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The Relationship Between Content Preparation and Literacy of Science Teachers and High School Enrollment Size

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Abstract

This study examines the relationship between teacher content preparation and literacy among high school earth science teachers and school size in the state of North Carolina. The results indicate that small schools have a relatively larger percentage of earth science teachers with no formal course training in this subject when compared to earth science teachers in large schools. Also, the results suggest a general trend correlating increasing school size with teachers who have completed a greater percentage course-work in earth science. The findings show that teachers from smaller schools are especially deficient in their knowledge of selected geography and, to a lesser extent, geology concepts. Plate tectonics was the only concept studied where there was a significant difference between small and large size schools in teacher familiarity indices; earth science teachers from smaller schools were not as knowledgeable about this concept as their counterparts from larger schools. While no other significant statistical difference was found between school size and teacher preparation and literacy, in general small schools had both higher percentages of teachers with no completed course work experience in earth science as well as lower indices of familiarity among the selected concepts.

Key Words: teacher preparation, teacher literacy, earth science, school size.

Introduction

This paper is concerned with the issue of teacher preparation and literacy in earth science instruction as they are related to school size. While this issue has been recognized in earlier studies (Sarason, Davidson, & Burton, 1986; Porter & Rossbach, 2003), more recent studies have focused on enhancing quality teaching of geography and earth science in the classroom through such pedagogical strategies as group learning, critical thinking, and the use of technology (Dozier, Johnson, & Rogers, 2006; & Schlechty, 2005). These approaches to better instruction are important to consider, but there has been little discussion on the preparation and literacy of teachers in subject areas like earth science and the effect of these factors on the quality of instruction in this subject area (McNeil, 1999; Wineburg & Grossman, 2000). This paper considers classroom course content by an analysis of preparation and literacy by earth science teachers across high school enrollment size categories and among geographic regions in North Carolina. Teacher preparation is identified as the degree to which high school science teachers have prepared themselves to accomplish effective earth science instruction by considering the number of courses they have completed in this subject area. Teacher literacy is measured by their knowledge of important concepts in earth science.

Our public schools need serious examination of ways in which classroom instruction may be improved. While the teaching profession has been admirable in many respects, inadequate teacher preparation in some subjects has been seen as exacerbating the difficulties of instructing students, especially in large schools characterized by impersonal environments. The responsibility of earth science instruction when teachers have had little or no formal training in the subject contributes to these challenges. Earth science, as a formal course of instruction, has not been given the same degree of attention as other sciences in high school and undergraduate curricula. While subjects like chemistry, physics, and biology have been taught on a regular basis, only since the academic year 1999-2000 has earth science become a required course in North Carolina high schools (North Carolina Department of Public Instruction, 1999). Consequently, many science teachers in the state have minimal educational experience in this subject area and are not prepared to provide the most effective instruction. This issue is seen as a microcosm of national concerns, as it relates to determining what factors contribute most to more effective instruction in all subject areas and subsequent learning in the nation's public schools.

Large school districts have been associated with population growth and migration patterns over the past fifty years. As people migrated to more populated areas, a new kind of school organization emerged that led to "depersonalization" in larger schools (Lewis, 1999). The challenges of providing adequate instruction within large schools reflect the importance of school size as an indicator of the degree to which effective instruction can take place across curricula (Lee & Smith, 1997). Larger school size is generally associated with greater challenges to learning because of increased difficulties in the administration due to student diversity in ethnicity, social class, and ideologies (Oxley, 1994; Portner, 1996; Howley, 1997). As a result of these challenges, larger school size has also been associated with high dropout rates (Alspaugh, 1998) although it has been suggested that larger schools may be more effective in student learning despite this problem (Guarino, Satibanez, & Daley, 2006). In fact, student reading, writing, and math skills improved over a three year period while the dropout rate fell after the merger of three school districts in Guilford County North Carolina, one of the state's largest school systems (Weast, 1997).

It may be argued that while larger schools attract more qualified teachers, the quality of instruction may be compromised because more class time is spent dealing with discipline issues rather than focusing on instruction. While these concerns are not exclusive to large schools, they may be disadvantaged because of more diverse student populations and impersonal environments. Many teachers are not properly trained to deal effectively with issues of interpersonal relationships and social interaction (Blair, 2000; Athanases & Martin, 2006). Despite the challenges that larger schools face, there is some evidence that they experience higher academic achievement than small schools on SAT scores and on the percentage of students who take the test (Gardner, Ritblatt, & Beatty, 2000). In contrast to larger schools, smaller schools are said to offer more effective learning due to positive interpersonal relationships and fewer discipline problems (Raywid, 1998; Ark & Wagner, 2000; Blair, 2000). Parents apparently agree that smaller schools are generally better for their children's education, but indicate that the very best teachers are probably not attracted to smaller schools (Bainbridge & Sundre, 1990).

Fewer resources going to smaller school districts invariably lead to lower teacher salaries. This situation may contribute to serious regional discrepancies in teacher qualifications and literacy, and tend to discourage more qualified teachers to desire employment within rural school systems. Nonetheless, a greater sense of belonging and caring for the welfare of students, apparently characteristic of smaller schools, has been linked to minority and less advantaged students receiving more effective instruction in these environments (Riegle-Crumb, Farkas, & Muller, 2006). These inherent qualities in smaller schools have been linked to fewer layers of bureaucracy

(Black, 1996; Lee, Smerdon, & Alfeld-Liro, 2000). In addition to a greater sense of community (Furman, 2002), advantages of smaller schools, presumably within more personal environments, may include better student attendance and improvement in student academic achievement for some students. Regardless of enrollment, school administrators should be more attuned to the concerns of the surrounding community (Theobald, 2006). For example, the concern of parents regarding student learning has been linked to the preparation that teachers receive in providing effective instruction to their children (Hoy, 2000; Gursky, 2000).

One study considers schools as "houses" and suggests that smaller houses lead to such desirable results as more effective management of extracurricular and co-curricular activities, student group activities, physical resources, administrative support, and teacher involvement (Oxley, 1989). Thus, the result of smaller school size is alleged to enhance the learning potential of students (Cushman, 2000). One school administrator contends that the greatest advantage of small schools is that there are fewer layers of bureaucracy to interfere with rescuing at-risk children (Black, 1996). Others see schools as "businesses" and suggest that more money should be funneled into teacher salaries, which will, they insist, enhance teacher competence and increase learning by students (Craig, 2006). A review of these issues is necessary in order for improvements to be made in classroom instruction, especially when new subjects like earth science are introduced into the curriculum.

Teacher education programs in undergraduate curricula, in connection with teacher preparation and literacy, have been a part of many research efforts. Studies have focused on the ability of these programs to train teachers to contend with a variety of issues that confront them in the public schools. Andrews (2000) has suggested that more attention should be directed towards teachers developing knowledge and skills in an integrated manner across disciplines, including earth science. Current standards for teacher certification and licensure assume that teachers will have a deep understanding of student learning, development, and diversity (Oxley, 1994; Hoy, 2000; Ball, 2000). Some argue that extended year teacher preparation (Breidenstein, 2000) and teacher education programs that communicate with science organizations (Craven, 2000) can provide the depth and breadth of professional knowledge and skills that teachers need to maximize instruction and subsequent student learning. However, there is some recognition that there is a shortage of qualified individuals to fill teacher education programs (Wolf-Wendel, Baker, Mahlios, Tollefson, & Twombly, 2006). It also has been suggested that computer technology be an integral part of the preparation process (Robertson, 2000; Bain, 1998; Shakeshaft, Mann, Becker, & Sweeney, 2002), as well as teacher participation in classroom research (Rathgen, 2006). Vojtek and Vojtek (2000) indicated that educators must work together to ensure that all teachers attain a certain level of computer literacy and skill, and to be adequately trained to integrate technology effectively as a learning tool throughout the curriculum.

Research on the association of school size and the quality of classroom instruction and learning has not considered the relationship between school size and the degree to which high school science teachers are prepared to teach specific subjects like earth science. This void in the research is addressed in the present study, and serves to help generate more discussion and research on school size and teacher preparation/literacy.

Methodology

High school earth science teacher content preparation and literacy were examined across school size categories and geographic regions. School size categories were divided into small (750 students and below; n=19); medium (751 to 1499 students; n=29); and large (1500 students and above; n=15). Data collection resulted from the completion of the following two stages. The first stage involved the acquisition of the teacher content preparation and literacy data, establishment of school size categories, and division of the state into geographic regions. A questionnaire package was mailed to the science chairs of 310 high schools representing each of the 117 school districts in North Carolina. Each package included a questionnaire for the science chair to complete. Information was requested about the approximate student enrollment to indicate school size, the number of science teachers at the school, and how many years earth science has been offered. The second item in the package included a separate questionnaire for science teachers (including the science chair). This questionnaire included items concerning the content preparation and literacy of science teachers as it related to their earth science teaching experience during the 1999-2000 academic year. Only questionnaires returned by science teachers who had taught earth science during this period were used in this study. A total of 63 questionnaires were retrieved from science teachers who had taught earth science during the 1999-2000 academic year at these schools. The data were then divided into school size categories and geographic regions.

Figure 1 shows the geographic regions considered, which were based on the state United States Postal Service (USPS) Zip code zones. The six regions based on this categorization are as follows: Northeast (NE), Southeast (SE), East North Central (ENC), West North Central (WNC), Southwest (SW), and

West (W). Both the NE and SE regions are primarily rural and physiographically are a part of the state's coastal plain. The W region is also rural but is largely a mountainous area. Those regions contain some of the state's smallest school districts. The ENC, WNC and SW regions lie in the piedmont and contain both the state's largest urban areas and some of the largest school districts. The SW region includes the state's largest city (Charlotte) in Mecklenburg County and also represents the state's largest public school system. The ENC region contains the second largest school system in Wake County, which has the state capital of Raleigh and is the second largest city in the state. This region also has the Durham County and City School systems, which together form one of the larger school systems in the state. The WNC region has the third and fourth largest school system in the state in Guilford County (Greensboro) and Forsyth (Winston-Salem) respectively.

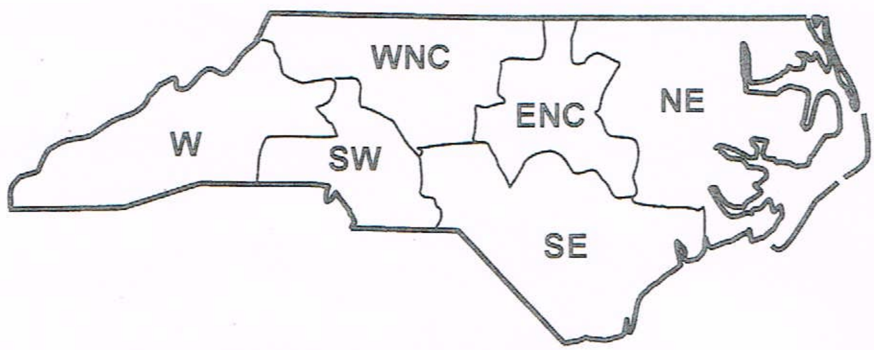

Figure 1. North Carolina Geographic Regions.

The second stage of this research dealt with developing a set of indices for teacher content preparation and literacy. To develop indices of teacher content preparation, the question was asked: how many undergraduate and/or graduate courses have you completed in earth science or a related area? Tabular, graphic, and map presentations are used to show the percentage of teachers having completed earth science or a related course for school size classes and within designated regions.

To address teacher literacy, a scale was developed to ascertain the degree of knowledge of major concepts in earth science with which teachers should be familiar. Teacher literacy was addressed by using the following scale of familiarity:

Weight	*Degree of Familiarity:*
1.	**I have never heard of the concept.** (I did not study it in my formal course work)
2.	**I have heard of the concept but do not know its definition or meaning.** (I know about the concept through the media but otherwise I am not familiar with this concept)
3.	**I am slightly familiar with the concept.** (I have read about the concept)
4.	**I am familiar with the concept.** (I have studied the concept as an undergraduate earth science student)
5.	**I am very knowledgeable of the concept.** (I studied this concept in my teacher preparation courses in the content field. I have taught this concept in my teaching)

This scale was used in the teacher's response to their familiarity with the following earth science concepts in associated subject areas:

1) Atmospheric Science (Coriolis Effect, Greenhouse Effect, and Hydrologic Cycle)
2) Geology (Plate Tectonics, Groundwater, and Rock Cycle)
3) Geography (GIS and Spatial Analysis)
4) Environmental Science (Food Chain and Photosynthesis).

GIS is an abbreviation for Geographic Information System, which is defined as a computer system for capturing, storing, querying, analyzing, and displaying geographically referenced data (Chang, 2004). With the exception of GIS and spatial analysis in Geography, the selected subjects and concepts are included in most current college earth science and physical geography textbooks (Christopherson, 2003; Marshak, 2001; Jacobson, 2000). GIS and spatial analysis are considered because they form the foundation by which earth science concepts may be examined spatially using current technology (Eastmond, 2000).

To determine literacy in earth science, teachers were asked to assign a number from 1 to 5, corresponding to their degree of familiarity described above, for each of the ten concepts. To arrive at specific teacher literacy indices, two procedures were used. First, the weights each teacher recorded for the ten selected concepts were summed and divided by the total number of concepts to arrive at an average weight (henceforth referred to as a literacy value) for each teacher within school size categories. Subsequently, a table was constructed to show the number of teachers within each familiarity category based on their literacy value.

Second, the weights each teacher assigned to concepts within a given subject area were divided by the number of concepts within that subject area to arrive at an average weight (literacy value) for each teacher. Literacy values were then summed and divided by the number of teachers in a school size category to arrive at a literacy value for that size category. Another table was constructed to compare literacy values for subject areas within school size categories.

Analysis was conducted by the use of descriptive statistics and two non-parametric statistical tests. Both tests rank the scores and then subject them to a significance test. The first, the Kruskal Wallis H-Test determine whether several independent samples are from the same population. The second, the Mann Whitney U-test, performs the same type of test for pairs of independent samples. The sum of the ranks for each of the various samples can be compared to determine which sample contains the higher mean score, and then the significance test determines whether the difference between these ranked means is significant. A common confidence level used to reject the null hypothesis is $p<0.05$. Both these tests are sufficiently sensitive to reject the null hypothesis even when small sample sizes are present. The tests are robust in determining that score ties are minimized. They are applicable to the data sets in this study (Friedman 1972; Linn 1997; Norusis, 1998). A "permutation test" also was applied based on the characteristics of the raw data. It was assumed that the respondent sample sizes (from each school) and each respondent's reported scores are always the same as the actual sample obtained. But the null hypothesis is expressed by assuming that the school size of each respondent could be randomly chosen, instead of exactly as it was observed.

Results

Teacher Preparation and School Size

One objective of this study was to compare teacher content preparation with high school size. Content preparation was measured by the percentage of teachers surveyed having completed earth science or related courses at the undergraduate and/or graduate level. Figure 2 and Table 1 give a descriptive review of the data. The graph in Figure 2 shows that while small, medium, and large schools had a relatively high percentage of teachers having completed five or more courses in earth science, only large schools had a low percentage of teachers never having completed a course in this subject. Table 1 is a tabular account of the graphic presentation. It shows that while all school size categories had over 30 percent of their teachers having completed five or more courses in earth science, (31.6 for small, 34.5 for medium, and 40.0 for large), only large schools had a low percentage of teachers not having completed a course in earth science at 6.7 percent. In contrast, 31.6 and 24.1 percent of teachers from small and medium sized schools respectively have no formal course work in earth science. Also, the table shows that the mean number of courses completed by the teachers in each school size category range from 2.42 for small schools to 3.40 for large schools. This suggests an apparent pattern of more experienced earth science teachers being employed in larger schools.

Table 2 and Figure 3 give a statistical summary of relationships in the data. The results for statistical hypothesis tests concerning differences in teacher preparation between school size categories is shown in the Table 2. To compare all school sizes in one hypothesis test, the Kruskall-Wallis rank sum test is appropriate. The chi square test statistic value is 2.19 (df = 2, prob. = 0.33), indicating that there is no significant difference in teacher preparation between all school sizes.

Even though the statistical test fails to find significant differences among the three school sizes, it is instructive to consider a hypothesis comparing only two school sizes. The greatest differences observed are between the small schools and the large schools. For this, the Mann-Whitney-Wilcox on rank sum test is applicable. We should not expect to find a significant difference, and indeed we do not. The rank sum statistic is W=105.0 (prob. = 0.19).

Figure 3 gives a clearer description of the relationship between school size and number of earth science courses taken by using the boxplot and the

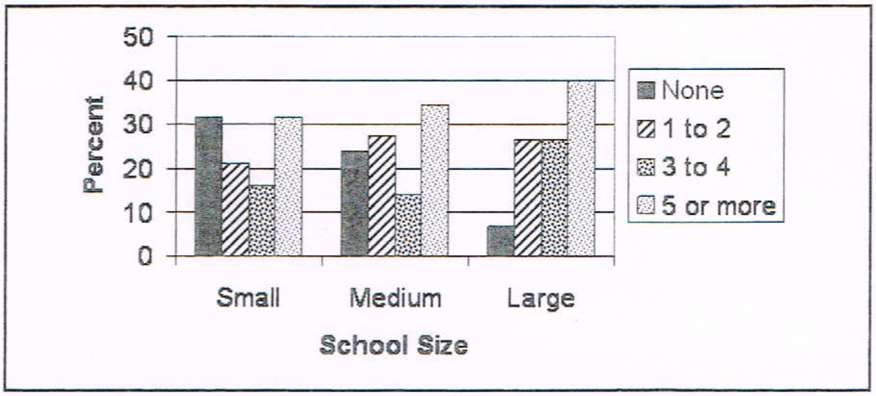

Figure 2. Percentage of teachers surveyed having completed a specified number of earth science or related courses at the undergraduate and/or graduate level.

Table 1

The number of teachers having completed courses in earth science as a measure of teacher preparation by school size.

School Size	Statistic	Completed courses							Mean Number of completed courses
		0	1	2	3	4	5	**All levels**	
small	Number	6	2	2	2	1	6	19	2.42
	Percent	31.6	10.5	10.5	10.5	5.3	31.6	100	
medium	Number	7	4	4	4	0	10	29	2.55
	Percent	24.1	13.8	13.8	13.8	0.0	34.5	100	
large	Number	1	1	3	2	2	6	15	3.40
	Percent	6.7	6.7	20.0	13.3	13.3	40.0	100	
All School sizes	Number	14	7	9	8	3	22	63	2.71
	Percent	22.2	11.1	14.3	12.7	4.8	36.5	100	

Table 2

Statistical hypothesis for differences in teacher preparation between school size categories using the Kruskall–Wallis Rank Sum Test.

School Size	**N**	**Mean Score**	**Three-sample**	**Small vs. large**
			Mean Rank	Mean Rank
Small	19	2.42	27.41	17.83
Medium	29	2.55	34.58	—
Large	15	3.40	49.40	30.50
All Sizes	63	2.71		
Statistical Test			Kruskal–Wallis chi-squared	Wilcoxon rank sum W
Test Statistic			2.19	105.0
Significance Level			0.33	0.19

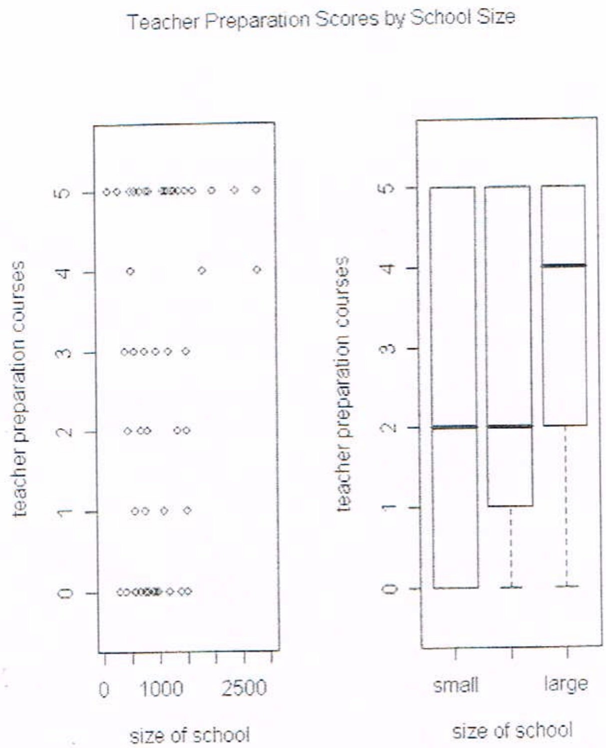

Figure 3. Scatterplot (left-a) and boxplot (right-b) showing the relationship between school size and number of earth science courses taken as a measure of teacher preparation. (For ease of reading, Figure 3 is repeated on p.87)

scatterplot graphs, which are shown in tandem. The scatterplot shows each respondent teacher score (although there are fewer than 63 points visible, because two or more teachers from the same school with the same score have to be plotted at exactly the same point). A general trend correlating increasing school size with teachers who have taken more coursework in earth science is apparent (Figure 3a). This substantiates the descriptive review of the data presented earlier. The boxplot in Figure 3b shows the same relationship in a simpler way, grouping the schools by size and plotting only the median (thick line in the center of each box), upper and lower quartiles (vertical edges of each box) and the range (extent of the whiskers that extend outward from the box). Boxplots are frequently used for "exploratory data analysis," and more detailed explanations of them are given in Chambers, Cleveland, Kleiner, and Tukey, (1983); and Cleveland (1993; 1994). The boxplot shows the medians and the lower quartiles of teacher preparation increase with increasing schools size. (There is no useful information in the upper quartiles, maximums, or minimums; these respective statistics are the same for all school sizes.)

The results from the descriptive review of the teacher preparation data and its statistical analysis suggest that the percentage of teachers in small and medium size schools with some course work in earth science approaches the level of experience teachers have in this subject in large schools. However, small schools especially have a much higher percentage of teachers who have never completed a course in earth science than either medium size or large size schools. Thus, contrary to small schools, large schools have a much lower percentage of teachers who have never completed a course in earth science. While some highly qualified teachers in earth science also are employed in small schools, a disturbingly high percentage of teachers with no completed course work in earth science also end up in smaller schools. Presumably, unlike larger and wealthier school districts, small districts are likely to have fewer financial resources to attract the most qualified teachers and so employ less qualified teachers. This is consistent with published accounts that parents are concerned that children in smaller schools are not taught by the most qualified teachers (Bainbridge & Sundre, 1990).

In addition to the descriptive and statistical review of the teacher preparation data, a spatial interpretation of the data is shown in Figure 4, which illustrates the regional variation in teacher preparation. In the SW and ENC regions more than 50 percent of teachers had enrolled in five or more earth science or related courses. These regions contain the two largest school systems in the state (Mecklenburg and Wake County respectively). The regional analysis suggests teachers with more experience (with respect to courses taken in earth science) are attracted to areas with larger sized schools. The SW region with the state's largest school district was the only area with no respondents who had not completed at least one earth science or related course. The WNC had 50 percent of teachers that had not taken an earth science or related course. This pattern may reflect the high proportion of the population in this region living outside of Forsyth County, which contains Winston-Salem, its largest city. Smaller sized schools within this relatively large region, but located outside of the Winston-Salem/Forsyth County School District, may follow the pattern that small school size is associated with teachers that have little or no experience in terms of course-work taken in earth science. A more definitive conclusion about this association may be provided with further research at the intra-regional level of analysis. The smaller populated W and the NE regions also had relatively high percentages of teachers that had not completed a course in earth science at about 30 percent and 20 percent respectively. The SE region had less than 10 percent who had not completed an earth science course.

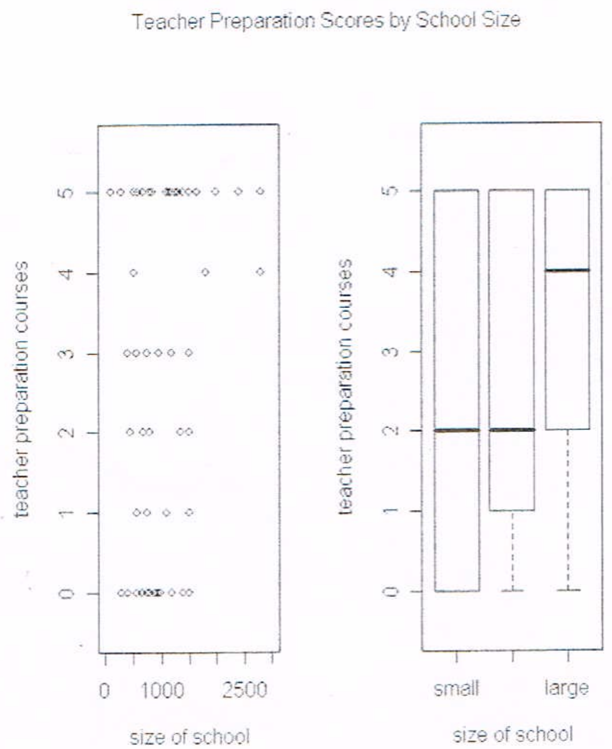

Figure 3. Scatterplot (left-a) and boxplot (right-b) showing the relationship between school size and number of earth science courses taken as a measure of teacher preparation.

Teacher Literacy and School Size

Tables 3, 4, and 5 give a descriptive review of teacher literacy indices, as summarized by categories of familiarity, across school size categories for the selected subject areas and associated concepts. Table 3 shows the percentage of teachers in specified familiarity categories. It is apparent that medium and large schools have a greater percentage of teachers that are more familiar with the selected subject areas than teachers in small size schools. Specifically, the percentage of teachers within the "very familiar with the subject" category (4.00–4.99) is 66.7 percent for large schools and 65.5 percent for medium size schools. This compares to only 36.8 percent

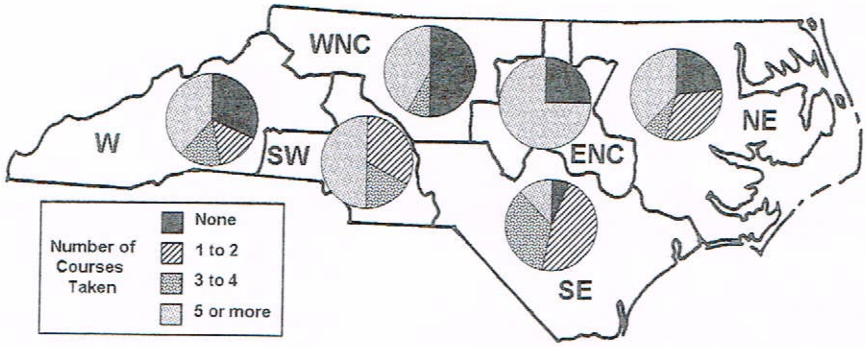

Figure 4. Map of regional variation in teacher preparation. Wedges of the pie charts are proportional to the percentage of teachers have completed a specified number of undergraduate and/or graduate courses in earth sciences or related areas.

for small schools. Moreover, only large schools had teachers in the "very knowledgeable" category (5) at 13.3 percent. By contrast 63.2 percent of teachers from small schools were in the "only slightly familiar" category (3.00–3.99) compared to 31 percent for medium schools and only 13.3 percent for large schools in this category.

Table 4 shows the literacy value for teacher's response to their knowledge of the individual's selected subject areas in earth science by school enrollment size. The most evident aspect of the table is that the larger schools had higher values for three of the four subject areas than either medium or small size schools. Large schools had the highest literacy values among all school size categories for Geology (4.64), Atmospheric Science (4.58), and Geography (2.93). Only for Environmental Science did teachers from large schools not have the highest literacy value. Medium size schools had the highest value at 4.81 for this subject area, followed by large schools with 4.73 and small schools with 4.55. Geography had the lowest literacy value in each school size class at 2.93 (large), 2.45 (medium), and 2.21 (small). Each subject area had a higher literacy value for large size schools than for small size schools, but Geography had the largest difference in values between large schools and small schools among the subject areas. For example, the difference between small size schools and large size schools was 0.72 for Geography, 0.50 for Geology, 0.18 for Environmental Science, and 0.16 for Atmospheric Science. Thus, in contrast to Geography, literacy values were the most similar among the school size classes for Atmospheric Science and Environmental Science.

Table 3

The number of teachers within weight average (familiarity) categories for all concepts in earth science as a measure of teacher literacy by school size category.

School Size	**Statistic**	**Literacy Categories***				**Total Number**
		2.00 to 2.99	3.00 to 3.99	4.00 to 4.99	5.00	
Small	Number	0	12	7	0	19
	Percent	0.0%	63.2%	36.8%	0.0%	
Medium	Number	1	9	19	0	29
	Percent	3.4%	31.0%	36.5%	0.0%	
Large	Number	1	2	10	2	15
	Percent	6.7%	13.3%	66.7%	13.3%	
All Schools	Number	2	23	36	2	63
	Percent	3.2%	36.5%	57.1%	3.2%	

Table 4

Literacy value for teacher's response to their knowledge of individual subject areas by school size.

SCHOOL SIZE		INDIVIDUAL TOPICS				OVER ALL AREAS
	N	Atmospheric Science	Geology	Geography	Environmental Science	
Small	19	4.42	4.14	2.21	4.55	3.92
Medium	29	4.37	4.44	2.45	4.81	4.09
Large	15	4.58	4.64	2.93	4.73	4.30
All Schools	63	4.43	4.40	2.49	4.71	4.09

Table 5 shows counts of how many teachers had each possible weight score (henceforth referred to as literacy scores). Teacher counts are categorized for each subject area and concept, and within that, each school size and literacy score. (For readability, when any grouping's score count is zero for all school sizes, we suppressed the zeroes.) The right margin of the table summarizes the mean literacy score for each concept and school size. Large schools had a higher mean score than small schools for every concept studied except for the Hydrologic Cycle and the Food Chain. For Hydrologic Cycle, small schools had the highest mean literacy score of 4.68 compared to 4.60 for large schools and 4.55 for medium schools. For Food Chain, medium size schools had the highest mean literacy score compared to 4.58 for small schools and 4.67 for large schools. Small schools had the lowest mean literacy score except for the already mentioned Hydrologic Cycle and Greenhouse Effect. For the latter concept, medium size schools had the lowest value of 4.69 compared to 4.87 for large schools and 4.74 for small schools.

In addition to the descriptive summary of the literacy data given above, Table 6 and Figure 5 include statistical summaries of these data. Table 6 shows significance test results from teachers' responses regarding familiarity with each concept by school size, as well as the mean score of familiarity for those size categories. The null hypothesis is that weight means are equal for all school sizes. These data are not amenable to analysis with the Kruskal-Wallis or Wilcoxon tests, so analysis of variance was applied to test whether the school size means are different for different concepts, i.e., to illustrate the differences among school size categories. The default hypothesis test used by analysis of variance is predicated on the residual errors having a normal distribution. To verify the significance tests a permutation test of the F statistics was employed. To use the permutation test, we determined the distribution of F under the null hypothesis by randomly permuting the school size categories of each respondent 2000 times and computing the empirical value of F for each permutation. The hypothesis test results are shown for both representations of the null distribution and vindicate the robustness of the traditional analysis of variance F test. Under these conditions Plate Tectonics is the only concept where school size results in significantly different values. An F statistic of 3.68 is significant at the 0.03 level and shows that teachers from the small schools score significantly lower on average than teachers from medium or large schools regarding their knowledge of this concept.

Figure 5 is presented to more clearly describe the relationship between school size and subject familiarity. Here, a scatterplot and a boxplot of the teacher mean literacy scores are pictured in tandem. The scatterplot shows each respondent teacher score. The scatterplot (Figure 5[5A]) shows a general trend correlating increasing school size with teachers' overall familiarity with the selected concepts. A linear least-squares trend line has been overlaid on the scatterplot. The equation of the trend line is:

Mean score = 3.80 + 0.28 * [school size/1000]; with R^2 (multiple correlation) = 0.097.

The regression line quantitatively represents the average relationship between school size and teacher literacy scores, although the very low value of R^2 signifies that only 9.7 percent of the variation between teachers is accounted for by school size.

The boxplot in Figure 5[5B] shows the same relationship in a simpler way, grouping the schools by size and plotting only the median (thick line in the center of each box), upper and lower quartiles (vertical edges of each

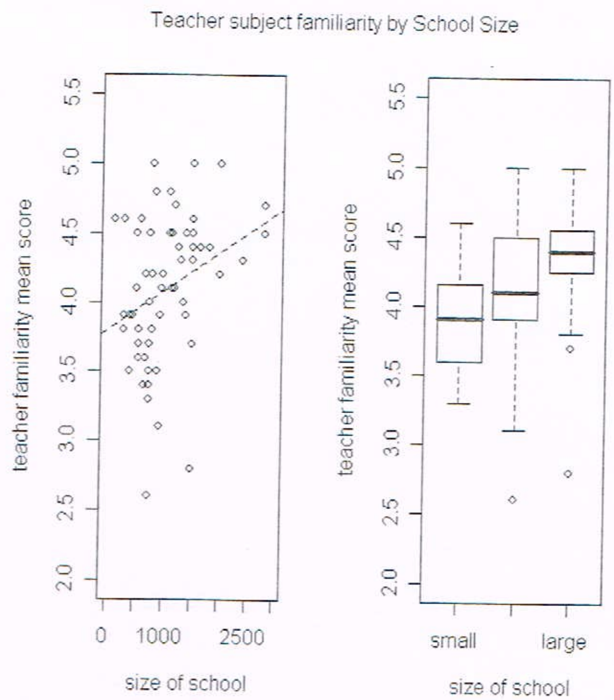

Figure 5. Scatterplot (left-A) and boxplot (right-B) showing the relationship between school size and teacher mean literacy scores as a measure of teacher literacy of the selected subject areas and concepts.

Table 5

Numbers of teachers with actual weight scores (literacy values) for each concept under subject areas and school size category.

Subject Area	Concept	School Size	Actual Weight Scores					Mean Score
			1	2	3	4	5	
Atmospheric Science	coriolis effect	small	1	1	3	9	5	3.84
	coriolis effect	med	1	2	6	11	9	3.86
	coriolis effect	large	0	0	4	3	8	4.27
	greenhouse effect	small		0	0	5	14	4.74
	greenhouse effect	med		1	1	4	23	4.69
	greenhouse effect	large		0	1	0	14	4.87
	hydrologic cycle	small		0	0	6	13	4.68
	hydrologic cycle	med		1	2	6	20	4.55
	hydrologic cycle	large		0	2	2	11	4.60
Geology	plate tectonics	small			1	12	6	4.26
	plate tectonics	med			1	10	18	4.59
	plate tectonics	large			1	2	12	4.73
	groundwater	small			4	9	6	4.11
	groundwater	med			4	11	14	4.34

(Table continues)

Table 5 (continued)

Subject Area	Concept	School Size	Actual Weight Scores					Mean Score
	groundwater	large			2	3	10	4.53
	rock cycle	small			7	4	8	4.05
	rock cycle	med			3	12	14	4.38
	rock cycle	large			2	1	12	4.67
Geography	GIS	small	7	5	5	1	1	2.16
	GIS	med	8	5	12	3	1	2.45
	GIS	large	1	5	2	5	2	3.13
	spatial analysis	small	5	7	4	3	0	2.26
	spatial analysis	med	8	6	10	4	1	2.45
	spatial analysis	large	2	6	3	2	2	2.73
Environmental Science	food chain	small		0	1	6	12	4.58
	food chain	med		0	0	4	25	4.86
	food chain	large		1	0	2	12	4.67
	photosynthesis	small			0	9	10	4.53
	photosynthesis	med			1	5	23	4.76
	photosynthesis	large			1	1	13	4.80

Table 6

Significance test results from mean scores of teacher familiarity indices for each concept by school size.

Subject	Subject means across school sizes	Subject std. errors	F statistic	F test significance level	Permutation test significance level
hydrologic cycle	4.58	0.12	0.9287	0.40	0.40
greenhouse effect	4.73	0.17	0.7585	0.47	0.50
coriolis effect	3.95	0.65	0.6425	0.53	0.55
rock cycle		4.31	0.32	1.3255	0.270.26
groundwater	4.35	0.27	1.3111	0.28	0.28
Plate tectonics	**4.50**	**0.21**	**3.6807**	**0.03**	**0.03**
spatial analysis	2.42	2.17	1.0771	0.35	0.34
GIS	2.56	2.03	1.2049	0.31	0.31
photosynthesis	4.65	0.14	1.3048	0.28	0.26
food chain	4.71	0.16	0.6891	0.51	0.53

box), the range (extent of the whiskers that extend outward from the box), and a few "outliers" (individual points that are unusually far away from the interquartile range of the data). The boxplot shows the medians and the lower and upper quartiles of mean literacy scores increase with increasing school size, whereas there is no relationship discernible here between the lowest quartile of mean literacy scores and school size.

The results of the descriptive review of the familiarity data and its statistical analyses suggest that teachers in all size categories have a similar level of knowledge of the selected concepts in Environmental Science and Atmospheric Science across size categories. Geology was second to Geography in the difference in mean literacy score between small and large sized schools with a difference of 0.50. For all school sizes combined, Environmental Science had a considerably higher weight average (4.71) and, therefore, was most familiar to the selected teachers, while Geography had the lowest weight average (2.49) and was least familiar among the teachers. When the mean literacy scores for all subject areas in earth science combined are considered, the scores of 3.92, 4.09, and 4.30 are for small, medium, and large school sizes respectively, and 4.09 overall. With respect to the selected concepts, teachers from larger schools generally had higher mean literacy scores than teachers from smaller schools. However, only for Plate Tectonics was there a statistically significant difference between school size and mean literacy scores (i.e., teachers from large schools have higher mean literacy scores than teachers from small schools for this concept). The results of the statistical and descriptive analysis suggest an emerging pattern where earth science teachers in large schools are more familiar with the selected concepts than their counterparts in smaller schools.

In addition to the descriptive and statistical review of the teacher literary data, Figure 6 shows a spatial variation in teacher literacy by region as measured by the weight average for teacher's response to their knowledge of the selected subject areas in earth science by school size. The pattern that emerges reveals that five of the six regions studied had a slight increase in the weighted average with increasing school size categories. The SE region (Figure 6d) is an exception because there appears to be, in the graphic presentation, a uniform distribution of weight averages across size categories in this region. Table 7 substantiates what is shown in Figure 6d. This table shows the responses to knowledge of the selected concepts by region and school size, and the results are that in the SE region the averages were 3.9, 3.8, and 3.9 for small, medium, and large size schools respectively. Thus, the difference in the earth science literacy of teachers across school size categories was only 0.01. In addition to the SE region, two other regions, the NE and WNC, had teachers represented in all three school size categories. For each of these regions there was a progressive increase of weight averages from the small to the largest school size category (Figure 6a and 6e). Of the remaining three other regions, ENC and SW regions did not have teachers represented in the small size category, but weighted averages increased from medium to the largest size category in both regions (Figure 6b and 6c). The remaining W region also had a category that did not have any teachers, which was for the largest size class (Figure 6f). As with most of the other regions, this region revealed a weighted averages increase with increasing size in the region, from small to medium size categories.

The findings from the spatial analysis indicate there is little regional variation in teacher literacy based on the selected measures. However, there is a consistently small, but discernable variation among size categories within each region across the state with regards to literacy values. Specifically, there is a small increase in literacy values from small to medium to large

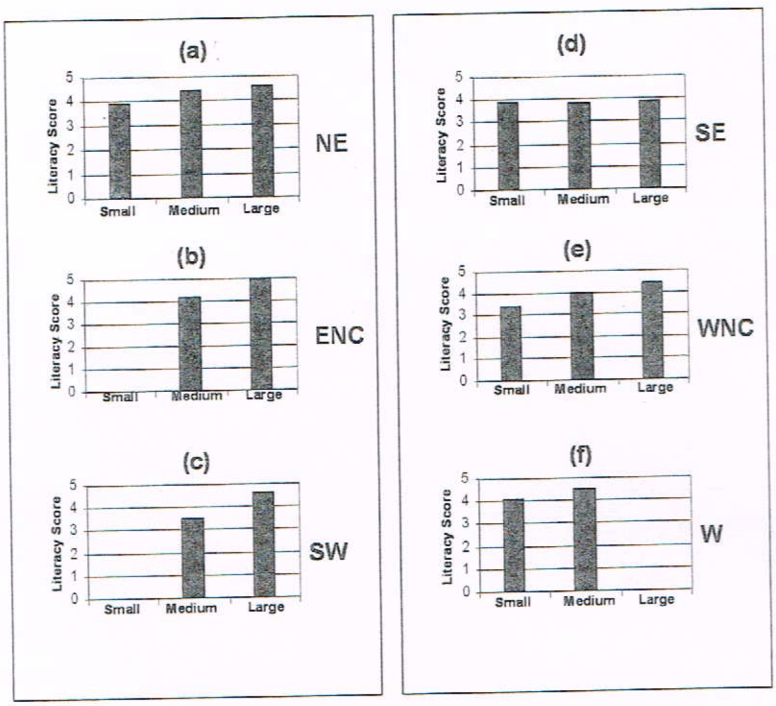

Figure 6. Graphs showing the regional variation in teacher literacy as measured by the weighted average for teacher's response to their knowledge of the selected subject topics in earth science by school size.

Table 7

The weighted average for teacher's response to their knowledge of the selected concepts combined by region and by school size category.

	School Size Category		
Region	Small	Medium	Large
NE	3.9	4.4	4.6
SE	3.9	3.8	3.9
ENC	—	4.2	5.0
WNC	3.4	4.0	4.4
SW	—	3.5	4.6
W	4.1	4.5	—

Dashes indicate no teachers represented.

school size categories in four of the six regions. It is not clear whether advantages of smaller schools such as having less bureaucracy (Black, 1996; Lee, et al., 2000) and a greater relationship with the community (Gardner, et al., 2000) can overcome perceived or real limitations in teacher preparation and literacy. Also, more qualified teachers (based on the selected measures) appear to be attracted to larger schools despite challenging issues such as discipline problems and high dropout rates (Howley, 1977)

Conclusion

This paper has discussed the variations in measures of teacher content preparation and literacy in earth science among high school earth science teachers relative to school enrollment in North Carolina. For teacher preparation, it was observed that teachers from the smallest schools had the highest percentages who had never taken an earth science or related course. The results indicate that teachers in large schools have studied significantly more earth science than teachers in the small schools. The data also suggest a general trend correlating increasing school size with teachers who have taken more coursework in the subjects they are teaching. On the other hand, the data suggest that smaller schools have more difficulty in attracting and retaining more experience teachers for earth science instruction.

For teacher literacy, it was found that high school earth science teachers have little knowledge of basic geographic concepts, but were quite knowledgeable about the other subject areas included in the study (Environmental

Science, Geology, and Atmospheric Science). The Geography concepts of GIS and Spatial Analysis were found to be least familiar to the teachers surveyed based on their literacy values. These concepts had the lowest literacy values among the concepts studied across school size categories. A reason for this occurrence is probably attributable to little or no discussion of these terms in Earth Science textbooks and therefore they were not covered during the formal education of teachers who did complete some course work in earth science.

For the state as a whole this study found an emerging pattern where earth science teachers in large schools are more familiar with the selected concepts than their counterparts in small schools. Teacher literacy did not vary considerably among regions in the state, but teachers from larger schools consistently were more knowledgeable about all the subject areas combined than teachers from smaller schools within most regions. Plate tectonics was the only concept where school size was a significant variable. Small schools had a mean score on this concept that was significantly lower ($p < 0.05$) for the teachers surveyed than medium and large size schools.

This study concludes that while larger schools may be disadvantaged because of more impersonal environments that may hinder teaching effectiveness, teachers with more experience in earth science are employed in those North Carolina high schools. Additional research in the form of a greater number of respondents would generate a larger dataset and therefore would provide a more detailed pattern of both teacher preparation and literacy across school enrollment size categories. However, the preliminary findings indicate that school size is an important factor in hiring and retaining teachers with adequate preparation and literacy in earth science.

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