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Secondary School Students' Perceptions of the Environment of the Science Laboratory

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ABSTRACT *The purpose of the study was to ascertain the influence of school-type and gender and their interaction on students' perceptions of the science laboratory environment. Senior secondary 3 science students (105 males and 100 females) randomly drawn from 5 secondary schools in Calabar participated in the study. Two research questions were stated to guide the study. The Science Laboratory Environment Inventory was used in data collection. The data were analyzed using 2 x 2 x 5 factorial ANOVA with repeated measures on the laboratory environment factor. The results of the analysis indicated that the main effects for school-type and gender were not significant, while the main effects for laboratory environment and the interaction of the three variables were significant (p<.05). Post-hoc analyses indicated that, of the 5 dimensions of the laboratory environment, open-endedness was least favorably perceived. Single-gender school females and co-educational males, respectively, perceived the student cohesiveness dimension significantly more favorable than single-gender school males.*

KEY WORDS: *Laboratory environment, Students' perceptions, Dimensions of laboratory environment*

Introduction

Science consists of an organized body of knowledge, an attitudinal disposition, as well as a process and activity. It is concerned with the practical working out of ideas through the manipulation of materials in such a manner as to lead to discoveries (Nuffield Foundation Science Teaching Project, 1967). The extant fund of scientific knowledge was developed through the processes of science. Doing science therefore requires the acquisition of the science process skills. Thus, one important aim of science education is to facilitate students' acquisition of the science process skills through practical work in the laboratory. Specifically, the aim of laboratory teaching is to facilitate students' acquisition of manipulative skills (i.e., ability to set up, manipulate and use efficiently standard laboratory equipment), observational skills (i.e., ability to observe accurately, read instruments correctly, and record the observations accurately), experimental and interpretive skills (i.e., ability to carry out investigations, present and interpret observations and experimental data, and evaluate the reliability and accuracy of experimental procedures), planning skills (i.e., ability to plan experimental procedures using standard laboratory techniques and to modify established techniques to suit novel experimental situations) as well as the development of such attitudinal characteristics as cooperation, persistence and resourcefulness in dealing with practical tasks, and enthusiasm for science (Dynan & Kempa, 1977). Consequently, laboratory teaching is a veritable science teaching strategy, which provides opportunity for students to manipulate materials and equipment in order to understand better the concepts and principles in science as well as the nature of the scientific enterprise.

The results of some studies (e.g., Watson, Prieto, & Dillon, 1995) have however shown that practical work in the laboratory has only marginal effects on students' understanding of science. As a result, given the rising cost of instruction and the press for efficiency in teaching, many educators (e.g., Lunnetta, Hofstein, & Giddings, 1981; Pickering, 1980; Walberg, 1991) have begun to ask whether laboratory experiences contribute to anything unique and important enough to justify their expense and time. Earlier, Bates (1978), while pursuing the same questions, had concluded from a review of studies involving laboratory work that though lecture, demonstration, and laboratory teaching methods appear equally effective in transmitting science content, but laboratory experiences are superior for providing students with skills in working with equipment, and have a greater potential for nurturing positive students' attitudes and for providing a wider variety of students with opportunities for success in science. Obviously, the value of laboratory activities in science teaching is indisputable and is therefore emphasized (Abdullahi, 1979, 1982). The boredom reportedly experienced by students in laboratory classes (Fraser, Okebukola, & Jegede, 1992) does not diminish the value of laboratory work. It may only be indicative of poor organization, management, and coordination of laboratory activities by teachers. Teachers' management and coordination of laboratory activities is still largely unknown.

A step towards ameliorating students' negative attitudes and reactions to laboratory work as well as poor learning outcomes is to determine the laboratory work management and coordination techniques of science teachers vis-à-vis the psychosocial characteristics of the learning environment of the science laboratory. This is important because "the sociocultural environment determines to a great extent how an individual (or group of individuals) functions, interprets and reacts to various stimuli" (Ogunniyi, Jegede, Ogawa, Yandila, & Oladele, 1995, p. 818).

Though educational researchers have shown progressively increasing interest in the conceptualization, measurement, and investigation of students' perceptions of the psychosocial characteristics of their classroom learning environments (Fraser, 1986, 1989, 1994; Fraser & Fisher, 1982, 1983; Fraser & Walberg, 1991; Haertel, Walberg & Haertel, 1981; Haladyna, Olsen, & Shaughnessy, 1982; Moos, 1979; Walberg, 1976), and though science education researchers are leading in research on classroom learning environments (Fraser, Giddings, & McRobbie, 1995), much work has not been done on the science laboratory environment (Hegarty-Hazel, 1990) particularly in Nigeria. The only known study in Nigeria, which is essentially developmental, has however indicated that the various dimensions of the science laboratory environment, namely, student cohesiveness, open-endedness, integration, rule clarity, and material environment, are substantially associated with students' attitude towards science laboratory work (Fraser, Okebukola, & Jegede, 1992).

Obviously, there is need for more studies in science laboratory environments in Nigeria, and the present study was designed to determine the influence of school-type (coeducational/single-gender), students' gender and their interaction on secondary school students' perceptions of the five dimensions of the science laboratory environment, that is, student cohesiveness, open-endedness, integration, rule clarity, and material environment. More specifically, the study was designed to answer the following research questions:

1. What is the nature and extent of senior secondary three (SS 3) science students' perceptions of the following five dimensions of the science laboratory environment: student cohesiveness, open-endedness, integration, rule clarity, and material environment?
2. How do students' gender, school-type (coeducational/single gender) and their interaction influence students' perceptions of the five dimensions of the science laboratory environment?

Methodology

Sample

The sample consisted of 205 senior secondary 3 (SS3) science students (105 males and 100 females) randomly drawn from five schools in former Calabar Municipality (now Calabar Municipality and Calabar South local government) of Cross River State, Nigeria. The Nigerian education system provides for six (6) years of post-primary education divided equally into three (3) years each of Junior and Senior secondary (or high) school education. SS3, is the last year of the senior secondary (or high) school. SS3 students were chosen as subjects for the study because in most of the schools students have the opportunity to perform practical work in the laboratory only in SS3, and their practical experience in the laboratory will enable them to give reliable information on the environment of the science laboratories in their schools. The schools used for the study include three coeducational schools and two single-gender schools (one each of Boys-only and Girls-only schools) out of 14 coeducational, 3 Girls-only and 2 Boys-only schools. The schools were selected by the stratified random sampling technique on the basis of school-type. Only schools that have science laboratories and have presented students for the final West African senior school certificate examination (WASSCE) were selected for the study. Only students, who offered the science subjects, Physics, Chemistry and Biology, and were present in school on the day the instrument was administered, participated in the study. Forty-one (41) students were randomly selected from each of the five (5) schools so as to avoid redundancy of responses since they will be reporting on the same laboratory or set of laboratories in a given school.

Instrument

The Science Laboratory Environment Inventory (SLEI) developed by Fraser, Giddings and McRobbie (1992) was used for the study. There are two forms of the SLEI: The class Form which involves an individual student's' perception of the class as a whole, and the Personal Form, which involves a student's perception of his/her own role within the classroom. Each of these two forms of the SLEI has Actual and Preferred versions (Fraser, et al, 1995). Generally, each form and version of the SLEI consists of the following five dimensions of the science laboratory environment: Student cohesiveness (extent to which students know, help and are supportive of one another), Open-endedness (extent to which laboratory activities emphasize an open-ended, divergent approach to experimentation), Integration (extent to which the laboratory activities are integrated with non- laboratory and theory classes), Rule Clarity (extent to which behavior in the laboratory is guided by formal rules), and Material Environment (extent to which laboratory equipment and materials are adequate). Each of the five dimensions of the SLEI has seven items measuring it, giving a total of 35 items for the whole instrument. Twenty-two of the items are positively stated while 13 are negatively stated. Examples of items in the 5 dimensions of the Actual version are as follows: "Students are able to depend on each other for help during laboratory classes" (Student cohesiveness, positive); "In our laboratory sessions, the teacher decides the best way to carry out the laboratory experiments" (Open-endedness, negative); "What we do in our regular science class is unrelated to our laboratory work" (Integration, negative); "Our laboratory class has clear rules to guide students activities" (Rule clarity, positive); "Equipment and materials that students need for laboratory activities are readily available" (Material environment, positive). The instrument is a five-point Likert-scale with the following response options for the Actual version: Almost never, seldom, sometimes, often, and very often. These response options were respectively scored 1 to 5 for positively stated items and in the reverse order for negatively stated items.

Though the Actual and Preferred versions of the Class Form of the SLEI were used in data collection, the results reported here are based on the Actual version. A comparison of the results of the Actual and Preferred versions has already been reported (see Kalu, 2001). For a Nigerian sample and using the individual as the unit of analysis, Fraser, Okebukola and Jegede (1992) reported an internal consistency reliability values ranging from .49 to .71 for the 5 dimensions of the Actual version of the SLEI. In this study, using the Cronbach alpha, the internal consistency of the 5 dimensions of the Actual version was established to be within the range .52 to .69.

Data Collection Procedure

In each of the 5 schools, the instrument was administered to the students personally by the researcher with the help of the science teachers and was collected back from the students immediately after completion.

Data Analysis and Results

The data generated with the instrument were analyzed using a 2x2x5 (school-type by gender by laboratory environment) factorial analysis of variance (ANOVA) with repeated measures on the laboratory environment factor. The mean perception scores and the standard deviations for the 5 dimensions of the science laboratory environment for each school-type and gender group as well as the results of the ANOVA are shown in Tables 1 and 2.

The results in Table 1 indicate that Open-endedness as a dimension of the science laboratory environment, has the least total mean perception score ($\bar{x}$ = 19.35, SD = 4.05), followed by Material Environment ($\bar{x}$ = 21.84, SD = 5.00), student cohesiveness ($\bar{x}$ = 22.69, SD = 3.57), Rule Clarity ($\bar{x}$ = 24.03, SD = 4.46) and integration (Mean = 25.31, SD = 4.91), in increasing order of magnitude of mean perception scores. The same trend applies to each school-type and gender group.

Table 1
Descriptive statistics of Students' Perception Scores
on the Five Dimensions of the Laboratory Environment

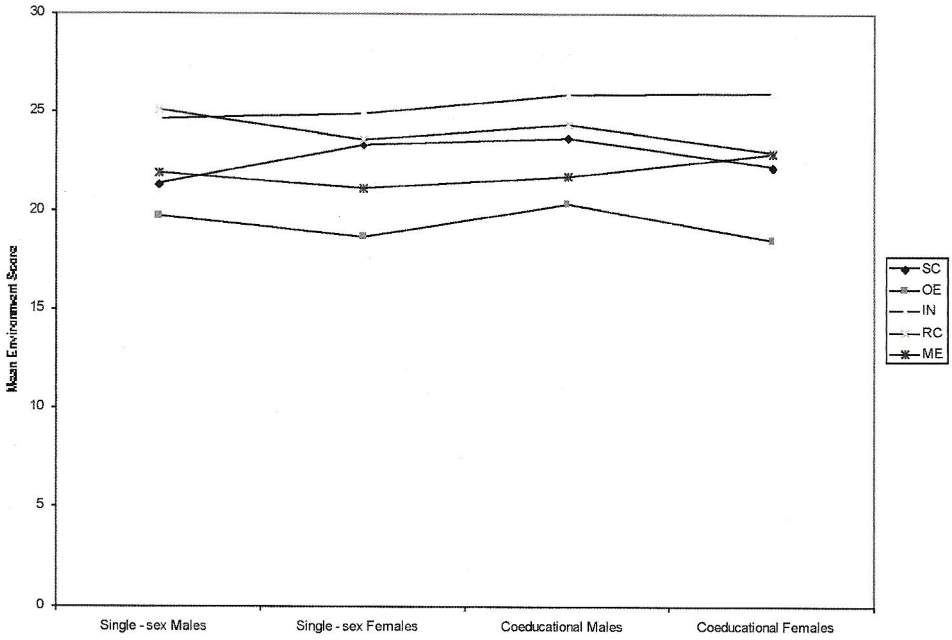
School-type/ Gender		Student Cohesiveness		Open Endedness		Integration		Rule Clarity		Material Environment	
	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Single-gender	108	22.39	3.63	19.18	3.72	24.80	5.31	24.27	4.64	21.46	5.06
Coeducational	97	23.03	3.48	19.54	4.41	25.89	4.37	23.77	4.25	22.27	4.93
Male	105	22.54	3.46	20.03	3.70	25.26	5.01	24.72	4.75	21.83	5.35
Female	100	22.85	3.68	18.63	4.30	25.37	4.82	23.31	4.03	21.86	4.63
Total	205	22.69	3.57	19.35	4.06	25.31	4.91	24.03	4.46	21.84	5.00

Table 2
Summary of the School-Type by Gender by Laboratory Environment ANOVA
with Repeated Measures on the Laboratory Environment Factor

Source of variation	SS	df	MS	F
Between subjects	5869.84	204		
School-type (A)	58.98	1	58.98	2.06
Gender (B)	57.10	1	57.10	2.00
Ax B	5.40	1	5.40	0.19
Error (Between)	5748.36	201		
Within subjects	18372.60	820	28.60	
Laboratory Environment (C)	4216.61	4	1054.15	61.75**
A x C	75.12	4	18.78	1.10
B x C	151.00	4	37.75	2.21
A x B x C	202.13	4	50.53	2.96*
Error (within)	13727.74	804		

*** p <.05 **, p < .001, Critical Values: $F_{.05}$ (4,804) = .38; $F_{.001}$ (4,804) = 4.62**

The results of the ANOVA (Table 2) indicate that main effects of school-type and gender are not statistically significant while the main effect of laboratory environment and the interaction of the three variables are statistically significant (F_{Tab} 2.38 < F_{cal} 2.96; F_{Tab} 4.62 < F_{cal} 61.75; p<.05 and p<.001 respectively). Rather than present a mass of F-values resulting from post-hoc analyses of the significant interaction, which is likely to offend our sensibilities and befuddle our thinking, we decided to depict the interaction graphically. As shown in Figure 1, the interaction is, to a large extent, disordinal. Apart from open-endedness, the other 4 dimensions cannot be consistently rank-ordered for the four groups of students.



KEY: IN=Integration, ME=Material Environment, RC=Rule Clarity, OE=Open-Endedness, SC= Student Cohesiveness

Figure I. Graphical Illustration of the Interaction of the Five Variables.

The results of the post-hoc analyses (not shown) indicate that there is no significant difference (p >.05) in the mean perception scores of the following group of students in the specified pairs of dimensions of the laboratory environment: Single-gender school males, Student Cohesiveness/Material environment and Integration/Rule clarity; single-gender school Females, student cohesiveness/Rule Clarity and Integration/Rule Clarity; Coeducational School Males, student Cohesiveness/integration, open-ended ness/material environment and Integration/Rule Clarity; and Coeducational school Females, student Cohesiveness/Integration, student cohesiveness/Material environment and Rule Clarity/Material Environment. The remaining 30 pairs of points are significantly different in magnitude. It is noteworthy that, apart from one case, open-endedness was perceived significantly (p<.05) less favorable than the other 4 dimensions by all groups of students.

Also, the post-hoc analyses indicate that the following gender groups differ significantly (P<.05) in their perception of the specified laboratory environment dimension (gender group with greater mean score is listed first): Student Cohesiveness, Single-gender school females and males, and Coeducational school Males and Single-gender school males; Open-endedness, coeducational school males and females; Rule Clarity, single-gender school males and Coeducational school females; and Material Environment, Coeducational school females and single-gender school females. Apparently all groups of male and female students were homogeneous in their perception of the Integration dimension.

Discussion and Implications for Education

The results have indicated that Open-endedness is the least favorably perceived dimension of the science laboratory environment, followed by Material Environment, with Integration being the most favorably perceived dimension. Except for Coeducational school males who do not perceive Open-endedness and Material Environment significantly different, all other groups of students perceived open-endedness as being significantly less favorable than all other dimensions. Males and females were homogeneous in their views except in coeducational schools where males perceived open-endedness significantly more favorably than females. This means that close-ended laboratory activities dominate much of science education in the secondary schools in Calabar Municipality, and it corroborates the results of similar studies in other countries (Fraser, et al, 1995; Hodson, 1988; Lumpe & Scharmann, 1991). The laboratory activities are apparently only those that aim at verifying relationships already discussed in the class, especially since Integration is the most favorably perceived dimension by both gender groups and school-types. This means in effect that for teachers the aim of laboratory work is only to train students on how to follow instructions and manipulate apparatus. This is actually erroneous. Laboratory work should develop in the students the skills of inquiry in science, which goes beyond mere skills in manipulation of apparatus.

Science teachers' inability to organize open-ended, inquiry-oriented laboratory activities may be due to a lack of understanding of the inquiry instructional strategy and how to implement it, or due to conservative inertia wherein teachers tend to teach the way they were taught. These have far-reaching implications for teacher education. For one, there is a need to change science teacher education courses to incorporate more open-ended methodology, involving all the aspects and implications of practical work. In-service and pre-service teachers should be helped to delineate the components of the inquiry teaching strategy and to develop the necessary skills for its adoption in the classroom. Teacher education should help science teachers to develop the expert knowledge and skills for laboratory work. Teachers should be equipped to make practical work environment–oriented particularly at the lower levels and to avoid the danger of imparting to students, (un)consciously, the concept that practical science is something that belongs to the science laboratory only.

Secondly, teacher education should help science teachers to be flexible enough to easily adapt to changes. Indeed, it should equip them not only for changes, which already exist in schools but also for those that are not yet even envisaged. This includes changes in technology, changes in pedagogy and changes in curricular content. It should not only enable teachers to become adept in operating new equipment, but also to become sensitive to the fact that the availability of new media, like radio and television, in the children's homes makes important changes to their responsiveness in class. Teacher education should equip science teachers to adapt their pedagogy or teaching styles to changes in curricular content, in technology, in the pupils themselves, and in the organization of the educational system. Lawton (1987) is of the view that this can only be achieved through a process of continuing professional education, spanning the entire career of the teacher, vis-à-vis the integration of educational theory with practice. This is an issue that deserves deeper analysis.

The results have also shown that the main effects of school-type and gender are not significant. This means that separately, on their own, they do not influence students' perceptions of the science laboratory environment. This contradicts the results of previous studies, such as Fraser et al. (1995), Lawrenz (1987), Trickett (1978), and Trickett et al. (1982). Nevertheless, the interaction of school-type, gender and laboratory environment was significant indicating that different gender groups in different school-types differed in their perception of the various dimensions of the laboratory environment. Of particular interest is the finding that single-gender school females and coeducational males, respectively, perceived the student cohesiveness dimension significantly more favorably than single-gender school males. What this means is that rather than being helpful to and supportive of one another in the science laboratory male students tend to compete with one another, and the competition among the male students is fiercer in single-gender schools. Granted competition, the tendency to strive to excel one another, is part of the nature of male homosapiens. It serves to boost their ego. However, the results of studies comparing the performance of students in competitive and cooperative interaction settings (e.g., Humphrey, Johnson & Johnson, 1982; Okebukola, 1984; Okebukola & Ogunniyi, 1984) have indicated that cooperative interaction promotes greater mastery and retention of material studied, as well as practical skills, than competitive interaction. There is therefore the need for teachers, particularly those in male-only schools, to discourage the pristine, primordial competitive instinct of male students and strive to engender and inculcate the spirit of cooperation and supportiveness among the students during practical work. Science actually thrives on that spirit.

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