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A study of the need for improvement in classroom environment for optimum pupil growth, development and performance as an integrated whole

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TUDY OF THE NEED FOR IMPROVEMENT IN
OM ENVIRONMENT FOR OPTIMUM PUPIL GROWTH,
NT AND PERFORMANCE AS AN INTEGRATED WHOLE

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E. B. H.

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CHAPTER I

THE NEED FOR VISUAL-CENTERED CLASSROOMS

Dr. Norman L. Munn[1] of Bowdoin College recognized the individual as being the product of his heredity and environment. Dr. Arthur I. Gates[2] of Teachers College, Columbia University, wrote: "That the effects of heredity and environment are interwoven from the time of birth, that they cannot be isolated and studied in pure form, is now generally agreed." This principle seems to be generally accepted among educators, but in the writer's twenty years' experience in public schools education, environment has been considered mostly as personalities exerting influence on the individual, until comparatively recently. Dr. Charles E. Skinner of New York University commented: "The changes wrought in the environment often become potent means for changing the individual."[3] Dr. Howard C. Warren defined "environment" as "covering all physio-chemical, biological, and social phenomenon which act from without on the individual."[4] The Dictionary of Education[5] stated that environment is "a general term designating all the objects, forces, and conditions that affect the individual through such stimuli as he is able to receive."

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1. Psychology, pp. 70-87.
2. "The Nature and Measurement of Intelligence," Educational Psychology, p. 238.
3. "The Nature and Scope of Educational Psychology," Educational Psychology, p. 3.
4. Dictionary of Psychology.
5. Carter V. Good, Editor.

Extensive investigations in the past decade have shown the important part that daylighting, artificial lighting, color, seating, temperature controls, and other physical factors of the classroom play in the growth, development, performance, and well-being of the child.

Evidence of growing interest among educators is to be found in the numbers of institutes or conferences of the past two or three years[6] as well as research programs by educational institutions.[7] In the U. S. Office of Education,[8] efforts of such men as Dr. Nelson E. Viles[9] and Dr. Ray L. Hamon[10] are directed towards advanc-

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6. University of Richmond (with the Richmond Schools, A. I. A., Virginia State Department of Education, and Virginia Education Association); University of South Carolina (with South Carolina Department of Education); University of Georgia (with Georgia State Departments of Health and of Education); University of Pennsylvania; University of Pittsburgh (with A. I. A., I. E. S., Optometric Associations and others); University of Minnesota (with St. Paul Schools, the State Department of Education, and sixteen other state agencies and organizations); Indiana University (with Purdue University, Indiana State Department of Public Instruction, and the Indianapolis Schools); Washington University (St. Louis); Stanford University; University of Miami (Florida); Massachusetts Institute of Technology (with New England School Development Council); University of Montana; Central Oregon College of Education (with Oregon State Department of Education); Pacific University; Eastern Oregon College of Education (with Oregon State Department of Education); Central Washington College of Education; and others.
7. State Teachers College at Oshkosh in cooperation with Wisconsin Optometric Association; University of South Carolina; South Carolina State Department of Education, School Plant Division, collaborating with four school systems; University of Minnesota in cooperation with St. Paul Schools; Ohio State University; Mississippi Southern College; Central Washington College of Education; University of Pittsburgh; Purdue University in cooperation with West Lafayette Schools; Richmond (Virginia) Public Schools; and others.
8. Federal Security Agency, Washington 25, D. C.
9. Formerly of the Missouri State Department of Education and formerly Instructor in Educational Administration, University of Missouri.
10. Chief, School Housing, Division of School Administration.

ing the knowledge that a classroom is more than an enclosure to provide housing.[11]

In July, 1945, Mr. Harold D. Hynds reported studies

> to improve those physical conditions of school buildings that are conducive to classroom comfort and instructional efficiency. ... Educators, psychologists, and ophthalmologists agree that the mental attitude of children and visual acuity are greatly improved when classes are conducted in bright and inspiring rooms. ... Poor lighting or dark colors and glossy surfaces not only reduce school efficiency, but cause physical discomfort and in some cases permanent injury to the eyes.[12]

Among the more extensive fact-finding studies were those of the Texas Inter-Professional Commission on Child Development[13] under the direction of Dr. Darell B. Harmon,[14] whose purpose was to guide the Texas State Department of Health in planning, operating, and evaluating the activities carried on in its long-range program in child

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11. In 1948, Dr. Hamon was one of the principal speakers at the Institute on School Buildings held at the University of Wisconsin by the School of Education. The proceedings of this institute was published by the University in the book <u>Planning Modern School Buildings</u>.
12. "Choosing Colors for Classrooms," <u>School Business Affairs</u> (official organ of the Association of School Business Officials), July, 1945.
13. Consisting of fourteen state professional societies and organizations, including the Texas State Teachers Association; the State Medical Association of Texas; the Texas Dental Society; the Illuminating Engineering Society; the Texas Society of Architects; and organizations of educational and medical specialties.
14. Dr. Harmon is now an independent consultant in the study of physical and psychological factors of the classroom as they affect the growth and learning of the child. For ten years, until April 1, 1947, he had been director of school health services and associate director of maternal and child health for the Texas State Department of Health, and for seven years, concurrently, executive director of the Texas Inter-Professional Commission on Child Health. The previous twenty years he spent in educational research, teacher education, and college administration.

development. Architectural Record in February, 1946, observed: "Dr. Harmon's pioneer work in Texas has been in progress for seven years, and has created a sensation among health authorities and illuminating engineers. But its significance is really architectural. If the doctor has proved himself a splendid architect, he has also demonstrated that the architect on occasion can be the Nation's best practitioner in preventive medicine." In this same issue, Harmon's thirteen page article "Light on Growing Children" was presented, reporting how seeing involves the whole body, stress diagrams of faulty lighting, and how daylighting was improved at Mexia.[15] It was demonstrated that

> Our ability to see in three dimensions ceases at a point where one side of a three dimensional object is around six times brighter than the other visible surface. The ratio of difference established ... for daylight supplemented with artificial lighting is only 2 to 1 (three times better), and is one-third better than the Illuminating Engineering Society maximum standards of 3 to 1.[16] ... In order to get the best position for study, fully adjustable seats were developed ... to be placed in an unconventional arced pattern so that each child received proper support and balanced illumination to discourage body distortion. "Fully adjustable" means that every seat becomes flexible to the individual contour needs of the little students. An adjustable working surface on each desk brings desk work to exactly the right distance and angle for best seeing.[17]

Mr. C. E. C. Dyson of the Toronto Board of Education in reporting[18] on the earlier studies wrote:

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15. Twenty-four demonstration centers were set up, one of the first being located in the W. M. White School at Mexia.
16. "Brightness and Brightness Ratios," Report No. 1 of the Committee on Standards of Quality and Quantity for Interior Illumination of the Illuminating Engineering Society. Illuminating Engineering, December, 1944.
17. T. D. Wakefield, "Classrooms Designed for Seeing," Electrical South, July, 1947.
18. C. E. C. Dyson, "Modern Classrooms with limited Funds, "School Business Affairs (reprint).

> With a view to finding the causes of physical defects, 160,000 children were scientifically tested by doctors and men of other professions over a period of nine years.[19] The children were given thorough podiatrics examinations and nutritional, visual, psychological, educational and other similar tests. As a result of the investigation, the improvements made in the classrooms alone are reported to have reduced eye troubles in certain schools as much as two-thirds, nutrition difficulties by forty-four per cent and chronic infection by thirty per cent. ... One of the buildings in which the improvements were introduced was twenty-seven years old. In one of the grade schools in which there were 396 children enrolled, the examinations[20] showed that 53.3 per cent of these children had functional and organic visual difficulties; seventy per cent had signs indicative of nutritional difficulties. Six months after the room had been remodeled,[21] only 22.8 per cent of the children showed refractive eye difficulties (a reduction of 57.1 per cent). Nutrition problems had dropped 44.5 per cent below those recorded at the start of the investigation and the signs of chronic infection had been reduced nearly thirty per cent.

Better Light Better Sight News continued:

> At the same time that the children's health difficulties went down, their performance records went up. In the six months period of working in daylight-controlled classroom environment the children of the experimental school grew a mean average of 10.2 months in educational age, with a median growth of ten months and a modal growth of ten months. In the controlled school the mean educational growth was 6.8 months of educational age, the median six months and the modal growth six months.[22]

The Villa Marie Academy in West Chester, Pennsylvania, reported the average grades of all students rose 10.3 per cent after the academy modernized its classrooms.[23]

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19. The first three years were consumed in an inventory of the physical and psychological difficulties disturbing school children. Concurrently, a check was made of classroom factors which might be related to those difficulties.
20. November, 1942.
21. Redecorated, daylight controls installed, and the seating rearranged.
22. "Good Lighting Aids Good Health," Better Light Better Sight News, Vol. 15, No. 6, 1947.
23. Barclay Adams, "The Reflectance Factor in School Lighting," School Equipment News, April, 1951.

Screening surveys were also made of over 4,000 classrooms occupied by these children. In a preliminary report[24] on these surveys, the director observed:

> Analysis of the data showed that at least fifty-two per cent of the elementary school children were leaving the elementary school with an average of 1.8 observable preventable defects per child.[25]... The large overlapping of visual, postural, nutritional, (chronic) infection, and behavior difficulties, would seem to point to common factors in the causes of these defects. ... Probably from four out of five to nine out of ten of the observed difficulties have their origin during the elementary school period. ... Inter-correlation of the defects observed with classroom factors would seem to indicate the following in order, are ... contributing to the causes or severity of the defects: (1) improper seating; (2) improper lighting; (3) improper placement of working materials ... Observations made on relations between the physical factors of the classroom and the difficulties in children would also tend to indicate that these deviations are caused by or precipitated by the resultants of the various environmental forces affecting the child ...

In 1946 a report "Latest Techniques in School Lighting" appeared in The Magazine of Light. This was prepared by Prof. R. C. Putnam[26] and Mr. J. R. Anderson, Nela Park Engineering Division, Lamp Department, General Electric Company. They reported:

> Seeing and education are partners. Our educational system is built on seeing. It is only necessary to consider the difficulty in teaching visually handicapped children to realize how much depends on eyes and seeing in education. By far the greatest percentage of impressions reaching the brain comes from the seeing process. Anything which improves the ease, the accuracy and the comfort of seeing aids teaching.

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24. Darell B. Harmon, "Some Preliminary Observations on the Developmental Problems of 160,000 Elementary School Children," Medical Woman's Journal, March, 1942.
25. Later, more thorough and intensive tests and measurements showed the incidence of difficulties run considerably higher than the preliminary screening surveys indicated.
26. Prof. Putnam was on leave at the time. He is Professor of Illumination, Case School of Applied Science, Cleveland, and a consulting illuminating engineer.

> Much has been learned in the last few years concerning the role of good lighting on eye conservation and the reduction of fatigue. Researches and publications of Dr. Matthew Luckiesh,[27] Dr. Charles Sheard, Dr. R. J. Lythgoe[28] and others gives proof of the effect of lighting and accompanying visual conditions on the consumption of human energy as well as on the ease and comfort of seeing.

Of interest in connection with this introduction is the report of Dr. Louis J. Colman[29] in 1947 that statistics reveal the percentage of defective vision at the age of ten is nine per cent, and at the age of fifteen is twenty-five per cent. In Texas, studies discovered that defective eyesight increased from eighteen per cent in the first grade to forty per cent in the third, and to eighty-two in the graduating class.[30] Educators familiar with the U. S. Office of Education's estimate that eighty per cent of a child's learning is absorbed through the eyes must also realize that twenty per cent of all school children have visual handicaps.[31]

Volume 15, 1947, of <u>Better Light Better Sight News</u> in an article "Good Lighting Aids Good Health" reported further on the Harmon research:

> To see properly, the child adjusts not only his eyes but his head, his trunk and his entire posture. His whole body exerts an effort to concentrate on the area on which his eyes focus. In the classroom, where close, sustained visual work is required, this is especially wearing.
>
> Johnny's body may easily grow along the lines of stress induced by poor lighting, with accompanying physical and psychological damage. Dr. Harmon also believes that activity, in most instances, takes precedence over growth in the use of nutrients. If Johnny consumes too much of his

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27. <u>Light, Vision and Seeing</u>.
28. Special Report No. 173, <u>Medical Research Council</u>, 1932, Vol. 31.
29. Former Director, Prevention of Blindness Division, Florida Council for the Blind.
30. Sarah Gordon, "Bye, Bye, Blackboard," <u>Better Homes and Gardens</u>, November, 1948.
31. Barclay Adams, <u>op. cit.</u>

> energy through continued bodily stresses caused by poor lighting, he has not enough left either to protect his growth or to provide a defense against infectious disease.

It has been pointed out that other physical ills like headaches, nervousness, nausea and general fatigue are associated with eye fatigue. When extra energy is expended for seeing, the nutritional balance is affected also.[32]

Following the preliminary surveys, intensive studies were begun in those areas which appeared to contain the major factors conditioning the health and educational problems observed. Because of the significant place improper seating and lighting had occupied on the list of possible contributing causes of children's difficulties, the effects of light and classroom equipment were given important places in these intensive studies. Four classrooms were renovated in the Rosedale School in Austin in November, 1946. Harmon demonstrated that when a child is doing close visual work, if any area in his field of vision is more than three times brighter than any other part, there is a harmful effect. "Brightness distribution" came in for serious consideration.

"In other words, the whole area in a child's field of vision should have the same brightness. Common offenders against this principle are glare, especially from windows, and dark areas such as floors, desks and blackboards. And of course in many classrooms there is just not enough light, especially on the side away from the windows."[33]

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32. Educating in a Truer Light.
33. "Good Lighting Aids Good Health," op. cit.

In the Rosedale rooms, the entire fenestration area was torn out and panels of light-directing glass blocks built above the casement windows. These blocks contained prisms which admitted light from the outside and re-directed it upwards into the room. Venetian blinds were used for daylight control in the area below the glass blocks. At Mexia, Harmon had established brightness ratios in terms of whites and grays. At Rosedale, he introduced color, but had to solve new problems in paint chemistry in mixing paint not only to provide light diffusion but also to utilize color without disturbing brightness ratios subjectively.

> Various colors of the spectrum do not appear equally bright to the eye: Colors towards the middle of the spectrum, such as yellow-green, appear much brighter than colors towards either end. This difference will affect the child much as do differences in brightness, and is called "subjective brightness."
>
> Another color problem was the fact that different colors fall to focus at different points in front of, on and behind the retina, technically known as chromatic aberration. In immature or children's eyes these differences in the optical effects of various colors can be a severe stress. ... Dr. Harmon took into account all these factors in designing the colors. In the Rosedale rooms two or more different colors have been used without adverse contrasts of subjective or color brightness.[34]

An observation of interest was made about this time by Mr. Ralph P. Orchard of the Lakewood, Ohio, Board of Education:

> Color psychologists say many things about color. Color is an interpreter of moods. Color is an uplifter of spirits. In food it is an invitation to partake. In a sunrise it is an emblem of Hope. In sunsets it is an invitation to dream and meditate. Color is magnetic and

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34. "Good Lighting Aids Good Health," op. cit.

> important in all phases of life. The forest would be drab, indeed, without its foliage of green and gold and brown, gardens without the hues of asters and the brilliance of the marigold. Sky and sea would be a monotonous expanse without their ever-changing shades of blue and green. But for all of these, color does its most effective work in the home and in the school where much of the working hours are spent, where life is really lived.[35]

Mr. Orchard concluded, "In Lakewood, we believe that the use of color in classrooms and throughout school buildings is one of the great contributing factors to improved morale of both students and faculty, to increased interest and application by the students and to favorable and cooperative action on the part of the parents and the public at large."

Expanding recognition of the Texas studies and formulation of the term "The Harmon Technic"[36] came in 1947. The Nation's Schools in May presented a portfolio "Lighting - Color - Furnishings." It amplified the discovery that the whole body is involved in the process of seeing.

> To see properly, the child adjusts not only his eyes but his head, his trunk and his entire posture. The whole body tries to center itself on the brightest area affecting the eyes. At home on the floor with the Sunday comics, Johnny can squirm about until the light and his body position are in harmony. But it is in the classroom that he must sit at a close, sustained, visually centered task in an environment of pronounced contrasts of light and dark areas. To establish a balance between his environment and his work requires of him tiring physical and psychological effort.

In the same issue, The Nation's Schools reported an experiment in "brightness distribution" in an old building:

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35. Ralph P. Orchard, "Interior Painting of Schools."
36. Copyrighted.

> On a sunny day and with the conventional clear glass windows, a child near the windows may have a contrast between the brightness of the sky in his field of vision and the brightness of the task of as much as fifty to one, while a child at the inside wall who can also see the sky will be subjected to a contrast between the sky and his task approaching 450 to one. ... To reduce the brightness at the windows and yet utilize this light in the room, the shades were taken off ... and light diffusers made of white fabric[37] stretched on wood frames were substituted. ... It is common knowledge that about two-thirds of the total working light in a room comes from the upper half of the window opening. The white fabric diffusers transmitted sixty per cent of the light in a diffuse manner and threw a large part of the remainder upwards and across the ceiling from which it was reflected downward upon the pupils' desks.[38]

> The generally accepted view among color authorities has been that the distinction between warm and cool colors is psychological. Harmon research proves that the distinction is measurable, at least partly, in physical terms. By changing the color of the paint on the walls and ceiling, Dr. Harmon found as much as a five degree change in room temperature can be effected. The explanation of this phenomenon lies in the rapidity of heat reflection by some colors. If the classroom has on walls and ceilings a paint that will absorb heat, the heat will stay on the surface of the wall and be re-radiated very slowly. If it reflects heat waves, the heat will radiate out into the room rapidly, to be soon felt by those in the room.

One very significant result of Harmon's research reported here should be recognized, for it is still due for further study and very likely eventual general acceptance when lighting becomes more than a quantity expressed in footcandles. This research indicated "that the high light intensities recommended by illuminating engineers during the past few years may not be nearly as important as is the proper brightness ratio in the field of vision; the greater bright-

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37. Glass cloth (Fiberglas).
38. Similar diffuser-reflectors are installed in an experimental classroom in the George Wythe Building of John Marshall High School in Richmond, photographs of which are shown in Plates 4 and 6.

ness contrast, the higher the amount of illumination to overcome it."[39]

That recent emphasis on the seeing-in-the-classroom problem has broadened considerably from the narrow footcandle concept was pointed out by the National Council on Schoolhouse Construction.

> The relationships of brightness, brightness-differences, and total visual fields have supplemented the elementary discussions of footcandle standards. The problem has now shifted from "how much light should we have" to "how well can we see." The relative importance of the factors which constitute good visual environment in schools has been modified from the realm of opinion centering about light quantity recommendations to the more educationally acceptable concern about the positive correlation between good seeing conditions and the conservation of human resources. The philosophy of those who would attempt to claim material educational growth solely on increased quantities of light at desk-top level has been abandoned for a more acceptable approach which takes into consideration the entire visual environment as it affects the physical, mental, and emotional welfare of students.[40]

Hamon[41] emphasized the importance of balanced brightness or low contrast in Pamphlet 104 of the U. S. Office of Education, Lighting Schoolrooms. "We are not so much concerned about how much light we have; the real problem is, how well can we see." Several of the statements of this pamphlet are reported here:

> Brightness balance will not be accomplished until color is considered as an equal partner to light. ... It is a fundamental principle of lighting that more light shall

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39. The 1947 Westinghouse Lighting Handbook and the 1948 GESCO General Electric Lighting Guide recommend thirty footcandles of illumination maintained in service for classrooms. The 1947 I. E. S. Lighting Handbook reported current recommended practice in lighting levels at the work (maintained in service) at this same quantity.
40. Guide for Planning School Plants.
41. Chief, School Housing, Division of School Administration.

> shine on the visual task than into the eyes. ... Ceilings should be finished with a reflection factor of eighty-five per cent. ... Walls ... should be finished with a minimum reflection factor of sixty per cent. The wainscoting, including the baseboard, should have a reflection factor of at least forty per cent. ... Trim may be finished in a different hue, but with a saturation which will give it approximately the same brightness as the adjacent walls. ... Floors should be finished and maintained with a reflection factor of from thirty to forty per cent. ... Chalkboards present a real problem. ... Probably the optimum ... available at present is ... a light-green chalkboard which has a light reflection factor of approximately twenty per cent. ... Equipment surfaces should be of non-glossy finish with reflection factors of from thirty to forty per cent. ... Educators and architects are giving increased attention to the possibilities of lighting with paint. ... Colors should be selected on the following bases: Reflection factor, artistic appearance, ease of maintenance, and adjustment to the orientation and the use of the area. ... Directional glass blocks and horizontal louvers[42] seem to be about the best tried method of shielding non-vision sources of natural light and achieving natural-light diffusion. ... Fluorescent lamps should be shielded from the field of vision in the schoolroom, unless a tube is developed with a much lower surface brightness than those now on the market. ... No bare filament lamp should ever be exposed to vision in a schoolroom under any conditions.

Wisconsin set up a Committee on Physical Environment of Schools as a part of its Cooperative School Health Program. Included in its "Guide for Better School Health" bulletins was <u>School Lighting</u>. It is pointed out that "There is great need for <u>rapid</u>, <u>accurate</u> and <u>easy</u> seeing plus the too often neglected <u>comfortable</u> seeing. But this need has not as yet become a matter of awareness on the part of many school administrators." Other highlights of this bulletin were:

> The physiologist and ophthalmologist tell us that a good deal of the nervous energy of the human body is used in seeing. The translation of a dim retinal image into its

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42. For example, venetian blinds on the vision strip.

> related mental concept (interpreting its meaning and significance) is not easy, and considerable energy is dissipated in this process. .... The retinal image produces a strain when the eyes tend to equalize the varying and excessive brightness factors in the field of vision. The same reaction takes place when the child is confronted with the printed white page, and the field of vision encompasses a dark desk surface,[43] or if a bright lighting fixture is in the field of vision.[44]... All due care should be taken to avoid sharp contrasts and glare. ... The effect of color as an important factor of schoolroom environment is underestimated — pleasing surroundings and judicious color selections are conducive to "peace of mind and tranquility" and in turn vitally affect the educative process. ... Unfortunately, teachers are usually so busy "teaching" that the control of lighting escapes them. ... The teacher should take light control as part of the teaching job. ... Anything which conserves eyesight and prevents us from becoming a "nation of ocular defectives" is worthwhile.

Recognition of the importance of what he termed "paint programming" was reported by Mr. Cecil A. Bassett in an article from which the following was taken:

> In recent years, school administrators have increasingly recognized and appreciated the indispensable part that painting plays ... and the basic benefits it provides. ... Interest in planned application of color for paint-styling building interiors to reduce visual tension, increase lighting efficiency, and improve working conditions, has developed at a remarkably rapid rate during the past decade. ... Planned color usage embodies selection of colors that ... maintain brightness contrasts in constant ratios determined by medical specialists and lighting engineers as correct for most comfortable vision ... to minimize eye strain. Reducing eye fatigue is vital, for it has been clearly shown time and again that tired eyes make tired minds and bodies. ... New York State administrators are awake to the need for better school conditions through color and light.[45]

At the Institute on School Buildings at the University of Wis-

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43. Or dark, oiled floors.
44. Or window area.
45. "Paint Programming Pays."

consin in 1948, Dr. Don L. Essex[46] discussed walls, ceilings and floors,[47] emphasizing the importance of careful treatment of these surfaces as a part of a child's surround. In this same year, under the sponsorship of the Illuminating Engineering Society and the American Institute of Architects, the American Standards Association published American Standard Practice for School Lighting. This was a revision of the 1938 code (previous code was 1932). Its purpose was to establish criteria of good illumination for the guidance of architects, engineers, school people, and others interested in the conservation of children's vision and in the efficiency of pupils and teachers.

In 1948, at least two additional national publications gave space to discussions of the importance of classroom environment. The School Executive[48] and Better Homes and Gardens[49] both presented features in their November issues. The latter indicated extending of interest into home areas.

Speaking before the Virginia Conference on Classroom Planning in Richmond in May, 1950, Superintendent Willett of the Richmond Schools, in summing up discussions on classroom environment, said: "We must be conscious of all these factors that contribute to health, that tend to lessen fatigue, that tend to contribute to the aesthetic impulses of the child, to (promote) work in a place

46. Russell T. Gregg, "Planning Modern School Buildings."
47. Dr. Essex was advised and assisted in preparing his manuscript by Mr. Frank C. Gilson, Architect, Division of School Buildings and Grounds, New York State Education Department.
48. T. D. Wakefield, "Brighten the Corners."
49. Sarah Gordon, op. cit.

that is conducive to his best work — they are factors that must be considered."

CHAPTER II

SURVEY OF A TYPICAL CLASSROOM OF THE DECADE 1920-30

A survey of a classroom whose features are either similar or identical to those of other Richmond classrooms constructed in the decade 1920-30 revealed startling deficiencies in surface reflectances when compared with the recommendations of the American Standard Practice on School Lighting or the National Council on Schoolhouse Construction. The reflectance of the floor only came within comparison standards. This floor had just been scrubbed as a part of the summer custodial maintenance program, and cannot be expected to retain its reflectance in use. These comparisons are shown in Table I. The approximate degrees of deficiencies are 325 per cent for ceiling and walls, four hundred per cent for trim, five hundred per cent for tackboards, two hundred per cent for chalkboards, and 175 per cent for desk tops.

This same classroom was surveyed for a comparison of brightness ratios and lighting levels with the same standards. The level of illumination was found to be from 175 to two hundred per cent low, depending upon the comparison standard. The brightness of luminaires to surface adjacent to them in the visual fields was found to be excessive by approximately ninety per cent. This survey is tabulated in Table II.

These measurements were determined by taking readings with the photronic cell of the meter held at a distance of twelve inches from

TABLE I

COMPARISON OF REFLECTANCES IN ROOM 216, ALBERT H. HILL JUNIOR HIGH SCHOOL, RICHMOND, VIRGINIA WITH RECOMMENDATIONS OF THE AMERICAN STANDARD PRACTICE ON SCHOOL LIGHTING AND NATIONAL COUNCIL ON SCHOOLHOUSE CONSTRUCTION[1]

Surface	Room 216	Recommendations	
		American Standard	National Council
Ceiling[2]	20%	80-85%	85%
Walls[2]	20%	50-70%	50% minimum
Trim[3]	8%	30-40%	40-60%
Tackboards[4]	9%	50-60%	no recommendation
Chalkboard[5]	6%	15-20%	30% maximum
Desk Tops[6]	15%	35-50%	30-40%
Floor[7]	19%	15-30%	30-40%

the surface being investigated, with the face of the cell being held parallel to the surface, facing towards the surface for one reading and away for the other. Percentages were computed by dividing the reflected reading by the direct reading. In all instances, the re-

1. Readings taken with Weston model 614 photronic footcandle meter on July 22, 1951; 3:00 to 5:00 p. M.; brilliant, sunny day with high sky brightness; roller shades mounted at head and at meeting rail of double-hung windows; fabric ecru dyed duck with practically no light transmission; adjusted to admit no direct sunlight on floor or desks; exposure 33° west of south.
2. Green color on both surfaces.
3. Varnished (gloss) dark oak.
4. Soiled tan cork.
5. Slate.
6. Stationary type desks in rows parallel to fenestration.
7. Unfinished rift pine.

TABLE II

COMPARISON OF BRIGHTNESS RATIOS AND LIGHTING LEVELS IN ROOM 216, ALBERT H. HILL JUNIOR HIGH SCHOOL, RICHMOND, VIRGINIA, WITH RECOMMENDATIONS OF THE AMERICAN STANDARD PRACTICE ON SCHOOL LIGHTING AND THE NATIONAL COUNCIL ON SCHOOLHOUSE CONSTRUCTION[8]

BRIGHTNESS RATIOS

	Room 216	American Standard	National Council
The central visual field (seeing task) to immediately adjacent surfaces in the surrounding field (brightness of paper to brightness of desk tops)	1 to 1/2	1 to not less than 1/3	1 to not less than 1/5
The central visual field (seeing task) to the more remote darker surfaces in the surrounding visual field (brightness of paper to brightness of floor)	1 to 1/2	1 to not less than 1/10	1 to not less than 1/5
The central visual field (seeing task) to the more remote brighter surfaces in the surrounding visual field (brightness of paper to brightness of ceiling)	1 to 2/5	1 to not more than 10	1 to not more than 10
Brightness of luminaires to surfaces adjacent to them in the visual fields	37 to 1	not more than 20 to 1	no recommendation

LIGHTING LEVEL[9]

	Room 216	American Standard	National Council
	5.0 F. C. lowest, 7.3 F. C. average	30 F. C. minimum	20 F. C. minimum

8. *Supra*, footnote 1.
9. With shades adjusted to eliminate direct sunlight. Four 200-watt incadescent filament luminaires burning.

sult is the average of several readings. In the case of level of illumination, this was a direct reading in footcandles, with the meter placed on each working surface.

CHAPTER III

AN EXPERIMENT WITH A TYPICAL CLASSROOM OF THE DECADE 1920-30

A demonstration classroom was set up by the Richmond Schools in room 110W, George Wythe Building, Richmond, Virginia in May, 1950, for use in connection with the Virginia Conference on Classroom Planning. This classroom was, before the experimental renovations, identical to room 216 at Albert H. Hill Junior High School except for exposure and floor material. In fact, their ages are identical. Plates 1 to 6, inclusive, show room 110W "before" and "after" changes.

Dark finish screwed-down desks, arranged in rows parallel to the fenestration, were removed. In their place, movable desks with natural finish birch tops were provided. These desks have a working surface which may be adjusted to ten degree or twenty degree angles to conform to requirement needs of the task, in addition to the level position for palms-down manipulations. Seats revolve to right or left and move forward and backward, and the lower cross-member of the seat back has flexibility for conforming to the back of the occupant at work. These combinations provide a combination for proper and comfortable support of the body while affording full freedom of movement for performance, for either right- or left-handed children.

Detergents were employed to remove floor oil, after which the floor was sanded and sealed. All slate blackboards were

PLATE I FRONT CORNER OF CLASSROOM 110W GEORGE WYTHE BUILDING BEFORE EXPERIMENT

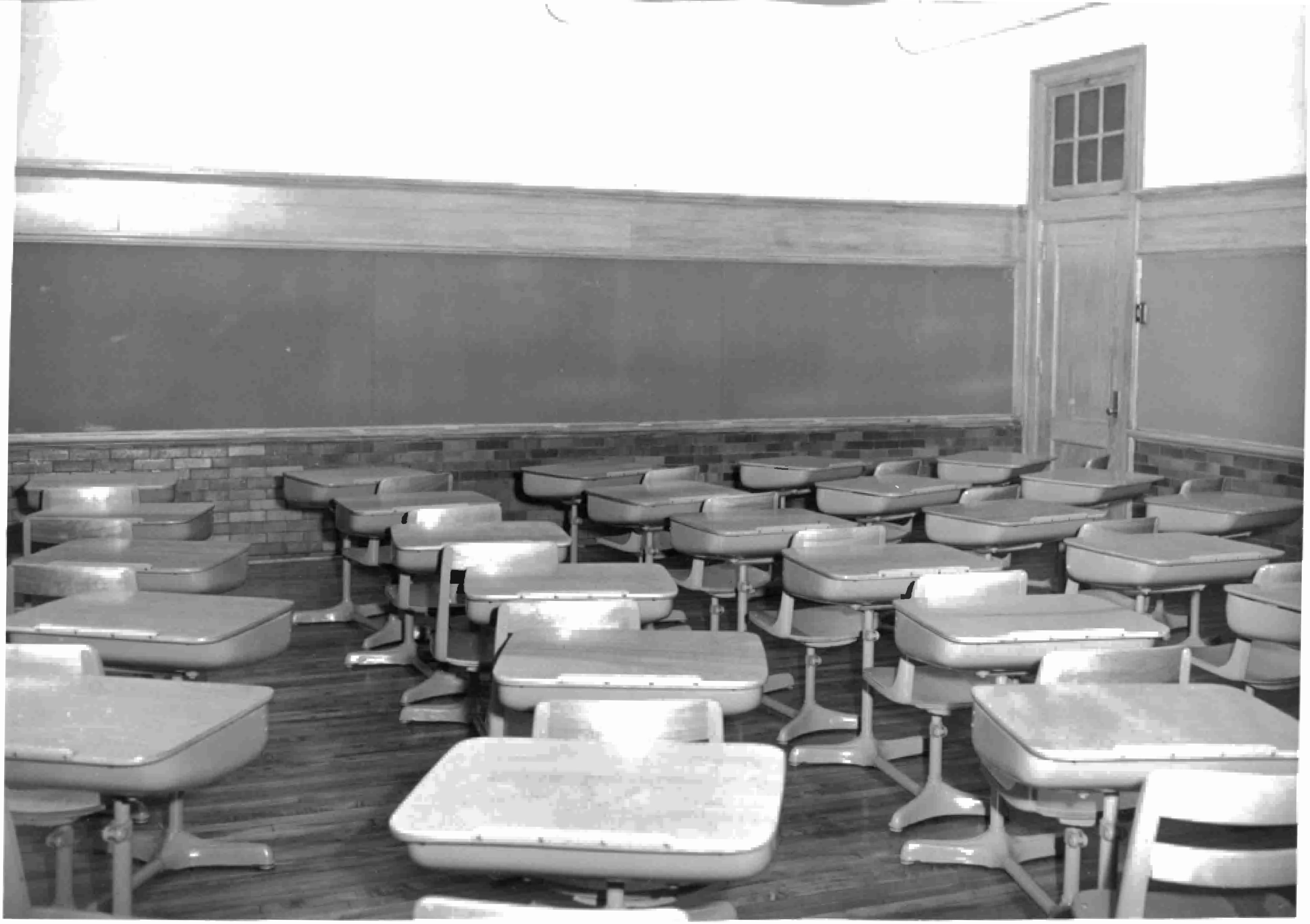

PLATE ii FRONT CORNER OF CLASSROOM 110W GEORGE WYTHE BUILDING SHOWING EXPERIMENT removed and replaced with either yellow-green chalkboards or tan corkboard for display purposes. On the structural mullion between window bays, slate was replaced with wood and corkboard.

The ceiling and inside wall were painted flat white, and the same white was "dropped" on the other walls to a height approximately ten feet above the floor. This was done because of the importance of the upper surfaces for light reflection, whether natural or artificial, although the depth was determined by the height of the luminaires in order to obtain maximum reflectance of the indirect light component. Due to the thirty-seven degrees south of east exposure, gray was used on the remaining walls, complementing the color and wave length of natural light entering the room. Glossy dark oak finish was taken off the trim and it was refinished limed oak.

Cloth shades were removed and the window bays treated in two methods to demonstrate methods of optic control of daylight as shown in Plate 6. In a practical installation, the diffuser-reflectors extend continuously from front to rear of room. While a small amount of sky shows above them here, due to the height at which the camera was held, this sky would be shielded to the seated eye on the corridor side of the room. Daylighting was supplemented with three rows of luminous indirect luminaires, capable not only of meeting dark-day requirements but also evening school activities.

Table III compares the reflectances of this classroom with the standards used in Chapter I. It should be pointed out that at

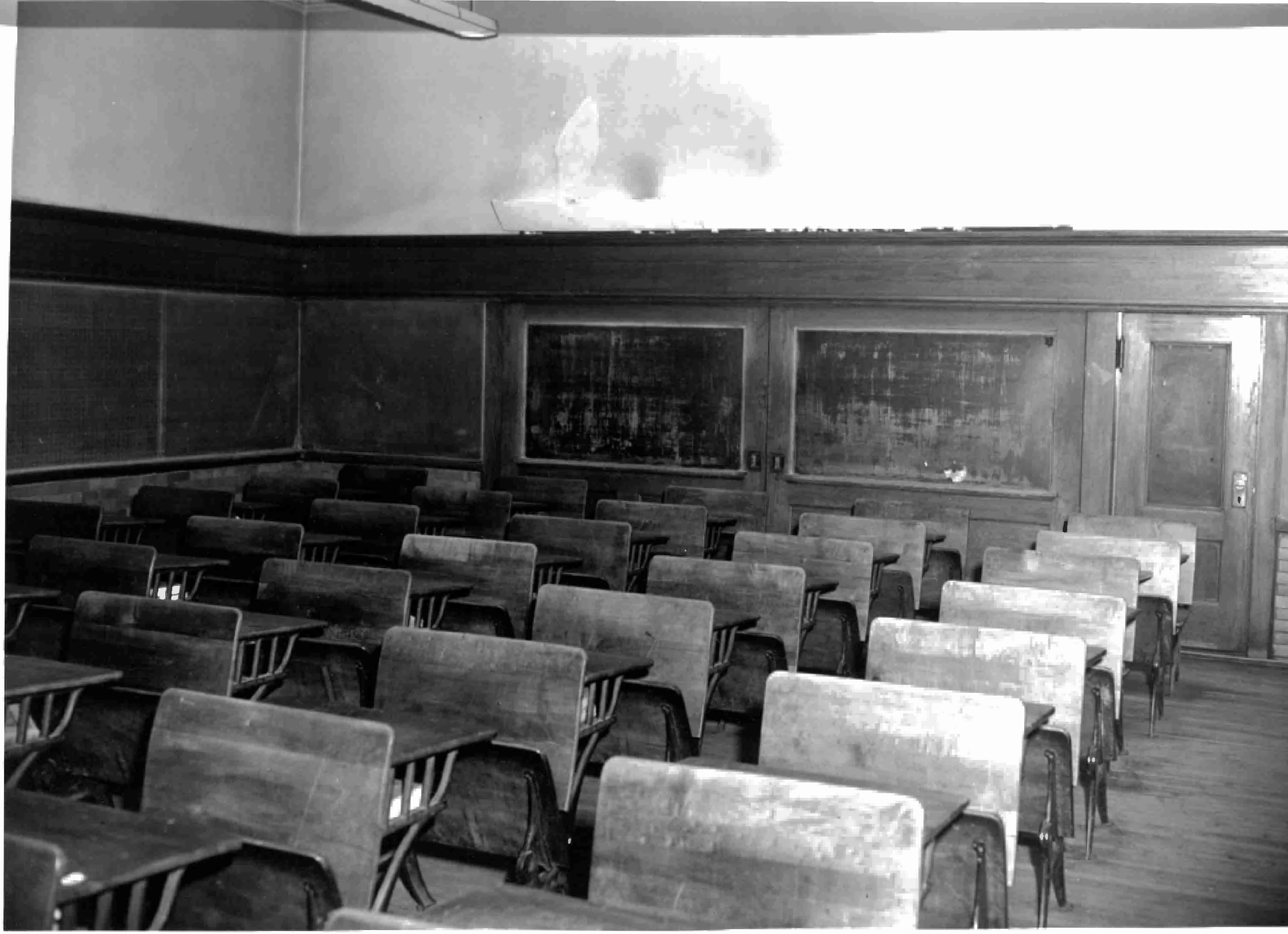

PLATE iii REAR CORNER OF CLASSROOM 110W GEORGE WYTHE BUILDING BEFORE EXPERIMENT

PLATE iv REAR CORNER OF CLASSROOM 110W GEORGE WYTHE BUILDING SHOWING EXPERIMENT

TABLE III

COMPARISON OF REFLECTANCES IN ROOM 110W, GEORGE WYTHE BUILDING, RICHMOND, VIRGINIA, WITH RECOMMENDATIONS OF THE AMERICAN STANDARD PRACTICE ON SCHOOL LIGHTING AND NATIONAL COUNCIL ON SCHOOLHOUSE CONSTRUCTION[2]

Surface	Room 110W	Recommendations	
		American Standard	National Council
Ceiling[3]	90%	80-85%	85%
Walls[4]	53%	50-70%	50% minimum
Trim[5]	23%	30-40%	40-60%
Tackboards[6]	20%	50-60%	no recommendation
Chalkboards[7]	22%	15-20%	30% maximum
Desk Tops[8]	31%	35-50%	30-40%
Floor[9]	20%	15-30%	30-40%

the time of the survey, windows had not yet been cleaned as a part of the summer custodial maintenance program, the luminaires, including fluorescent lamps, were quite dirty, and both diffusers

2. Readings taken with a Weston model 614 photronic footcandle meter on July 25, 1951; 2:00 to 4:00 p. m.; slightly overcast day with low average sky brightness; venetian blinds on three of the double-hung windows, with diffuser-reflectors (Fiberglas) and venetian blinds on three; blinds adjusted to admit no direct sunlight on floor or desks; exposure 37° south of east.
3. Flat white color.
4. White window wall, white "drop" from ceiling to approximately ten feet above floor, gray on other walls to chalk and tackboards.
5. Refinished in limed oak with flat varnish.
6. Tan cork.
7. Yellow-green.
8. Natural birch with non-glossy finish.
9. Sealed maple.

PLATE V WINDOW WALL OF CLASSROOM 110W GEORGE WYTHE BUILDING BEFORE EXPERIMENT and venetian blinds needed to be cleaned. The room, including lamps, had been in use for fifteen months since alterations. Standards were met and exceeded in five instances, approached closely in another, and missed by sixty per cent in the case of tackboards.

By comparison with the Hill classroom[1], the ceiling condition was found to be improved by 350 per cent, the walls by 143 per cent, the trim by 190 per cent, tackboards by 122 per cent, chalkboards by 266 per cent, desk tops by 107 per cent, and the floor by five per cent. If all items measured are given equal weight, the average improvement is 169 per cent for the room.

The survey of brightness ratios and lighting levels is recorded in Table IV, and it appears that the classroom meets the comparison standards in every respect.

1. Supra, Tables I and III.

TABLE IV

COMPARISON OF BRIGHTNESS RATIOS AND LIGHTING LEVELS IN ROOM 110W, GEORGE WYTHE BUILDING, RICHMOND, VIRGINIA, WITH RECOMMENDATIONS OF THE AMERICAN STANDARD PRACTICE ON SCHOOL LIGHTING AND NATIONAL COUNCIL ON SCHOOLHOUSE CONSTRUCTION

BRIGHTNESS RATIOS

	Room 110W	American Standard	National Council
The central visual field (seeing task) to immediately adjacent surfaces in the surrounding field (brightness of paper to brightness of desk tops)	1 to 7/6	1 to not less than 1/3	1 to not less than 1/5
The central visual field (seeing task) to the more remote darker surfaces in the surrounding visual field (brightness of paper to brightness of floor)	1 to 1/2	1 to not less than 1/10	1 to not less than 1/5
The central visual field (seeing task) to the more remote brighter surfaces in the surrounding visual field (brightness of paper to brightness of ceiling)	1 to 3	1 to not more than 10	1 to not more than 10
Brightness of luminaires to surfaces adjacent to them in the visual fields	1 to 5/6	not more than 20 to 1	no recommendation

LIGHTING LEVEL[11]

	44 F. C. lowest, 62 F. C. average	30 F. C. minimum	20 F. C. minimum

10. *Supra*, footnote 2.
11. With venetian blinds and diffuser-reflectors adjusted to eliminate direct sunlight. 18 luminous indirect fluorescent two-lamp luminaires burning; total 1800 watts.

CHAPTER IV

CRITERIA FOR VISUAL-CENTERED CLASSROOM ENVIRONMENT

The preceding findings would seem to indicate that a child's classroom environment is physically and psychologically wrong for him if it has any of the following features:

1. Screwed-down desks in straight rows parallel to the fenestration.
2. Tablet armchairs restricting freedom of movement for postural adjustment for best performance.
3. Dark-finished furniture or woodwork.
4. Glossy glare-producing surfaces on furniture, woodwork, walls or chalkboards.
5. Sun glaring through windows.
6. Large area of sky visible to him while he is working at desk.
7. Uncovered areas of glass in his field of vision, such as glass in corridor doors, on pictures, clocks, etc.
8. Harsh shadows and dark areas in the room.
9. Dark or drab finished walls; dark saturated dados or wainscots; gray, off-white, or colored ceilings and "drops."
10. "Cool" colors used in decorating rooms of north or shaded exposures; "Warm" colors in rooms of south or sunny exposures.
11. Large <u>blackboard</u> areas on front or inside walls; chalkboards of adult size and mounting height, rather than sized to fit the children.
12. Not enough light on dark days. Trees, shrubs, and other landscaping obscuring windows.

13. Dark or oiled floors.

14. Bare lamps and unshielded light fixtures.

15. A teacher who does not understand the importance of his environment, and does not make day-light control adjustments in accordance with his needs.

It would appear that a child is undergoing strain if he reacts to his surround, to his visually centered task, or to both in the following manner:

1. One side of his face appears much brighter than the other when he is looking either at his desk or at the front of the room. This is worse if the bright area also includes one eye.
2. He works closer to his tasks than a distance equal to the length of his forearm and hand from elbow to end of clenched fist.
3. He sits on one foot a great deal of the time.
4. He tilts his head to one side.
5. He places the center of his work to one side, rather than directly in front of him.

CHAPTER V

SUMMARY AND RECOMMENDATIONS

It is evident from this study that a child's ability to grow naturally and learn effectively is closely related to his posture and visual comfort in the classroom. His desk should adjust adequately to suit his body so as to allow him freedom in the activity through which he learns — supporting his reading, writing or other working material in a position permitting him to read or work without muscular and visual strain. If the activity requires use of the hands, they also must be supported and arms and hands balanced at a distance permitting both successful eye-hand co-ordination and efficient use of hands and eyes.

Vision or reacting to brightness is the principle form of activity in a classroom. It is estimated that eighty per cent of a child's time is devoted to visual centered tasks such as reading, writing, drawing and manipulative tasks. Not only must the eyes be adjusted to work at a definite distance from the task, but the head and body must also adjust to support and hold the eyes.

Where absorbing and continuous seeing tasks are being performed, the old idea of providing a quantity of light in a classroom or on a plane is outmoded. The incidence of direct glare, reflected glare, shadows and sharp brightness contrasts is too great for comfortable and efficient seeing.

A classroom environment in which seeing will be relatively effortless must be a reasonably uniform environment. This requires not only uniform distribution of light but uniform distribution of reflectances throughout the room. Too much brightness contrast between a seeing task and its background are productive of a measurable degree of eye fatigue. If the background is materially brighter or darker than the seeing task, the pupil of the eye must contract when the pupil looks at a bright area; it must expand when exposed to a dark area. Since eye muscles, like any muscles, tire from continuous flexing, seeing under conditions of marked brightness contrast is difficult and fatiguing.

Recent studies indicate that with this uniform surround, vision continues to improve as light is increased up to daylight values. And although high brightness contrasts have little effect on visual acuity at low levels of illumination, high brightness contrasts become increasingly deleterious to good seeing as light levels are increased.

Advanced thinking is that brightness variations should be no more than three to one. In simple terms, this means that the brightest surface in the classroom should not be more than three times as bright as the seeing task, and the seeing task should not be more than three times as bright as the darkest surface in the classroom.

In accepting this concept of classroom lighting, we change from the old criterion of "footcandles" to the new idea of creating a luminous environment. This modern idea, therefore, puts decoration (paint) on a par with lighting and requires the consideration of brightness distribution in the whole field of view.

Research indicates that a long-continued predominance of any color continuously activates the nerve-endings in the eye which are sensitive to that color. Sooner or later those nerve-endings tire from over-work. Even daylight is monotonous — south light is high in red and yellow; north light inclines to blue. Nature rebels at this overdose of one color by generating within the eye the complement of any color the eye is forced to look at for long periods. Outdoors, nature guards against the fatiguing effects of color monotony by offsetting sunlight's warm tones with the blue of the sky and the restful green of grass and trees. A simple test of this may be conducted by closing one eye and staring fixedly at blue for about twenty seconds. Then look at gray, first with the same eye and then with the eye which was closed. The eye over-exposed to blue will show its fatigue by seeing a yellowish, sandy color instead of gray.

In planning new construction, it is relatively easy to incorporate the known factors discussed herein. Fig. 1 is a plan of a modern classroom. Existing buildings, which will contain the predominance of classrooms of any school system,

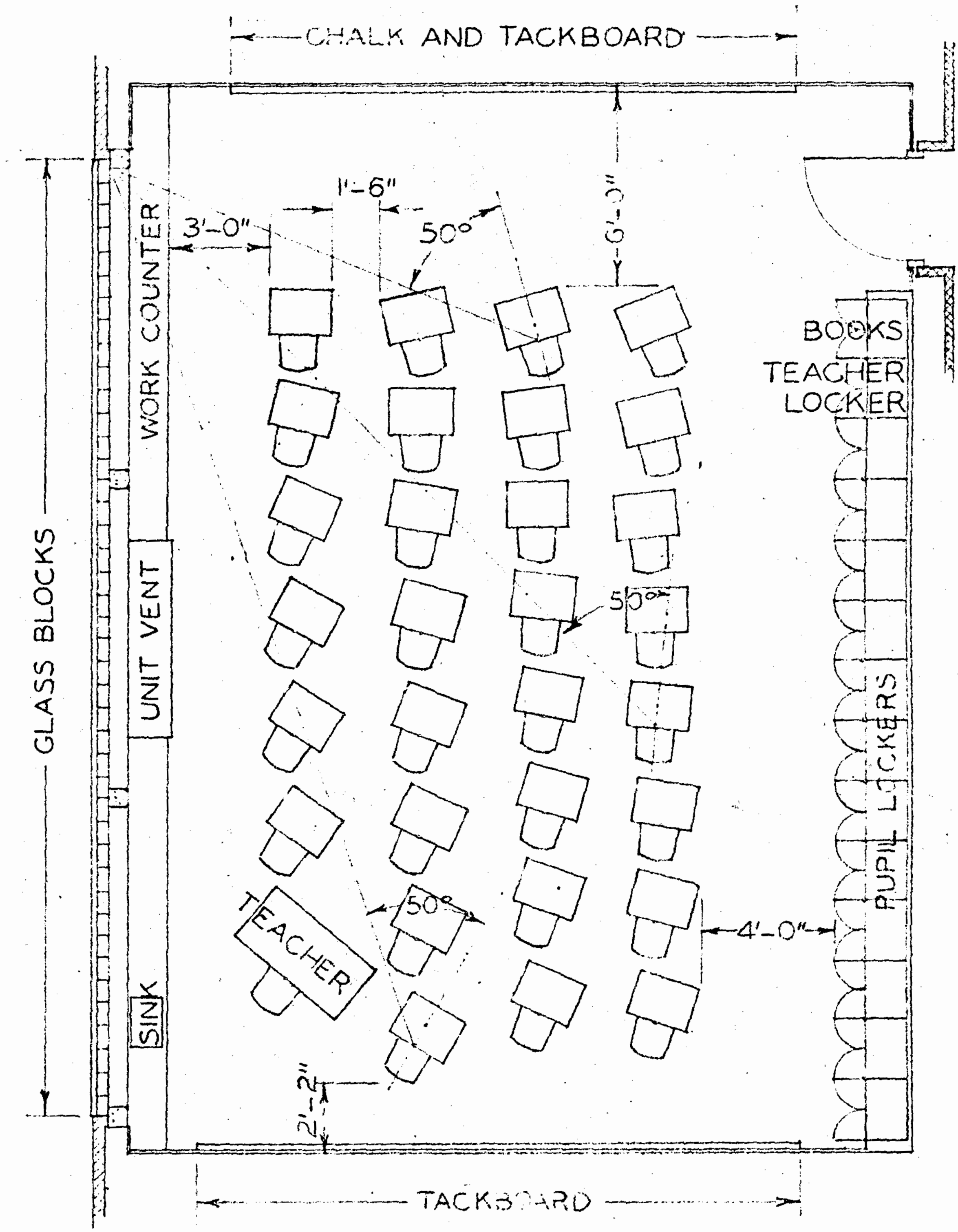

FIG. I. PLAN OF TYPICAL CLASSROOM
GEORGE MASON SCHOOL ADDITION
RICHMOND, VIRGINIA

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will require individual study for upgrading.

If screwed-down desks cannot be replaced with modern adjustable pieces of furniture allowing postural adjustment for bringing the body to balance with the task with freedom to perform, they should be refinished in light or natural finish and rearranged so that a fore-aft center line forms an angle of fifty degrees with the front line of fenestration. In Richmond, this type desk is being refinished natural with a dull varnish. The metal frames which were formerly black are painted a glossless tan.

Dark-finished woodwork should be refinished to provide light reflection within the established brightness ratios. This will have a reflectance of from thirty to forty per cent. Hardwood which may have been finished dark can be cleaned up with paint and varnish remover. If further bleaching is required to lighten, oxalic acid may be used. For open-grained hardwoods, such as oaks, a light filler such as white lead may be used, with the final finish being dull varnish.

It appears that the best means of daylight control is the light-directional prismatic glass block. This may be used for the uppermost part of the window, starting approximately six feet above the floor. If this is done, a diffusing fabric draw curtain should be provided for preventing screen wash-out for projection purposes. The vision strip beneath the glass block should be equipped with venetian blinds. If funds are not available for replacing clear glass with glass blocks, venetian blinds should extend from head to sill of window. The Richmond Schools manufacture their blinds, and find that the cost compares favorably with shades when long-term maintenance is taken into consideration since ladder tapes, tilt and pull-up cords are almost the only maintenance items if tiltors, cord locks and slats are selected with care. If blinds cannot be installed, and it is necessary to resort to shades, they should be of the two-roller type, mounted at the meeting rail. The fabric should be of a light diffusion type, so that it does not shut out needed light while preventing sunlight admission or exposing a large area of sky. If dark-out for projection purposes is not a consideration, glass cloth diffuser-reflectors may be used in the upper window areas, with venetian blinds below in a manner similar to the glass block installation. In an experimental Richmond classroom, it is evident that transmission-diffusion-reflection of the diffuse-reflector system is somewhat better than the venetian blind (maybe as much as ten per cent, the Wythe experiment would indicate).

Windows should be kept clean and curtains or drapes restricting light admission should be avoided. Trees and shrubs should not be allowed to obscure windows. For dark days, supplemental lighting is necessary.

Ceilings should be refinished with a flat white paint having either an oil, casein or rubber-emulsion base and having a reflection factor of at least eighty-five per cent. The effectiveness of the ceiling as a light reflecting agent may be diminished a degree when acoustic materials are applied to that area. The perforated-type acoustic tiles offer the best compromise now available between sound and sight-conditioned surfaces since they lose less of their acoustical properties when painted than do the non-perforated materials.

The exterior wall from ceiling to window sill should be painted white to "bounce" as much light as possible back into the room. Likewise, to reflect the maximum light from luminaries, the ceiling white should be "dropped" on other walls to ten feet above the floor.

Walls from ceiling or "drop" to dado or wainscot should be finished with a non-saturated pastel color having a minimum reflection factor of sixty per cent. Complement warm southern light with cool colors, such as sea green, sage green, gray and (sparingly) turquoise blue. Complement cold northern light by selecting a warm color, such as cream, rose-gray, and ivory. Complement the predominatly red western light with a cool color, such as sea green. For neutral eastern light, select gray, a neutral color, or sea green.

Wainscoting or dados, including baseboard, should be finished with a color having a reflection factor of at least forty per cent.

Trim should be finished to a reflectance of from forty to sixty per cent. If a "natural" finish, the varnish should be of the flat or dry-dull type.

Floors should be refinished so that they have a reflection factor of thirty to forty per cent. Maple or white oak hardwood floors well maintained with a good seal (no shellac, please!) should fall within this range. Worn-out floors may be replaced with asphalt tile more inexpensively than with wood, but checkerboard patterns should be avoided. The "C" color group of tiles usually produce desired reflectances, while "A" and "B" colors are too dark.

Slate blackboard may be refinished with one of the yellow-green finishes available more inexpensively than replacing with new boards. In Richmond, very satisfactory results have been obtained from using a yellow-green rubber-emulsion flat paint to which carborundum powder has been added for abrasiveness. Satisfactory new boards are available in pulpwood, cement-asbestos fibers, and glass, and require a minimum of washing maintenance. In either case, the reflectance should be approximately twenty per cent. Blackboard in excess of modern-day requirements should be converted to display space.

The findings of this study seem to indicate that out of research has evolved the concept of a class room having functional synthesizing of furniture, decoration, daylight control. supplementary lighting, and other physical aspects of the surroundings. Coordinated planning balances the physical forces in the classroom so as to meet children's growth needs, and to permit purposeful educational experiences without distortion of sensation or restraint of performance.

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VITA

Born in Easley, South Carolina, November 22, 1908. Educated in public schools there; graduating in 1925. Entered Clemson College in September, 1925, matriculating in electrical engineering, but changed to architecture at end of year; B. S. in Architecture, June, 1929. Member Tau Beta Pi. Married; two sons and a daughter.

Upon graduation, employed by engineering department of Atlantic Coast Line Railroad Company, inspecting on new construction work for the office of the architect. From April to August, 1931, worked with William R. Ward, architect, Greenville, South Carolina. After entering school work, continued to work summers with architects in Greenville, Asheville, and Richmond.

Entered the teaching profession in 1931 as an Industrial Arts instructor in the Richmond Public Schools, and continued through June, 1947, except for two interruptions. Principal of Richmond Vocational School 1938-39. Appointed assistant to the Director of Industrial Arts and Vocational Education in 1939. From September, 1936, to May, 1946, except for war interruption, taught architectural and general drafting in the evening at Virginia Mechanics' Institute. From September, 1946, to June, 1947, head of Department of Industrial Arts and Vocational Education at John Marshall High School. Since September, 1947, Director of Buildings and Grounds.

Served in S. C. N. G. and graduated in college R. O. T. C. Volunteered for duty in U. S. Navy in November, 1942, and was on active duty from July, 1943, to January, 1946, instructing in aviation training program. Underwent specialized training involving vision at Ohio State University and at N. A. S., Pensacola.

Extension and correspondence study from 1931 to 1940 with Radford State Teachers College, Virginia Polytechnic Institute, and the State Board for Vocational Education of Virginia. In June, 1946, enrolled as graduate student at the University of Richmond.