelligence and reaction to thermal environment. (Partly included in a study now underway)

9. Further studies should be developed using students from various grade levels ranging from kindergarten through college. (Older students—6th grade—are now used in the second study underway)

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