RELATIONSHIP BETWEEN STUDENTS' VISUAL ACUITY, PERCEPTION OF DAY LIGHT ILLUMINATION IN SCHOOL WORKSHOP AND ACCURACY LEVELS IN WORKSHOP PRACTICE

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Abstract The study investigated the relationship between students' perception of daylight illumination in workshop and their accuracy level in workshop practice. The woodwork bench shop of the School of Technical Educational. Federal College of Education (technical), Omoku, Rivers State, Nigeria was used for the study. A study population of fifty-six 300 Level NCE Technical Education Students during the 2009/2010 academic sessions was used for study. This population also constituted the study sample. The Pearson Product Moment Correlation statistics was used to test whether there is any relationship between the level of students' perception of daylight illumination in workshop and their level of accuracy in workshop practice. The results established that, there was a correlation between the two variables. That is, the accuracy level of the students' decreases as the task is carried out further away from the source of daylight.

Keywords: Daylight factor; Illumination; Luminance; Reflectance values; Visual acuity; Visual mechanism; near-sighted; far-sighted

1 Introduction

The primary source of light for day light is the sun. The light from the sun is needed to see and the amount require for good visual effect is greater than that required for mere discernment. Light is required in a building to illuminate the interior and its contents. Day lighting is therefore, the practice of using natural light from the sky to provide illumination in the interior environment (Heschong, 2002A). and where there is need to carry out some tasks such as reading, writing assembling or repair work as well as operating mechanical equipment, daylight is to illuminate the task appropriately and to an appropriate extent so that the visual mechanism can function at high level of efficiency (Vandenberg, 1979 ; Neufert, 1980; and Prouse. 1994). This is because, when there is adequate daylight illumination, there shall be improved visibility and mental stimulation and mood of the students shall also improve and hence improved performance (Heschong, 2002 B).

The degree of luminance resulting from the amount of daylight illumination on a task (job) becomes even more important in the workshop for students effective workshop practice. Therefore, day lighting is of major concern and must be incorporated in the building design in such a way that, the building and its occupied space provide satisfactory visual and thermal environment, even in the absence of artificial (electricity) light. In the same vein, Musa, Abdullah, Che-Ani, Tawil and Tahir (2012) reported that, lighting plays a very important part in our life, and that light is one of the lighting is one of the parameters that influence indoor environment quality.

Adequate illumination of workshop space ensures safety of students from machine and normal bench shop accidents. This therefore requires increase intensity of illumination at workstations as dictated by the task (Salmon and Salmon, 1980). Any daylight illumination adequate for the functions of task and amenity will be adequate also for safety (Vandenberg, 1979). Adams (1982) further stated that; the standard of lighting in industry is directly related to efficiency of production and safety'. Kalstrom (1999) also reported that, 'the most significant improvements you can make in a workplace are natural lighting and indoor air quality'. In a bench shop, there are cutting, manual filling and drilling, forging, fitting, wood plaining etc tasks to be carried out. However, bench shop practice can only be effective when the workshop space has adequate daylight illumination even where there is no electricity for artificial lighting.

Various factors are likely to affect daylight illumination of workshop space such as the number and size of window and door openings; contents in the internal space; workshop and window sill height; depth of the internal space from window openings; reflectance values of construction materials and visual acuity of students. The number and size of window and door openings affects the admission of daylight into a room space. For adequate day lighting of the internal spaces in the tropics, 40-80% of the external walls should be provided for window openings (Evans, 1979). However, providing adequate number of opening is one factor but achieving specific level of luminance and Daylight Factor (DF) for workshop spaces is also very essential (Vandenberg, 1979; and Adams, 1982). The contents in the internal space such as columns; the floor-ceiling height, and congestion in workshop space could affect daylight illumination. That is, they are likely to obstruct the penetration of daylight into the interior of a workshop space. This could create patches of sunlight or shadows, which in turn affect proper vision and make accidents more likely (Salmon and Salmon, 1983). In this regard, the organization of the internal space of a workshop should be such that, it has high floor ceiling; internal space free of columns, and the equipment layout should ensure efficient flow pattern (Jones, 1980; and Salmon & Salmon, 1980).The relationship between the horizontal worktop heights to the height of window sill is also important in daylight illumination. This is because, the measurement of light failing on the horizontal plane is determined at this height. Therefore, worktop height is usually kept at between 850 to 900 mm (Vanderberg, 1979 and Jones, 1980); this is about the height of a window sill.

The depth of the internal space from window openings is another factor, which affects daylight illumination of workshop. This is because; the depth to which natural light can penetrate is limited. The areas remote from the windows are likely not to be adequately illuminated. Therefore, it is appropriate to maximize the natural light by bringing it into the building at as high an elevation as possible (Kalstrom, 1999). The materials used in the construction of the doors, windows and walls; and the paint applied to the walls and ceilings also affects the daylight illumination of a workshop space according to their reflectance values (Vandenberg, 1979; and Adams 1982; and Evans, 1994). That is, dull surfaces are not likely to reflect daylight adequately inside the workshop space. There is therefore, the need for an accurate estimation of the amount of daylight entering a building since it is a key step in evaluating day light designs (Li, Cheung and Cheung, 2006).

Apart from the physical factors that affect daylight illumination, the visual acuity of the students of the workshop space is very important. No matter how illuminated a workshop space may be, the students may be either near sighted that is; they may only achieve a proper focus of near objects. Other students may be far sightedness, that is, they see clearly at far distance but encounters difficulty in seeing properly at near distance. Visual acuity is therefore the ability of the eyes to differentiate between detailed features of what we see or it is the ability to see fine details of an object (McCormick and Sanders, 1993).

1.2 Statement of problem

The problems of daylight illumination of workshop space occur when (1) the workshop space do not have adequate enlarge windows to admit enough daylight for illuminating the interior. This means, students require extra effort to see their tasks during workshops practice and (2) the students using the workbenches remote from the window openings are likely not to see their tasks properly and this may affect their accuracy level during workshop practice. In effect, the problem of daylight illumination of workshop space is mainly due to design defects. Therefore, the effect of day light illumination in school workshops on students' visual acuity and accuracy levels in workshop practice deserves special consideration and hence this study.

1.3 Objectives of the Study

The main objective of the study is to find out the effect of day light illumination in school workshops on students' visual acuity and accuracy levels in workshop. Based on this objective, the study attempts to ascertain:

1. The coverage areas of the window opening on the external walls, and whether they admit adequate daylight to illuminate the interior;
2. The reflectance values of the materials used in the construction of the doors, windows and walls; and the paint applied to the walls and ceilings;
3. The level of visual acuity of the students, and whether, they have any

1.4 Research Questions and Hypotheses

In addition, the study sought answers to the following research questions:

1. What is the required coverage area of the window opening on the external walls of the workshop?
2. What is the level of visual acuity of the students (test for near and are sightedness)?
3. What is the level of the student's perception of daylight illumination in the workshop space?

4. What is the accuracy level of the students on a given task in the workshop?

The following null hypotheses were also formulated as a guiding statement:

1. There is no relationship between the level of visual acuity of students and their level of perception of the daylight illumination in a workshop space; and
2. There is no relationship between students' level of perception of daylight illumination of workshop and their accuracy level in workshop practice.

2 Methodology

2.1 Participants

The participants were 56 Nigeria Certificate in Education (NCE) 300 Level Technical Education students of the Federal College of Education (Technical), Omoku, Nigeria during the 2009/2010 academic session. This population also constituted the study sample. The choice of the 300 Level students was because they had a relative exposure to bench work for at least for two years.

The woodwork bench-shop in the School of Technical Education of college was used for the study. The choice was made because the college produces graduates Technical Education after a three year programme, and the students were expected to manipulate bench shop equipment and tools at the end of the three-year programme. The size of the work benches were 1.6 m long, 0.9 m wide and 0.9 m high, and are arranged orderly in four columns and six rows. There are twenty-four (24) benches with two (2) students to a bench; that is, a capacity for forty-eight (48) students. Each bench has two bench vices fixed at the two opposite diagonal edges. The distance of each bench vice from the two opposite window facades (light source) is 2.5 m, 4.1 m, 5.3 m, and 6.9 m respectively.

2.2 Instruments

The instrument for data collection was:

1. Physical measurement of the building components such as window and door openings; floor and walls, and the distance to tasks from window opening. This is to ascertain whether the window openings are large enough to admit the required daylight illumination.
2. The data on the visual acuity of the students was collected to ascertain their perception of the level of the legibility of alphabet characters when viewed at various given reading distances. This was to test whether any of students had any visual impairment such as near-sightedness or far-sightedness. To test for near sightedness, the letter-**E** of about 13.5 mm high with the same width and printed in back on a white background was kept at a reading distance of 2.5 m, 4.1 m, 5.3 m and 6.9 m respectively from the students. The expected response of the students to the level of legibility of the letter-E at the given distances was very legible, legible, fairly legible or not legible using a four point on the Likert scale.

The capital letter **E-** test was conducted by placing the letter at the reading distance of 20 ft (6 m). This is the most important and common subjective test where optometry instruments and equipment are not available. The test can be given by a person with little training (Encyclopedia

Britannica Vol. 17, 1983; Collier Encyclopedia, Vol. 18, 1957, and New Home Medical Encyclopedia Vol. 2, 1974). Any student who cannot see the letter **E** at the 6 m distance was near sighted. The size of the letter **E** for the distance of 6 m was calculated from the following equation (McCormick and Sanders, 1993).

$$H\ (mm) = 0.0022\ D + K_1 + K_2 \quad (1)$$

Where H = height of the letter **E** (mm)

K = Correction factor for illumination for normal viewing condition (0.06)

K = Correction factor for important viewing condition (0.075).

To test for far-sightedness, the students were allowed to red from the normal printed letter characters in a textbook at reading distances of 100 mm, 200 mm, 300 mm, and 400 mm respectively. The expected students' response to the level of legibility of the printed characters in the textbook at the given distance was very legible, legible, fairly legible and not legible respectively. For the fair- sighted test, the effect of the test is to cause a recession of the near point so that nearby objects have to be viewed at a distance for the eyes to see clearly (Coiler Encyclopedia Vol. 7, 1957). Students who see the printed character beyond 330 mm were far sighted.

3. Allowing students to respond to their perception of the level of daylight illumination in the workshop space at work bench distances of 2.5 m, 4.1 m, 5.3 m and 6.9 from the window openings. The response to the level of daylight illumination is either, excellent, very adequate, adequate, fair or poor at the given distances in a four point Likert Scale.
4. Assigning students to a given task of "Measure, cut and Measure". Each student was to cut a high yield reinforcement iron bar of 16 mm diameter into four equal parts of 50 mm. The accuracy of the tasks was ascertained by measuring the cut tasks with a Vernier Caliper. A tolerance level of $\pm$ 3 mm was used and the ratings assigned were very accurate, accurate, fairly accurate and not accurate. Every student was exposed to the same level of daylight illumination at the given distances of the task position (bench vices) from the light source.

The reliability test was carried out to test the instruments (2), (3), and (4) by pilot testing fifteen 200 Level NCE Technical Education students during the 2009/2010 academic session other than the ones used for study. The Cronbach Alpha Coefficient (α) was used to determine the reliability of the instrument. The Coefficient values for the instruments (2, 3, and 4) were 0.65, 58 and 0.56 respectively, indicating that reliability of the instruments.

3 Results

3.1 Research question one

What is the required coverage area of the window opening on the external walls of the workshop?

The results on Research Question one which sought to ascertain whether the coverage area of the existing window openings on walls were large enough to admit adequate daylight to illuminate the internal space was determined after calculating the Daylight Factor (Df) using the data in Table 1. The Daylight Factor (DF) was determined using the following equation (Vandenberg, 1979) in conjunction with the data in Table 1.

$$Df = \{10WH/ L (L^2+H^2) \} + \{4GR/ F (1-R)\} \quad (2)$$

Where, W, effective width of window opening = 1.7 m

H, effective height of window opening = 1.15 m

L, distance of the reference point (distance of the last task from light source) = 6.9 m

G, Effective area of one window opening = 1.96 m^2

F, Floor area of bench shop = 238.5 m^2

R, Average Reflectance of surfaces = 0.44

Therefore, $Df = \{10 \times 1.7 \times 1.15^2\}/ \{6.9 (6.9^2 + 1.15^2)\} + \{4 \times 1.96 \times 0.44\}/ \{238.5 (1 - 0.41)\}$

$= 0.089$ or 8.9%

In determining the required area of window opening in the bench shop, the following equation was used (Vandenberg, 1979) with the data from Table 1.

$$P = 10 \times Df \times F \quad (3)$$

Where, P, Required area of opening = m^2

Df, Required Daylight Factor = 8.9%

F, Floor area of bench shop = 238.5 m^2

Therefore, $P = \{10 \times 8.9\} \quad \times \{238.5\}/100 \quad = 212.72\ m^2$

In addition, the required area of window opening (P) using the average DF of 5%

$P = 10 \times \{5 \times 238.5\}/100 = 119.25\ m^2$

The calculated values of the required area of window were between 119.25 m^2 and 212.27 m^2. These values are far more than the values of the area of existing window openings of 23.60 m^2. In addition, the value of 23.60 m^2 for the existing window openings constituted only 12.3% of the walls. This percentage did not meet the average requirement of between 40-80% (Evans 1979). The implication was that, the bench shop was not adequately illuminated with daylight.

3.2 Research question two

What is the level of visual acuity of the students (test for near and are sightedness)?
Tables 2 and 3 presented the results for Research Question two that tried to find out the students' visual acuity for near-sightedness and far-sightedness at the given reading distances from daylight source. The results in Table 2 revealed that, the mean scores were more than the median score of 2.5. The implication was that, at the required farthest distance of 6.9 m, the letter **E** was legible to all the students indicating that, there was no visual impairment observed. That is, the student can see far objects at the required distance and no student is near sighted. The results of the students' visual acuity with respect to far-sightedness at the given reading distances from the eye are presented in Table 2.

The results in Table 3 indicated that, at the limiting distance of 330 mm, the letter characters in the textbook were legible to all the students. This is shown by the mean scores, which were more than the median score of 2.5. The implication was that, the students' visual acuity was very high and they do not seem to have any visible visual impairment. They can see letter characters of textbook legibly within the limiting distance. No student was far-sighted and the visual acuity level of the students was not likely to affect effective workshop practice.

3.3 Research question three

What is the level of the student's perception of daylight illumination in the workshop space?
Research Question 3 sought to find answer to the students' perception level of daylight illumination in the workshop space and the results presented Table 4 showed that the mean scores were less than the median score of 3.0 in three out of the four variables (distance from window openings). The implication of the result was that, the level of daylight illumination in the workshop space began to diminish after a distance of 2.5 m from daylight source.

Research question four

What is the accuracy level of the students on a given task in the workshop?
The results of the accuracy Level of the Students in a given task in workshop practice with respect to Research Question 4 as presented in Table 5 indicated the average values of the students' level of accuracy in the "measure, cut and measure" task during workshop practice.
The results in Table 5 revealed that, the accuracy level decreased when the distance of the task from window openings (source of daylight) increased. The mean scores of the students' accuracy level for the variables were more than the median score of 2.5 for distances 2.5 m and 4.1 m and less for distances 5.3 and 6.9 when distance of the task is farther away from the window openings.

Hypothesis on

There is no relationship between the level of visual acuity of students and their level of perception of the daylight illumination in a workshop space.

The results of Pearson Product-Moment Correlation used in testing Hypothesis (HO_1) on whether there was no relationship between the level of visual acuity of the students and their level of perception of daylight illumination in the workshop are presented in Table 6 and 7. The mean scores of students' visual acuity level with respect to near sightedness at the different reading distances was designated X and their level of perception of daylight illumination in the workshop at the different distances of the task from daylight source was designed Y. The result of the Correlation coefficient test in Table 6 revealed that the calculated r-value of 3.18 was greater than the table value of 0.88 and hence the null hypothesis was rejected. This means, there was a significant relationship between the level of visual acuity of the students and their level of perception of daylight illumination in the workshop. In addition, the Pearson Product-Moment Correlation was also used in testing the hypothesis with respect to far sightedness. The results in Table 7 revealed that, the calculated r-value of 2.143 was greater than the table value of 0.88. The hypothesis of no relationship between the level of students' level of visual acuity and their level of perception of daylight illumination in the workshop was rejected. The implication of these results was that, since the students were not visually impaired, their level of perception of daylight illumination in the workshop space was likely to be correct.

Hypothesis two

There is no relationship between students' level of perception of daylight illumination of workshop and their accuracy level in workshop practice.

The Pearson-Product Moment Correlation was further used to test the research Hypothesis (HO_2) which sought to establish whether there was no relationship between students' level of perception of daylight illumination in workshop and their accuracy level in workshop practice and the results are presented in Table 8. The mean scores of the students' perception of daylight illumination was designated X and their accuracy level was designated Y. The calculated r-value of 0.984 was greater than the table value of 0.811; and this indicated that, a significant relationship between the students' perception of daylight illumination in workshop and their accuracy level in workshop practice existed. Hence, the null hypothesis was rejected. The implication of the result was that, the bench shop was not adequately illuminated and vision was relatively impaired since the accuracy level of the students in the given tasks decreased as the distance of the tasks from the daylight source increased.

4 Discussion

The findings revealed that, the bench shop was not adequately illuminated with day lighting for effective students' workshop practice. This means that, the incidence of daylight into the bench shop space was not adequate to provide the required daylight illumination that would have enabled the students execute their tasks effectively. The reason for this is because; the area of wall covered by window opening was only 23.6 m^2 instead of the required window coverage area of between 191.25 m^2 and 212.27 m^2. The value of 23.6 m^2 window coverage area was far less than the 40-80% requirement (Evans, 1979) for standard service illumination for Daylight Factor of 5% (Adams 1982, Vandenberg, 1979).

It was expected that, in any workshop or laboratory space, the daylight penetration should be able to illuminate over the whole area of the space. It is only when a workshop space is adequately illuminated that there will be efficiency in production, (Adams, 1982) and safety in the workshop is also assured (Salmon and Salmon, 1980; and Halamka, 1980).

On the perception of students on the level of daylight illumination, there was a general agreement that, there was inadequate daylight illumination of the bench shop especially those workbenches located farther from the daylight source. This observation was consistent with Greene (1980) who stated that, 'the amount of daylight illumination from side wall window near the window sills is maximum; and decreases as the distance increases.

The findings also showed that, students' accuracy level for a given task became less and less accurate as the task was executed at distances further from the light source (Window openings). This report was in agreement with Adams (1982) who observed that, the standard of lighting in industry is directly related to the efficiency of production and to safety. Therefore, were adequate illumination is provided with increased intensity at work stations as dictated by the task, the visual mechanisms can function at a high level of efficiency and ensures safety. In the same vein, Fielding (2002) also opined that, there is a positive correlation between day lighting and academic performance'. Heschong (2002 B) further reported that, daylight makes a difference, not only in helping buildings become energy efficient but also for students who learn more effectively.

The relative depth of the bench shop space and the low floor-ceiling height of less than 3.6 m did not allow for adequate control of brightness to meet the requirement of the intended occupants. Moreover, where a building section could not admit enough daylight, the effect was that, patches of sunlight will be experienced in form of shadows and this effects vision and lead to accidents in workshops; and since the depth to which natural light can penetrate is limited, it is advisable to provide alternate day lighting methods to ensure adequate daylight illumination of the internal space of the workshop space. In this regard, Chao, Lijun and Xiangpei (2011) reported that, brightness is a key factor of environment, and the quality of it can influence task performance, comfort and well being. And the brightness can be used to direct viewers' attention to particular elements in the environment. Conversely, it was the view of Winterbottom and Wilkins that, aspects of classroom lighting and décor that can promote discomfort can impair task performance. It means that, there was a good deal of consensus on the value of day light and quality lighting design (Li, Cheung & Cheung, 2006, Villecco, Sekowitz & Griffiths, 1979) and that high performance in school is synonymous with sustainable school building (Eley, 2006).

5 Conclusion and Recommendations

There was a daylight illumination problem in the bench shop space. This was because, at the design stage, the sizes of individual window openings in relation to the floor area and the room volume, which provides space for sunlight penetration, was not considered. This affected students' effective workshop practice. Therefore, workshop should be properly oriented to ensure adequate admission of daylight into the bench shop; and appropriate roof lighting methods should be incorporated to ensure illumination of every part of the room space especially those areas remote from window openings. And where bilateral day lighting is provided, glazed fenestration should be preferred instead of wooden casement windows.

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Table 1: Data on physical measurements of existing building materials and components

Physical measurements		Reflectance Values for Medium Colours					
Components	1	Components	2	3	4	5	Average
Area of total window openings.	23.60 m^2	Ceiling	0.70	0.78	0.80	0.30	0.44
Area of walls	191.58 m^2	Walls		0.40	0.35	0.40.	0.50
Area of floor	238.50 m^2	Floor		0.15	0.18	0.25	-
Effective size of window openings	1.7 x 1.15 m	Average		0.42	0.44	0.48	0.40

Source: 1. Author's Fieldwork, 2010; 2. Burberry, 1979; 3. Evans, 1974; 4. Adams, 1982 and 5. Vandenberg, 1979.

Table 2: Visual acuity-test for near-sightedness

Reading Distance (m)	Very Legible	Legible	Fairly Legible	Not Legible	Mean Score (X)
2.5	56	-	-	-	4.0
4.1	56	-	-	-	4.0
5.3	50	6	-	-	3.89
6.9	43	13	-	-	3.77

Number of students = 56, Median score = 2.5

Table 3: Visual acuity- test for fair-sightedness

Reading Distance mm (X)	Very Legible	Legible	Fairly Legible	Not Legible	Mean Score
100	56	-	-	-	4.0
200	56	-	-	-	4.0
300	50	-	-	-	4.0
400	52	4	-	-	3.93

Number of students = 56, Median score = 2.5

Table 4: Students' perception of level of daylight illumination in bench shop

Distance of task from daylight source (m)	Excellent	Very good	Good	Fair	Poor	Mean Score (X)
2.5	7	19	21	9	0	3.43
4.1	5	8	26	14	3	2.96
5.3	0	0	23	21	12	2.20
6.9	0	0	10	19	27	1.70

Number of students = 56 , Median score = 3.0

Table 5: Students' accuracy level on a given task in workshop practice

Distance of task from Daylight source (m)	Very Accurate	Accurate	Fairly Accurate	Not Accurate	Mean Score (X)
2.5	8	30	18	0	2.82
4.1	4	29	21	2	2.63
5.3	1	25	26	4	2.41
6.9	0	20	31	5	2.27

Number of Students = 56, Media Score = 2.5

Table 6: Correlation coefficient of visual acuity (near sightedness) and students' perception of daylight illumination in workshop

Distance of task from daylight source (m)	X	Y	X^2	Y^2	XY
2.5	4.0	3.43	16.0	7.95	13.72
4.1	4.0	2.96	16.0	6.92	11.84
5.3	3.89	2.20	15.13	5.81	8.56
6.9	3.77	1.70	14.21	5.15	6.61
$\sum$	15.66	10.29	61.34	25.83	40.70

df = 3, $P \leq =0.05$, Table r-Value=0.8780, Calculated r-value=3.18.

Table 7: Correlation coefficient of visual acuity (Far sightedness) and students' perception of daylight illumination workshop

Distance of task from daylight source (m)	X	Y	X^2	Y^2	XY
2.5	4.0	3.43	16.0	7.95	13.72
4.1	4.0	2.96	16.0	6.92	11.84
5.3	4.0	2.20	15.13	5.81	8.80
6.9	3.93	1.70	14.21	5.15	6.68
$\sum$	15.93	10.29	63.44	25.83	41.04

df=3, $P \leq =0.05$, Table r-value=0.8780 Calculated r-value=2.143.

Table 8: Correlation coefficient of students' level of perception of daylight illumination and their accuracy level in workshop practice

Distances of task from Daylight source (m)	X	Y	X^2	Y^2	XY
2.5	3.43	2.82	11.76	13.72	9.67
4.1	2.96	2.63	8.76	6.92	7.78
5.3	2.20	2.41	4.84	8.80	5.30
6.9	1.70	2.27	5.15	6.68	3.86
$\sum$	10.29	10.13	63.44	25.83	41.04

df= 3, P≤=0.05, Table r-value=0.811, Calculated r-value=0.984