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ABSTRACT

This study determined Jamaican high school students' level of performance on five integrated science process skills and if there were significant differences in their performance linked to their gender, grade level, school location, school-type, student-type, and socioeconomic background (SEB). The 305 subjects comprised 133 males, 172 females, 146 ninth graders, 159 tenth graders, 150 traditional and 155 comprehensive high school students, 164 ROSE (Reform of Secondary Education), and 141 nonROSE students, 166 urban and 139 rural students, and 110 and 195 children of professional and nonprofessionals, respectively. Data were collected with the authors' constructed integrated science process skills test. Results indicated that the subjects' mean score was barely "average"; their performance in decreasing order was: interpreting data; recording data; generalizing; formulating hypotheses; and identifying variables. There were statistically significant differences in their performance based on their grade-level, school-type, student-type, and SEB in favor of the tenth graders, traditional high school students, ROSE students, and children of professionals, respectively. There was a positive, significant, and fairly strong relationship between their performance and school-type, but weak relationships among their student-type, grade-level and SEB and performance. (Contains 4 tables showing data, and 22 references.) (Author/CCM)

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An Analysis of Jamaican High School Students' Integrated Science Process Skills Performance

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Abstract

This study determined Jamaican high school students' level of performance on five integrated science process skills and if there were significant differences in their performance linked to their gender, grade level, school location, school-type, student-type and socioeconomic background (SEB). The 305 subjects comprised 133 males, 172 females, 146 ninth graders, 159 tenth graders, 150 traditional and 155 comprehensive high school students, 164 ROSE and 141 nonROSE students, 166 urban and 139 rural students, 110 and 195 children of professionals and nonprofessionals respectively. Data were collected with the authors' constructed integrated science process skills test. Results indicated that the subjects' mean score was barely "average"; their performance in decreasing order was: interpreting data, recording data, generalizing, formulating hypotheses and identifying variables; there were statistically significant differences in their performance based on their grade level, school-type, student-type, and SEB in favor of the tenth graders, traditional high school students, ROSE students and children of professionals respectively. There was a positive, significant and fairly strong relationship between their performance and school-type, but weak relationships among their student-type, grade-level and SEB and performance.

Introduction

While practical work in science is a key component of science education in many countries, it was not until the debut of programs such as "Science - A Process Approach "(SAPA), developed by the American Association for the Advancement of Science between 1963 and 1974, that the teaching of science process skills was specifically focused on in elementary and high school science curricula (Bredderman,1983). Classroom studies on scientific reasoning have centered on the basic and integrated science process skills and over the past three decades, many researchers have focused their attention on these skills (e.g. Germann & Aram, 1996; Molitor & George, 1976; Rainford, 1997). The *basic science process skills* (BSPS), provide the intellectual groundwork in scientific enquiry, such as the ability to order and describe natural objects and events. Examples of the BSPS are observing, classifying, measuring and predicting. The BSPS are the prerequisites to the integrated process skills. The ability to use BSPS is attributed to the ability to perform empirical-inductive reasoning or Piagetian concrete operational reasoning (Germann & Aram, 1996).The *integrated science process skills* (ISPS) are the terminal skills for solving problems or doing science experiments. Examples of ISPS are identifying and defining variables, collecting and transforming data, constructing tables of data and graphs, describing relationships between variables, interpreting data, manipulating materials, formulating hypotheses, designing investigations, drawing conclusions and generalising. The ability to carry out ISPS is attributed to hypothetico-deductive reasoning (Piaget's formal operational reasoning, Germann & Aram, 1996).

Since the 1960s, science process skills have been emphasized in the process-based integrated science (IS) curricula and textbooks for grades 7-9 students in the Anglophone- Caribbean (Soyibo, 1998). To improve access to, equity in and quality of education for all grades 7-9 Jamaican students, the Reform of Secondary Education (ROSE) project was introduced in 1993 in some pilot schools. By the end of 1999, all Jamaican post-primary schools were expected to be on the project (Soyibo & Figueroa, 1998). Really, grades 7-9 ROSE and nonROSE students use IS curricula that are identical in content and philosophy, but, in practise, the former are given the opportunity to do practical activities more than the latter. The ROSE science curricula, with emphases on BSPS and ISPS, are considered to be more student-centered than those offered to nonROSE students. ROSE science teachers undergo a two-week course tailored to equip them to utilize the project's methodologies and curriculum materials. Their lessons are also supervised by five teacher educators who provide them with feedback. Consequently, ROSE students are expected to do better than their nonROSE counterparts on any tests on any aspect of the grades 7-9 IS curricula (Soyibo & Figueroa, 1998).

With the introduction of the ROSE science curricula in Jamaica, it is expected that 18 basic and integrated science process skills will be taught in grades 7-9 through the use of laboratory approaches involving hands-on, minds-on activities. This position seems logical because some studies have shown that the use of activity-based approaches in science teaching, in contrast to the didactic approach, significantly improves students' science process skills achievement more than their science knowledge achievement (e.g. Reynolds, 1991). But a review of literature reveals that only few studies have been carried out on students' acquisition of science process skills in Jamaican ROSE and nonROSE high schools. Soyibo (1992) reported that Jamaican 7th graders' performance on four BSPS (observing, classifying, manipulating and inferring) and two ISPS (interpreting and predicting) was barely "average", while Rainford (1997) reported that Jamaican 7th graders' performance on three BSPS (observing, classifying and inferring) was poor and that their performance barely increased from pretest to posttest although they were taught the ROSE grade 7 science curriculum content. Internationally, many studies have been conducted on students' acquisition of BSPS and ISPS. Mattheis, Spooner, Coble, Takemura, Matsumoto, Matsumoto, and Yoshida (1992) found that a strong correlation existed between reasoning skills and ISPS among two large samples of North Carolina and Japanese junior high school students and that the reasoning and process skills improved as the students progressed from 7th grade to 9th grade. Germann and Aram's (1996) evaluation of American students' ability to perform the ISPS of analysing, recording data, providing evidence and drawing conclusions, revealed that only 61% of their subjects were able to perform and record the data successfully. While some researchers (e.g. Germann & Aram, 1996) have criticized the use of multiple choice tests that were commonly used to assess students' performance on science process skills (e.g. Molitor & George, 1976; Soyibo, 1992) only few researchers (Baxter, Shavelson, Goldman & Pine, 1992; Rainford, 1997) have developed practical laboratory tests to assess these skills.

There is evidence to suggest that despite the premium placed on the teaching of BSPS and ISPS in grades 7-9 in Jamaica since the 1960s, and despite the re-emphasis on the teaching of these skills in Jamaican ROSE grades 7-9 science curricula, there is a dearth of studies published on Jamaican high school students' performance on ISPS. Several past studies have reported inconclusive findings on the links among many independent variables such as gender, grade level, school location, school-type, student-type and socioeconomic background (SEB)) and differences in high school students' performance on specific science subjects. For example, regarding gender differences in science, many studies have reported that males generally outperformed females in science and mathematics (e.g. Third International Science and Mathematics Study, TIMSS, 1997)

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while some reported no gender differences in students' science performance (Greenfield, 1996; Rainford, 1997). Pertaining to school-type, some local studies reported that Jamaican students in traditional high schools significantly outperformed their peers in all-age, and comprehensive high schools in IS (Rainford,1997; Soyibo & Johnson,1998) and that with reference to student-type, Jamaican 7th and 8th graders, following the ROSE's IS curriculum, significantly outscored their nonROSE peers in science (Soyibo & Johnson, 1998).

With respect to students' science process skills performance, only few studies have reported that differences in students' BSPS performance are linked to their school location in favor of urban schools (Soyibo, 1992), school-type in favor of students in traditional high schools (Rainford, 1997) and SEB in favor of students from high low SEB (Gallagher, 1994). One justification for this study was that we could not access any published or unpublished studies that had investigated the links among the six independent variables reviewed above and differences in high school students' ISPS performance. However, we suspected that the six variables were likely to be linked to differences in the subjects' ISPS performance. We, therefore, put this conjecture to the test in this study.

Purpose of the Study

This study determined if (a) some Jamaican high school students' level of performance on a test of integrated science process skills (TISPS) was good or not; and (b) there were any significant differences in the students' performance on TISPS linked to differences in their gender, grade level, school location, school-type, student-type, and socioeconomic background (SEB) and their overall TISPS score.

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Research Questions

Answers were sought to the following questions:

1. Was the level of performance of some Jamaican 9th and 10th graders on a test of integrated science process skills (TISPS) good or not ?
2. Were there any significant differences in the students' performance on the TISPS linked to their gender, grade level, school location, school-type, student-type, and SEB ?
3. Were there any significant relationships among the students' gender, grade level, school location, school-type, student-type, and SEB and their overall performance on the TISPS ?

Methodology

Research Design The research design employed was a survey involving quantitative component that entailed an *ex post facto* dimension.

Sample The main study sample comprised 305 students (133 boys, 172 girls; 146 ninth graders, 159 tenth graders; 166 urban and 139 rural students; 150 traditional and 155 comprehensive high school students; 164 ROSE, 141 nonROSE students; 110 from high SEB and 195 from low SEB) randomly selected from four comprehensive and four traditional high schools in Jamaica. The pilot sample consisted of a class of 40 grade 9 students in a traditional high school. In Jamaica, 95% of the students who are admitted to the long-established "traditional" high schools (formerly referred to as "grammar schools") pass the common entrance examinations (CEE) at age 10 or 11, while 5% are admitted on the school principals' discretion, whereas only some of the students who are admitted to the comprehensive high schools (founded in the 1970s as junior secondary schools) pass the CEE while the majority gain admission by "age promotion from feeder schools" once they are

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12-years-old (UNESCO, 1983). In short, many Jamaican traditional high school students are generally intellectually superior to their comprehensive high school counterparts.

Instrument In line with the conceptual framework and three assessment dimensions suggested by Solano-Flores and Shavelson (1997) the performance assessment developed for the Test of Integrated Science Process Skills (TISPS) developed to measure the students' performance belonged to the comparative investigation task type where two or more objects are compared on some attributes. The three dimensions considered (methodological requirements, practical and logistic constraints to the assessment) were: content, equipment and use. The TISPS measured five skills and 12 subcategories of skills: recording data (3 subcategories: completing /constructing (a) graphs and (b) tables; collecting and transforming data into graphs and tables); interpreting data (2 subcategories: extracting information from (a)graphs and (b)tables); generalizing (3 subcategories: drawing general conclusions from data; interpolating/extrapolating between data points; identifying data that support a conclusion); identifying variables (3 subcategories: identifying the manipulated/causal variable; identifying the measured/responding variable; identifying the controlled variable); and formulating hypotheses (one subcategory: predicting relationship between the causal and the responding variable). For the main study, TISPS comprised 8 written performance items (maximum score = 41) and two hands-on performance tasks (maximum score=35) and the total score =76. Only three of the written performance items measured one subcategory of skill, while the two hands-on performance tasks tested all the five skills. One hour each was allocated to the three subsets of TISPS: Written performance test, Splash, and Is it hot or not ? (The last two were the hands-on tasks). TISPS Cronbach Alpha was 0.74 while the inter-rater reliability coefficients of the pilot scripts scored by one of the authors and an independent marker ranged between 0.89 and 0.91. The mean and SD of the pilot sample were 51.34 and 9.05. Details of the instrumentation are available from the authors.

Results

TABLE 1 HERE

The first objective of this study was to determine if the level of performance of some Jamaican 9th and 10th graders on a TISPS was good or not. Table 1 shows the subjects' means, percentage scores and standard deviations on the five skills. The table suggests that the subjects performed best on the skills of interpreting data, followed by recording data, generalizing, formulating hypotheses and worst on identifying variables.

The second purpose of this study was to determine if there were any significant differences in the students' performance on the TISPS linked to their gender, grade level, school location, school-type, student-type, and SEB. Their means and standard deviations were computed as shown in Table 2.

TABLES 2 & 3 HERE

Table 2 indicates that the mean of the (a) 10th graders is much higher than that of the 9th graders, (b) females is only slightly higher than that of males, (c) urban students is slightly higher than that of rural students,(d) traditional high school students is substantially higher than that of comprehensive high school students, (e) ROSE students is higher than that of nonROSE students, and (f) students from professionals' homes (high SEB) is much higher than that of students from nonprofessionals' homes (low SEB). Further analyses revealed that although the mean of ROSE students was slightly higher than that of their nonROSE peers on all the five skills (Table 3), it was only in respect of "recording data skill" that the mean of the former was statistically significantly higher than that of the latter ($t=3.60$, $p<.05$). To confirm if there were statistically significant differences in the subjects' overall means on TISPS linked to differences in the six independent variables, a 6-way analyses of variance (ANOVA) was computed. Table 4 displays the summary of the results.

TABLE 4 HERE

Table 4 shows that there were significant differences in the subjects' scores linked to their (a) grade level in favor of the 10^{th} graders, (b) school-type in favor of traditional high school students, (c) student-type in favor of ROSE students, and (d) SEB in favor of students from the professionals' homes (high SEB), and that there were no significant differences in their performance linked to their gender and school location.

The study's third objective was to establish if there were any significant relationships among the subjects' overall performance on the TISPS and their grade level, gender, school location, school-type, student- type and SEB. Table 5 shows the Pearson's correlation coefficients computed.

TABLE 5 HERE

Table 5 suggests that there was a positive, statistically significant and fairly strong relationship between the subjects' mean score and school-type ($r = .62$, $p < .001$), but weak relationships among their means and their student-type, grade level, and SEB, while there were no relationships among their TISPS performance and their school location and gender. These findings confirm the results of the data on which the ANOVA was based (Table 2).

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Discussion

Table 1 suggests that because the subjects' mean performance on the entire TISPS (36.56 or 49.40%) was barely "average", their overall level of performance in this study cannot be regarded as "good"considering the high premium placed on the subjects' acquisition of ISPS in their science curricula. Some of the possible reasons for the subjects' "mediocre" performance are now discussed. Many of the subjects might not be familiar with the types of tasks investigated and assessment used in this study because Germann, Aram and Burke (1996) asserted that students' good performance on ISPS was dependent on their experience with and domain-specific practice activities on the skills in prior tasks, while Ruiz-Primo and Shavelson (1996) reported that students' scores depended on the particular tasks investigated and on the particular method used to assess their performance. Indeed, one of the authors observed that during sessions of clinical supervision, as a teacher-educator in the sampled schools and other schools using the ROSE science curricula, teachers infrequently engaged their students' in hands-on science activities which was consistent with Soyibo's (1998) finding that the lecture-demonstration method is predominant in most Jamaican grades 7-9 science classrooms. Many of the subjects might have lacked the communication skills to explicitly express themselves in writing as evidenced in their TISPS scripts - a reason advanced for students' poor performance on science process skills (Germann, Aram & Burke, 1996; Rainford,1997) and for the poor science performance of many Jamaican students at all levels of education (Science Education Committee, 1999). Individual interview of the subjects, which could have been used to probe their answers and determine their in-depth understanding, suggested by Germann, Aram and Burke (1996), was not used in this study because it would have drastically limited the sample size.

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The subjects performed relatively better on the skill of recording data probably because most of the items requiring this skill gave prescriptive directions on what the subjects should measure and how to record (first level of the developmental progression of the skill). But a close look at the subjects' test scripts revealed that only of a few of them were able to construct tables and graphs and record data in more complex tables on their own, and that they were better able to complete and construct tables than graphs. The construction of graphs demands the ability to recognize relations between relations or formal operations in Piagetian terms which many students are incapable of (Shayer & Adey, 1981). The subjects performed fairly well on interpreting data that demanded extracting information from graphs and tables, but they were less successful (barely "average") on the skill of generalizing which entailed making conclusions, interpolating/extrapolating between/beyond data points and identifying supporting evidence. This might be due to the fact that the lecture method, that predominates in Jamaican schools' science classrooms (Science Education Committee, 1999; Soyibo, 1998), does not facilitate the development of generalizing skills and other ISPS in the subjects. The subjects' poor performance on the skills of identifying variables and formulating hypotheses might be due to the likelihood that they had not been taught the two skills and that their levels of cognitive development were inadequate to enable them to handle the skills. In sum, we are of the view that the teacher-centered mode of teaching science in the sampled schools, which did not allow the subjects to practice and internalise the skills over a fairly long period, was likely to be one of the main reasons for the subjects' poor performance on the skills.

That the 10^{th} graders significantly outscored the 9^{th} graders (Tables 2 and 4) was expected partly because (a) they might be more proficient in the use of the English language and in reading (Shaw, 1997), (b) of their greater amount of prior knowledge, experience in science education and higher level of cognitive development, and (c) it was mandatory for the 10th graders to do science practical tasks to fulfill the requirements for the award of the secondary education certificate in grade 11, the former were likely to have practiced more of the ISPS tested in this study than the 9th graders. The finding that the subjects in the traditional high schools significantly outscored their comprehensive high school counterparts receives an indirect support from Rainford (1997) regarding Jamaican 7th graders' performance on three basic science process skills listed earlier. The traditional high schools' subjects did significantly better than their peers in the comprehensive schools partly because many of them were likely to be academically superior to the latter based on their mode of admission to their schools discussed earlier and partly because they were likely to have also enjoyed better teaching facilities and the services of teachers of better quality (Science Education Committee, 1999; Soyibo & Johnson, 1998). We expected the ROSE students to outscore their nonROSE counterparts on each of the five skills because ROSE students were using the ROSE science curriculum that was designed to facilitate the development of science process skills in them, and the ROSE teachers had been trained in the methodology that would enable them to assist their students to acquire the process skills using a hands-on, process approach, while the nonROSE teachers had no training in such an approach. But, the actual difference in the ROSE and nonROSE students' overall mean score on the five skills was, indeed, minute, suggesting that, although the ROSE teachers were trained in the new methodologies for teaching science they might not be fully utilizing them or were not yet proficient at using the skills (Soyibo & Johnson, 1998). The finding that the subjects from professionals' homes (high SEB) significantly outperformed their peers from nonprofessional homes (low SEB) was expected and receives some indirect support from Gallagher (1994) regarding middle school students' performance on BSPS and the findings of many previous studies on the link between students' SEB and science performance (e.g. Blosser, 1994). Indeed, we conjectured that, while growing up, the subjects from professionals' homes, unlike their peers from nonprofessionals' homes, were likely to have had access to a wide variety of educational materials that could have enhanced their ISPS performance to which their peers from nonprofessionals' homes never had access. But we did not collect any data to confirm or refute this conjecture. The findings that there were no significant differences in the subjects' performance linked to their gender and school location are interesting as they suggest that Jamaican 9th and 10th graders could learn the five ISPS tested regardless of their gender and school location. The finding that there was no gender difference in their performance receives an indirect support from Rainford (1997) in respect of Jamaican 7th graders' performance on three basic science process skills, while the finding in respect of school location is indirectly inconsistent with Soyibo's (1992) finding that rural Jamaican 7th graders' significantly outscored their urban peers on four BSPS and two ISPS.

The finding that there was a positive, statistically significant and "fairly strong" relationship between the subjects' school-type and performance confirms the data in Tables 2 and 4 discussed earlier and suggests that this variable accounted for the highest variation in the subjects' overall performance. The findings that there were no relationships among the subjects' gender and school location and their performance are also consistent with the data in Tables 2 and 4. The weak relationships among the subjects' student-type, grade level and SEB and their performance suggest that there were other factors besides these three variables that contributed to the variations in the subjects' performance which were not investigated in this study. Such variables should be identified

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and explored in future studies on this topic. They include differences in the students' cognitive abilities, learning style, teachers' qualifications, teaching experience and teaching styles.

Conclusions and Implications

First, this study is significant because, we were unaware of any published or unpublished studies that had explored the six independent variables with the five ISPS we investigated either in Jamaica or elsewhere. For this reason, we were unable to find any previous studies with which this study's findings could be directly compared.

The didactic mode of teaching science in most Jamaican schools was implicated as the main probable cause of the subjects' mediocre performance in this study (Science Education Committee, 1999; Soyibo, 1998). The five ISPS tested in this study and related ones should be formally taught to the subjects from grade 7 including students' domain-specific practise activities, with multiple-related examples and immediate feedback should be provided to the subjects, while they should be assessed using both written and performance/practical tasks. This approach is likely to improve the subjects' knowledge of and performance on many ISPS irrespective of their differences on the six independent variables explored in this study.

That the ROSE students significantly outscored their nonROSE counterparts implies that the ROSE science curriculum and ROSE teacher training program seemed to have had some salutary effects on the ROSE students' ISPS performance. To improve ROSE and nonROSE students' understanding and performance on the ISPS tested in this study, Jamaican grades 7-9 science teachers should give their students the opportunities to perform worthwhile ISPS-demanding tasks.

The traditional high school subjects significantly outscored their comprehensive high school peers. To ensure that students in these two types of schools perform equally well on the five ISPS

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tested and related skills, the Jamaican Ministry of Education should ensure the even and equitable distribution of educational resources across school types in terms of teacher quality, science teaching facilities and the assignment of students to schools.

As expected, the 10^{th} graders substantially and significantly outscored the 9^{th} graders while subjects from professionals' homes (high SEB) significantly outperformed those from nonprofessionals' homes (low SEB). Hence, to improve the 9^{th} graders' performance on the ISPS tested and related ones, their teachers must ensure that the students perform hands-on, minds-on ISPS activities suitable to their intellectual development. To encourage students from low SEB to perform as well as those from high SEB on the ISPS, Jamaican grades 7-9 science teachers must employ student-centered instructional strategies that are likely to enhance the self-esteem, attitudes and motivation to learn science of both categories of students.

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Table 1
Means, percentages and standard deviations on integrated science process skills

Integrated science process skill*	Mean	Percentage	SD
Recording data	13.70	52.80	7.00
Interpreting data	8.88	74.00	1.71
Generalizing	7.44	49.60	3.67
Identifying variables	4.57	28.60	4.36
Formulating hypotheses	1.97	32.80	2.06
Overall test	36.56	49.40	15.65

* n = 305 in each case

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Table 2
Means and standard deviations by grade level, gender, school location, school-type, student-type, and socioeconomic background

Variables		n	Mean	SD
Grade level	9	146	33.55	15.28
	10	159	39.35	15.49
Gender	Males	133	36.54	15.46
	Females	172	36.60	15.82
School location	Rural	139	36.19	13.17
	Urban	166	36.89	17.46
School-type	Traditional high	150	46.48	11.30
	Comprehensive high	155	26.99	13.10
Student-type	ROSE	164	38.29	13.20
	NonROSE	141	34.57	17.90
SEB	Professionals	110	42.21	14.29
	Nonprofessionals	195	33.39	15.50

N = 305 per [illegible] variable SEB = Socioeconomic background

Table 3
Means and standard deviations of ROSE and NonROSE students on the sub-sets of TISPS

Integrated science process skill	ROSE		NonROSE	
	Mean	SD	Mean	SD
Recording data	15.01	5.17	12.20	7.93
Interpreting data	8.91	1.61	8.83	1.81
Generalizing	7.60	3.32	7.26	4.04
Identifying variables	4.70	4.00	4.42	4.75
Formulating hypotheses	2.07	2.01	1.86	2.13
Overall test	38.29	13.21	34.57	17.90

ROSE (n=164) NonROSE (n = 141)

Table 4

Summary of analyses of variance on student performance by grade level, gender, school location, school-type, student-type and socioeconomic background

Source of variation	MS	F
Grade level	2381.13	29.547**
Gender	223.66	2.775
School location	60.47	0.750
School-type	25924.57	321.695**
Student-type	921.03	11.429*
Socioeconomic background	1771.96	21.988**

*p < .001 **p < .000

Table 5

Pearson's correlation coefficients relating students' overall test score to the independent variables

	School-type	Student-type	Location	Gender	Grade	SEB
Overall score	.62**	.12*	.02	.00	.19**	.27**

*p < .01 **p < .001

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