Using GIS to Examine Regional Science and Mathematics Attainment

Mark C. Hogrebe
Lydia Kyei-Blankson
Li Zou

Center for Inquiry in Science Teaching and Learning (CISTL)
Department of Education
Washington University in St. Louis

Abstract

There is a growing demand for scientists and technicians as regions develop capabilities for high technology research and industry. To insure adequate human resources, area schools must provide quality scientific education. The Center for Inquiry in Science Teaching and Learning (CISTL) St. Louis Regional Database Project provides information to schools and the community about indicators of scientific attainment at elementary, middle, and high school levels.

Using the Missouri Assessment Program (MAP) science and mathematics tests as indicators of scientific attainment, test results are mapped to demonstrate variation across school districts in the St. Louis region. School and teacher characteristics such as enrollment, expenditures/student, teacher/pupil ratio, teacher education, salary, and experience are correlated with Missouri test results and mapped across area school districts. Patterns and relationships between demographic, school, teacher, and student variables are demonstrated and discussed.

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Research has consistently shown that students' academic performance is influenced by a variety of factors such as school inputs, teacher characteristics, and family attributes (Okpala, Okpala, & Smith, 2001; Okpala, 2002). Relationships between these variables are of great interest to educational researchers and school decision-makers because they can lead to understanding reasons for academic differences among schools and districts. Making relationships between student, teacher, and school more transparent assists policy decisions that affect the lives of everyone involved.

While it is obvious that schools and districts across the country differ in student demographics, teacher characteristics, and school structure and resources, real impact of this variation is felt at the regional level. Regional economies have key components that feed the economic engine such as manufacturing, service, and retail industries, banking and finance, real estate, transportation, entertainment, cultural capital, and so on. But the foundation for all of these components is the educational system that develops the human resources for the region. A region consists of multiple communities with schools and districts, and it is in understanding the extent of this variation in schools, teachers, and students that decision makers can develop informed policies that improve the educational enterprise and academic achievement of students.

The purpose of this research is to examine the relationships that exist between school and teacher variables and student achievement for districts located in the St. Louis region. Secondly, these relationships are given spatial and geographical perspective using GIS mapping to highlight differences and the importance of school district location in contributing to variability within the region. In essence, this study demonstrates the statistical ***relationships*** between non-spatial variables and displays the relationships in the geographic space of school district and region.

Specifically, the questions addressed in this study are:

1. What is the relationship of district socioeconomic status, enrollment, expenditure allocated to regular instruction per student, and teacher-pupil ratio with student attainment scores on the MAP test in science and mathematics for St. Louis area public schools? (MAP test is the State of Missouri Assessment Program used to assess student academic progress.)
2. What is the relationship of teachers' degree level, salary, and experience with students' science and mathematics attainment scores?
3. How can these relationships be demonstrated geospatially to show the extent of district variability within the St. Louis region?

Background on School and Teacher Variables

There is an extensive literature investigating the influences of socio-economic context of schools and school districts on student achievement. Socio-economic status is usually measured as the percentage of students on free-reduced lunch (Caldas & Bankston, 1997, 1999, Sirin, 2005). Researchers have consistently found that the socio-economic status of students (and therefore the schools they attend) is one of the most influential variables that affect student outcomes (Sirin, 2005). Often referred to as “status attainment research” (Tajalli & Opheim, 2004), the literature reports that schools with a higher percentage of ‘poor’ children on the average tend to post lower performance data. Conversely, the more affluent a school or school district, the better the achievement level of its students.

The research on the effect of enrollment on student achievement has yielded inconclusive results. After regressing student achievement data from 293 public secondary schools on school size, Fowler and Walberg (1991) concluded that enrollment was the next consistent, influential, and negatively related variable to school outcomes (after district socioeconomic status and percentage of students from low income families). The findings suggest that irrespective of their socioeconomic status, smaller school districts and schools are more efficient at enhancing students’ educational outcomes than larger schools. Alternatively, Hanushek (1997) found out that school size has no influence on student achievement.

The evidence provided by research studies on educational expenditure is mostly positive. On assessing the impact of school expenditure on student achievement, Dolan & Schmidt (1987) established the existence of a positive relationship between this school resource and student performance, with the effect of the variable being stronger at the elementary school level than at the middle or high school levels. Greenwald, Hedges and Laine (1996) corroborated this fact and further suggested that moderate increases in spending may be associated with significant increases in achievement. A similar discovery was made by Elliot (1998) when she linked US census data on school finance to data from the 1988 National Education Longitudinal Survey to determine whether schools’ financial resources affect students’ achievement in mathematics and science. Reasons suggested for this result was that increased per-pupil expenditures provided students with access to highly educated teachers who use more effective pedagogies in their classrooms. Nyhan and Alkadry’s (1999) study also revealed a statistically significant relationship between expenditure per student, but only at the middle school level.

Teacher-pupil ratio is a variable that gives an indication as to the average size of a class. According to Okpala, Smith, & Ellis (2000), “class size is an important educational resource because it indicates the availability of teachers that interact with students” (p. 6). However, various studies undertaken to determine the relationship between class size and student achievement have produced inconsistent results. Some researchers have suggested that children learn better in smaller classes (McGivern, Gilman, & Tillitski, 1989). Finn and Achilles (1990) conducted an empirical study to test whether smaller versus larger classes helped improve learning. In their study, students were randomly assigned to small and large classes within participating schools and were required to remain in their assigned classrooms for a period of two years. At the end of each grade, the researchers assessed students' mathematics and reading performance by way of standardized and curriculum-based tests. The results of the study showed that students' mathematics and reading ability had improved in the small compared to large classes. Nyhan and Alkadry (1999) also established an inverse relationship between class size and student achievement at all levels (elementary, middle, and high school levels) of public school education. However, results from a meta-analytic study by Hanushek (1997) showed that when family inputs are taken into consideration, student achievement was unaffected by class size. Wright, Horn, and Sanders (1997) also found that class size had relatively little influence on students' academic achievement. Irrespective of these negative findings, researchers continue to examine the relationship between class size and achievement and have suggested that reducing class size is a policy option that could be used to improve student learning (Ehrenberg, Brewer, Gamoran, & Willms (2001).

On the subject of the impact of teacher characteristics on student achievement researchers have suggested that how much teachers know concerning their subject of instruction has a positive impact on student attainment (Darling-Hammond, Berry, & Thoreson, 2001, Ferguson & Brown, 2000, Fetler, 2001, Goldhaber & Brewer, 1996, Monk, 1994). According to Wright, Horn, and Sanders (1997) teacher effects are dominant factors that affect student academic achievement. Results from a national data analysis conducted by Brewer and Goldhaber (1996) indicated a statistically significant positive link between teacher characteristics and students' achievement. Using data from the National Assessment of Educational Progress (NAEP), Darling-Hammond (2000) also established that various measures of teacher education, such as teacher preparation in education and certification, have strong positive correlations with student achievement. Based on these outcomes, Darling-Hammond concluded that policies adopted by states regarding teacher education may make an important difference in the qualifications and capacities that teachers bring to their work. However, Hanushek (1997) and Wayne and Youngs (2003) concluded that there is no systematic relationship between teacher characteristics and student achievement. In a review of existing studies on the relationship between student achievement and four categories of teacher characteristics (college ratings, test scores, degrees and coursework, and certification status) Wayne and Youngs (2003) found inconclusive evidence related to the relationship between teacher characteristics and student achievement. While some of the studies reviewed showed that relationships existed with teachers' college rating, test scores, degrees, course work, certification status and student achievement, others found no such relationships across the different grade levels and across different subjects.

Regarding the impact of teacher salaries on student performance, Sanders (1993) examined educational outcomes in Illinois for the 1989–1990 school year. Using several measures of educational attainment such as ACT scores, high school graduation rates, and the percentage in a high school planning to attend college, the study showed that increases in average teacher salaries led to increases in ACT scores, graduation rates, and the percentage of college-bound students. Conclusions from a study conducted by Smith (2004) also indicated an association between teachers' salaries and increases in students' test scores in mathematics.

In summary, this study explores two broad factors likely to influence student achievement in science and mathematics: School inputs and teacher characteristics. Measures of school inputs include district socio-economic status, enrollment, instructional expenditure per student, and teacher-pupil ratio. Teacher characteristics consist of three categories; namely, teacher salary, experience, and percentage with master's degrees. Although the findings from research undertaken to assess the effects of these factors on achievement have been mixed, studies have shown that socio-economic status, enrollment, and teacher-pupil ratio may be inversely related to achievement. Alternatively, higher levels of expenditure per student, teachers' salary, experience, and degrees have been associated with higher student achievement levels.

The Data

The data were gathered from 30 St. Louis public school districts and those selected to represent the St. Louis area had the highest concentration of school-aged children (5 – 17 years old) based on the 2000 U.S. census data. The districts form a contiguous area westward from the Mississippi River with the St. Louis City district as the eastern anchor.

In evaluating data from a regional perspective, it was important to define the scope of the region. For example, the present study did not include the Illinois side of the St. Louis region because the Illinois testing and criteria for determining Proficient/Advanced status are very different from Missouri's. The Proficient/Advanced categories between the two states are not directly comparable.

Secondly, a decision was made as to which type of variability to study: variability across districts or variability among schools in a district. The present study focused on district variability across the region and attempted to describe important characteristics of the districts. These characteristics included school, teacher, and student variables summarized at the district level.

The indicators of science and mathematics attainment were the Missouri MAP scores. For science, the MAP test is given in third, seventh, and tenth grades. The MAP test for mathematics has been given in the fourth, eighth, and tenth grades, but starting in spring of 2006 is given to grades 3 through 8 and at the high school level. In order to make the discussion for this study manageable, correlations were examined at the district level between MAP test scores in science and mathematics. Due to the high correlations between these scores at the district level, it was decided to focus the discussion on the MAP science results. The correlations between science and mathematics MAP scores were: third grade science and fourth grade math, $r = 0.85$; seventh grade science and eighth math, $r = 0.94$; tenth grade science and math, $r = 0.82$. These findings indicated that districts with high scores in one subject had high scores in the other and districts with low scores in one subject had low scores in the other. The results for Mathematics are reported in Appendix B.

In addition, since the correlations between the middle school and high school MAP test scores were also very high, the analysis used data from elementary and high school only. (Seventh and tenth grade science MAP scores, $r = 0.89$; eighth and tenth grade mathematics MAP scores, $r = 0.88$.)

The MAP science test measures students' progress relative to the Missouri Show-Me standards. It assesses eight content areas or strands: Matter and energy, Force and motion, Living organisms, Ecology, Earth processes, Universe, Scientific inquiry, and Science and Technology (see appendix for Mathematics content areas or strands).

The items on the test include three types:

- Multiple-choice items from the TerraNova, a nationally normed test.
- Constructed response items that require students to supply (rather than select) an appropriate response. Sometimes called an open-ended item.
- Performance event items that involve longer and more demanding tasks which require students to work through problems or experiments.

The MAP tests are scored by CTB/ McGraw-Hill and reported as MAP Scale Scores based on students' correct responses and points earned. The Scale Scores are used to indicate the current five achievement levels: Step 1, Progressing, Nearing Proficient, Proficient, and Advanced. Each achievement level provides a description of what students can do in terms of the content area at that grade level. (For more information see the "Missouri Assessment Program: Guide to Interpreting Results, Revised 2005" at the Missouri Department of Elementary and Secondary Education (DESE) website: www.dese.state.mo.us/divimprove/assess/GIR_2005.pdf). The level definitions below are from the district MAP data tables on the DESE website:

Step 1: Students are substantially behind in terms of meeting the Show-Me Standards. They demonstrate only a minimal understanding of fundamental concepts and little or no ability to apply that knowledge.

Progressing: Students are beginning to use their knowledge of simple concepts to solve basic problems, but they still make many errors.

Nearing Proficient: Students understand many key concepts, although their application of that knowledge is limited.

Proficient: This is the desired achievement level for all students. Students demonstrate the knowledge and skills called for by the Show-Me Standards.

Advanced: Students demonstrate in-depth understanding of all concepts and apply that knowledge in complex ways.

The indicator of attainment for each district was the percentage of students at the proficient plus advanced levels, separately for the third and tenth grades. The focus was on the percentage of students at the proficient and advanced levels because "proficient" as defined above is the achievement level desired for all students. Proficient means the students demonstrate science knowledge and skills that the State of Missouri defined as essential in the Show-Me Standards.

Data Analysis

Missouri MAP science and mathematics scores were gathered for the years 2000 through 2005. Since State funding for the science test was eliminated after 2002, schools could elect to give the science test on a voluntary basis; therefore, some schools did not administer the science test during each subsequent year and did not have data for all six years, but all districts had at least three years of data. For this report, the median was calculated to summarize each district's percentage of Proficient/Advanced students on the science and mathematics MAP tests during the 2000 – 2005 period. Selected school and teacher factors consisted of 2005 data obtained from the Missouri Department of Elementary and Secondary Education website: http://dese.mo.gov/schooldata/.

Pearson correlation analysis was used to determine the strength of the relationship between the selected school and teacher resources and the percentage of Proficient/Advanced students in science. In order to understand the variation in science attainment across the school districts as it related to the selected school and teacher factors, the data were given spatial and geographical perspective using GIS mapping.

Results

Table 1 reports the means, standard deviations, and range values. It is important to remember that these statistics are calculated from summary data for each of the thirty St. Louis area school districts. The figures represent variation across school districts, but do not tell anything about variation *within* the districts. For example, this can be seen in the minimum years of teacher experience at 8.9 years which is the lowest average experience for a district. Several of the variables have a wide range of values such as percentage of students with free/reduced lunch (8.7% to 97.2%), enrollment (561 to 37,166) and third grade percent proficient/advanced (7.4% to 82.4%).

Table 1

School and Teacher Factors, and Student Proficient/Advanced Percentage

Variable	Mean	SD	Minimum	Maximum
Percentage of students with free/reduced lunch	40.21	26.94	8.7	97.2
Teacher/ pupil ratio	17.77	2.74	13.0	22.0
Enrollment	8231.27	8411.79	561.0	37166.0
Teacher years experience	12.37	1.86	8.9	15.5
Teacher salary	47,467.97	5,346.82	38,701.0	60,069.0
Percent master's degree	60.34	14.06	22.5	86.4
Composite ACT Score	20.77	2.62	14.6	25.4
Third grade percentage Proficient/Advanced	48.8	15.44	7.4	82.4
Tenth Grade Percentage Proficient/Advanced	6.44	4.31	.3	16.2

Table 2

Correlation Coefficients for School and Teacher Variables with District MAP Student Proficient/advanced Percentage

	Third Grade	Tenth Grade
Enrollment	-.032	-.046
Teacher/student ratio	.068	-.300
Percentage of students with free/reduced lunch	-.771**	-.781**
Instructional expenditure/student	.267	.545**
Percentage masters' degree	.409*	.521**
Teacher years experience	.269	.525**
Teacher salary	.243	.460*
Composite ACT Score	.835**	.858**

** significance level of 1%;
* significance level of 5%

The correlations across districts for the school and teacher variables with student Proficient/Advanced percentages in third and tenth grade are reported in Table 2. (The correlation matrix for all variables can be found in Appendix A.) For the school variable of enrollment size, the number of students enrolled in a district was not related to the percentage of students classified as Proficient/Advanced on the MAP science test. Large and small districts had both high and low percentages of Proficient/Advanced students.

Next, the teacher/pupil ratio had almost no relationship to percentage of Proficient/Advanced students at the third grade level and a non-significant but low negative relationship at the tenth grade level. The negative trend suggests a lower teacher/pupil ratio might be associated with more students at the Proficient/Advanced level in tenth grade, but this relationship was not significant at the alpha 0.05 level for thirty districts. Expanding the number of districts would provide the opportunity to see if this trend is statistically significant. Also, the relatively small range of teacher/pupil ratios (13 to 22) makes it less probable to have a significant relationship with Proficiency status. The low ratio means that on the average, the class sizes are small across districts. If large class sizes jumped to 40 or 45, then it would be more likely to find that smaller classes are associated with a higher percentage of Proficient/Advanced students.

The third school variable was the percentage of students with free/reduced lunch status. Free/reduced lunch status had a highly significant negative relationship with percentage of Proficient/Advanced students at the third ($r = -0.77$) and tenth ($r = -0.78$) grades. Districts with more students participating in the free/reduced lunch program had fewer students at the Proficient/Advanced levels.

The school variable of expenditure for regular instruction per student was not significantly related to the percentage of Proficient/Advanced students in the third grade, but was significantly related in the tenth grade ($r = .54$). School districts with higher levels of regular instructional spending per student had a higher percentage of Proficient/Advanced students.

The next three variables relate to teachers in the districts. Districts with a higher percentage of teachers with master's degrees had more students at the Proficient/Advanced levels in both the third ($r = .41$) and tenth ($r = .52$) grades. Teachers' years of experience and salary were not significantly related to percentage of Proficient/Advanced students at the third grade, but were significantly related to percentage Proficient/Advanced at the tenth grade (teacher years experience, $r = .52$; teacher salary, $r = .46$).

Finally, as a type of validity check for the percentage of Proficient/Advanced students as a measure of student performance at the district level, it was correlated with the districts' average ACT composite scores. The correlation was high for both third ($r = .84$) and tenth ($r = .86$) grades. This finding indicates that districts with higher average ACT composite scores also tend to have higher percentages of Proficient/Advanced students in the third and tenth grades.

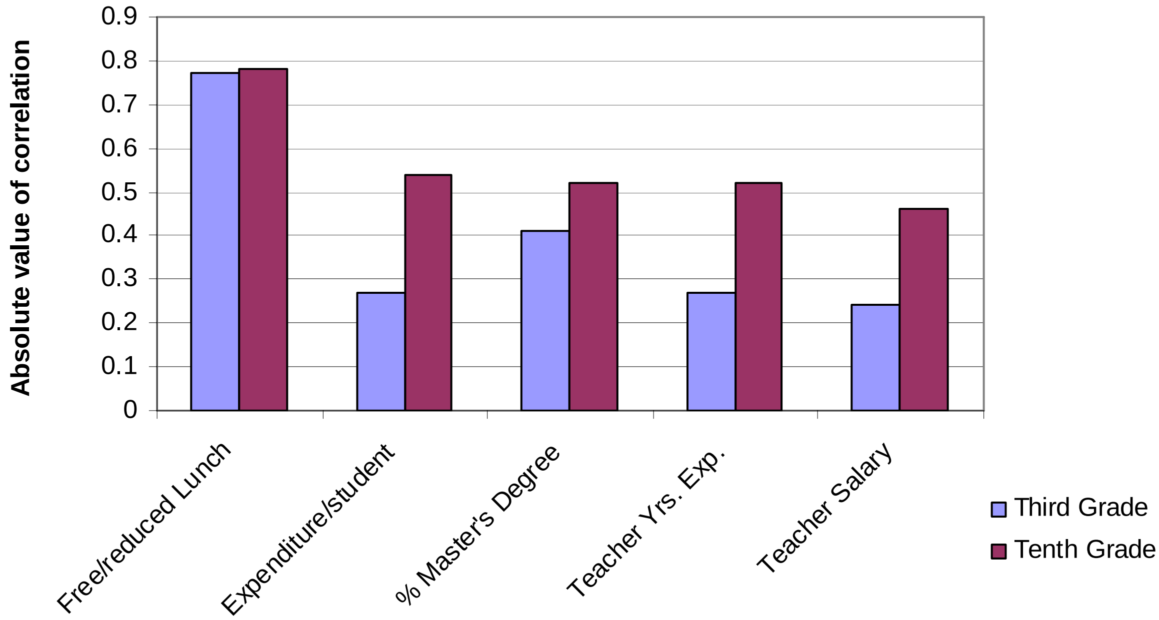
Discussion

The results show that one of the school variables (instructional expenditure/student) and two of the teacher variables (years experience and salary) had significant relationships with tenth grade percentage of Proficient/Advanced students, but not at the third grade level. This is especially interesting in that the range of percentage Proficient/Advanced students in tenth grade is much smaller (0.3% to 16.2%) than for the third grade (7.4% to 82.4%). If the relationship between two variables is operating similarly in two groups, the group with the greater range of values generally will have the higher correlation. Since the lower range group (tenth grade) demonstrates stronger relationships among these variables, the underlying relationships are probably different for third and tenth grades.

At the district level of analysis for the tenth grade, a greater percentage of Proficient/Advanced students in science was associated with higher instructional expenditures per student, lower percent participation in the free/reduced lunch program, teachers with more years experience, higher salaries, and greater percent with master's degrees. At the district level, more school, teacher, and family resources are related to a higher percentage of Proficient/Advanced students. These relationships are summarized by the absolute value of their correlations in Figure 1.

Figure 1.

District Level Correlations for School and Teacher Variables with Percentage of Proficient/Advanced Students in Science



However, from an overall perspective, even districts with the highest percentage of Proficient/Advanced students in tenth grade have only 16.2% at this level. According to the results of the MAP science testing program, there needs to be significant improvement in the percentage of Proficient/Advanced students even among the region's better resourced schools.

Once again, it is important to remember that these relationships were at the district level and based on variability between districts. Different relationships may very well emerge if the analyses are conducted at the school building level that incorporates *within* district variability between schools. Other types of analyses using cross level data for multi-level or hierarchical models in which both school level and student level data are included simultaneously may demonstrate still different perspectives on the relationships.

Spatial and Geographic Presentation of the Relationships between School, Teacher, and Student Variables

The spatial and geographic presentation of the relationships between school, teacher, and student variables used ArcView 9.1 to produce the GIS maps. Only variables with significant relationships to percentage of Proficient/Advanced students were used to create maps, except for teacher/student ratio at the tenth grade which approached statistical significance, $r = -0.30$.

Two approaches were used to represent the variable relationships geographically. The first was used to create geospatial maps for percentage of Proficient/Advanced students with percentage in free/reduce lunch program and instructional expenditures per student. A slightly different approach was employed comparing percentage of Proficient/Advanced students with the three teacher variables of salary, experience, and percent with master's degrees.

Correlation of Free/reduced Lunch and Instructional Expenditures with Percentage of Proficient/Advanced Students

In creating geospatial maps of school districts for free/reduced lunch and instructional expenditures, solid colors were used to designate the percentage of Proficient/Advanced students in three categories: lower third, middle third, and upper third. For third grade, the colors of red (lower third), yellow (middle third), and green (upper third) were selected to provide a visual cue as to how the districts were performing. For districts at the third grade level, these colors correspond to an approximation of the percentage of Proficient/Advanced that is likely to be considered acceptable (green), needs improvement (yellow), and needs much improvement (red) (see Figure 2).

In the tenth grade, the percentage of Proficient/Advanced students was much lower even for the better performing districts. The range of Proficient/Advanced students (0.3 percent to 16.2 percent) was also divided into categories by thirds. Since the percentage of Proficient/Advanced students in all districts was in the "needs much improvement" category, the categories were coded in three shades of red from lower (darkest red) to higher (lighter red) (see Figure 3).

The instructional expenditure variable was also divided into three categories (low to high by thirds), but was then coded as an icon. The icon was designed to provide two visual cues about the category it represented in order to facilitate interpretation when viewed on the Proficient/Advanced solid color map by district location. A small and red icon indicated the bottom third level of instructional spending, a medium-size, yellow icon represented the middle spending level, and a large, green icon was used for the top spending level.

The size and color coding of the icon representing instructional expenditures assists districts. A large green icon on a green district means that the district was in the upper third for both instructional expenditures and percentage of Proficient/Advanced

Figure 2. Free/Reduced Lunch and Percent of Student Proficient/Advanced on Science MAP Test for Third Grade, by School District

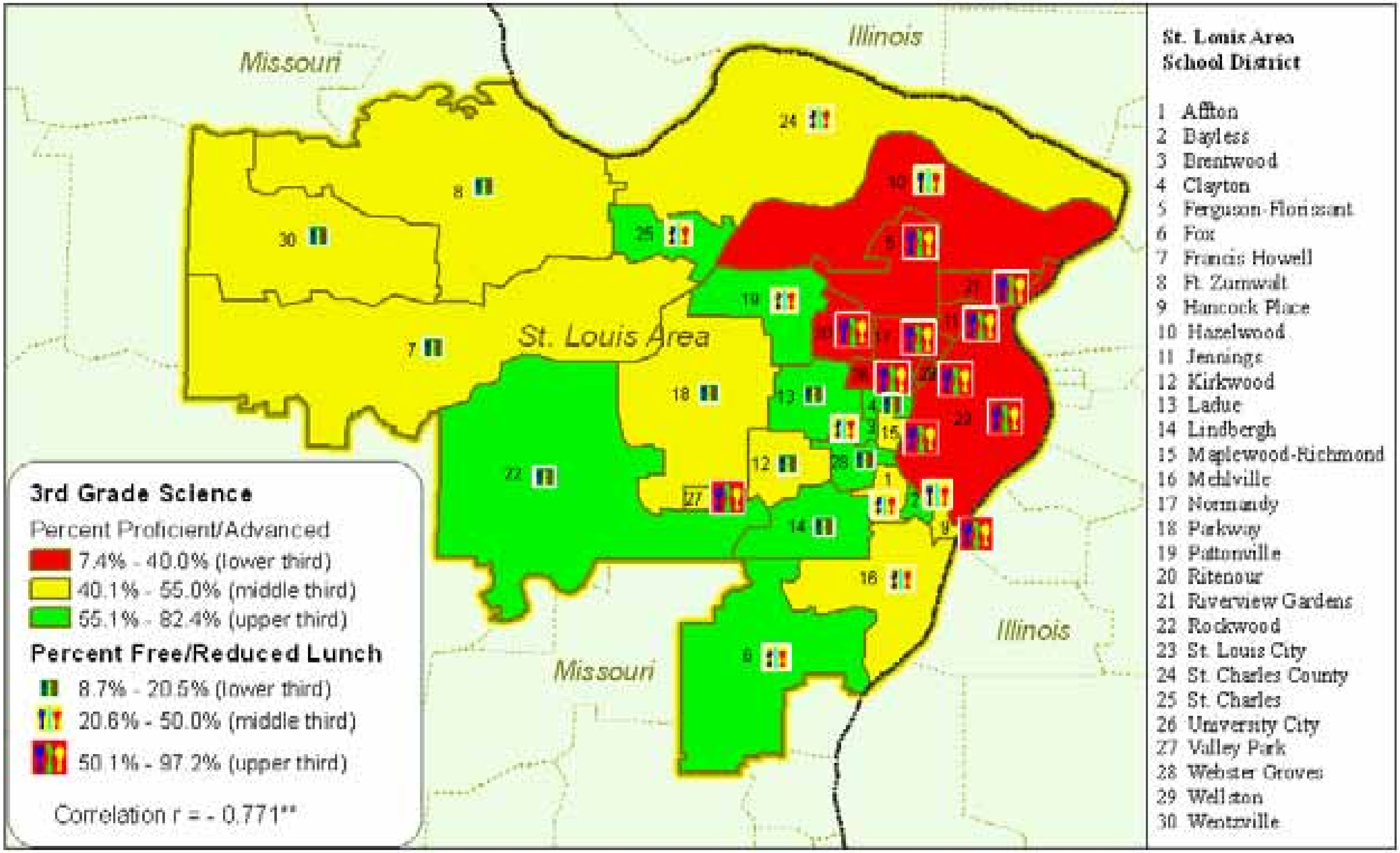
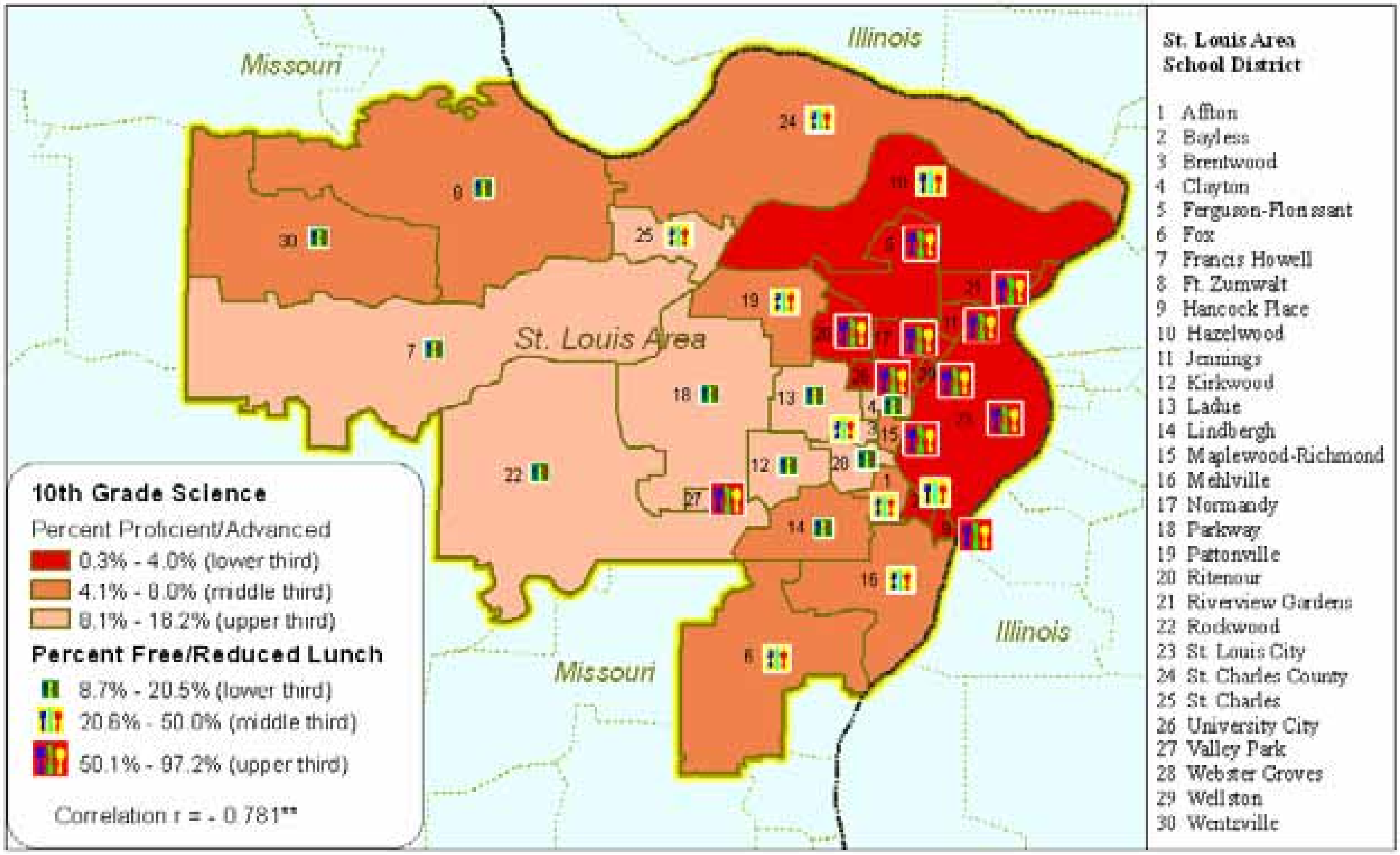


Figure 3. Free/Reduced Lunch and Percent of Student Proficient/Advanced on Science MAP Test for Tenth Grade, by School District



students. A small red icon on a red district indicates that the district was in the lower third for both instructional expenditures and percentage of Proficient/Advanced students. A small red icon in a green district represents a district in the highest third of Proficient/Advanced students, but lower third in instructional expenditures (see Figure 4).

These patterns represent the correlation between the variables. Higher correlations have more matches of district color and icon color (and size). Lower correlations have more color mismatches. The geospatial representation of the correlation lets the viewer see where the correlation is supported and where it is attenuated.

The geospatial representation of the correlation between average district instructional expenditures and percentage of Proficient/Advanced students (r = .54) clearly showed that districts with higher percentages of Proficient/Advanced students were mostly in the upper third of expenditures per student. Districts with the higher instructional expenditures clustered in the center of the region just to the west of St. Louis City.

The relationship between free/reduced lunch participation and percentage of Proficient/Advanced students was represented in a similar way with Proficient/Advanced percentages as solid colors (see Figures 2 & 3). However, since this was a negative correlation, the sizes of the red and green icons were reversed. A large red icon indicated that the district was in the upper third of districts with greater numbers of students receiving free/reduced lunches. Conversely, a small green icon indicated a district in the lower third with fewer students participating in the free/reduced lunch program.

The high negative correlations between free/reduced lunch participation and percentage of Proficient/Advanced students (third grade, r = -.77; eighth grade, r = -.78) were represented geospatially and easily identified in Figures 2 & 3. The large red icons that indicated high free/reduced lunch participation clustered in districts with the lowest percentages of Proficient/Advanced students. These districts were primarily St. Louis City and districts to the immediate northwest. The districts in the upper third for percentage of Proficient/Advanced students had fewer students participating in the free/reduced lunch program and clustered in the region west of St. Louis City.

Another example of a negative correlation is demonstrated in Figure 5 for teacher/student ratio at the tenth grade which approached statistical significance, r = -0.30. The districts just west of St. Louis City with the higher percentage of Proficient/Advanced students had the smaller teacher/student ratios. However, the middle and lower performing districts across the rest of the region had both large and small teacher/student ratios.

Correlation of Teacher Variables with Percentage of Proficient/Advanced Students

For the geospatial maps of school districts displaying the three teacher variables of salary, experience, and percent with master’s degrees, solid colors once again designated the percentage of Proficient/Advanced students in three categories: lower third, middle third, and upper third. The previous color patterns that showed percentage

Figure 4. Student Expenditure and Percent of Student Proficient/Advanced on Science MAP Test for Third and Tenth Grades, by School District

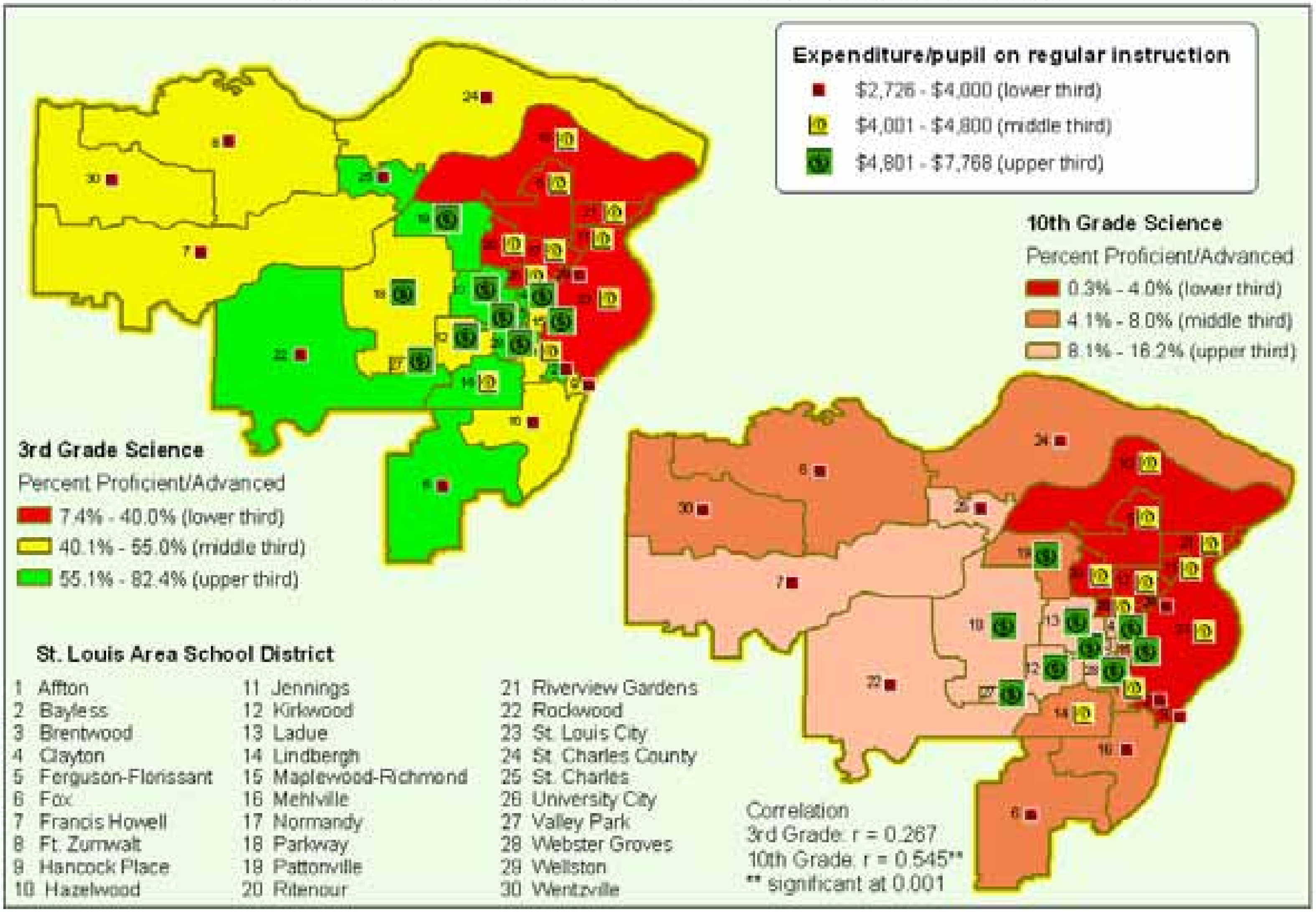
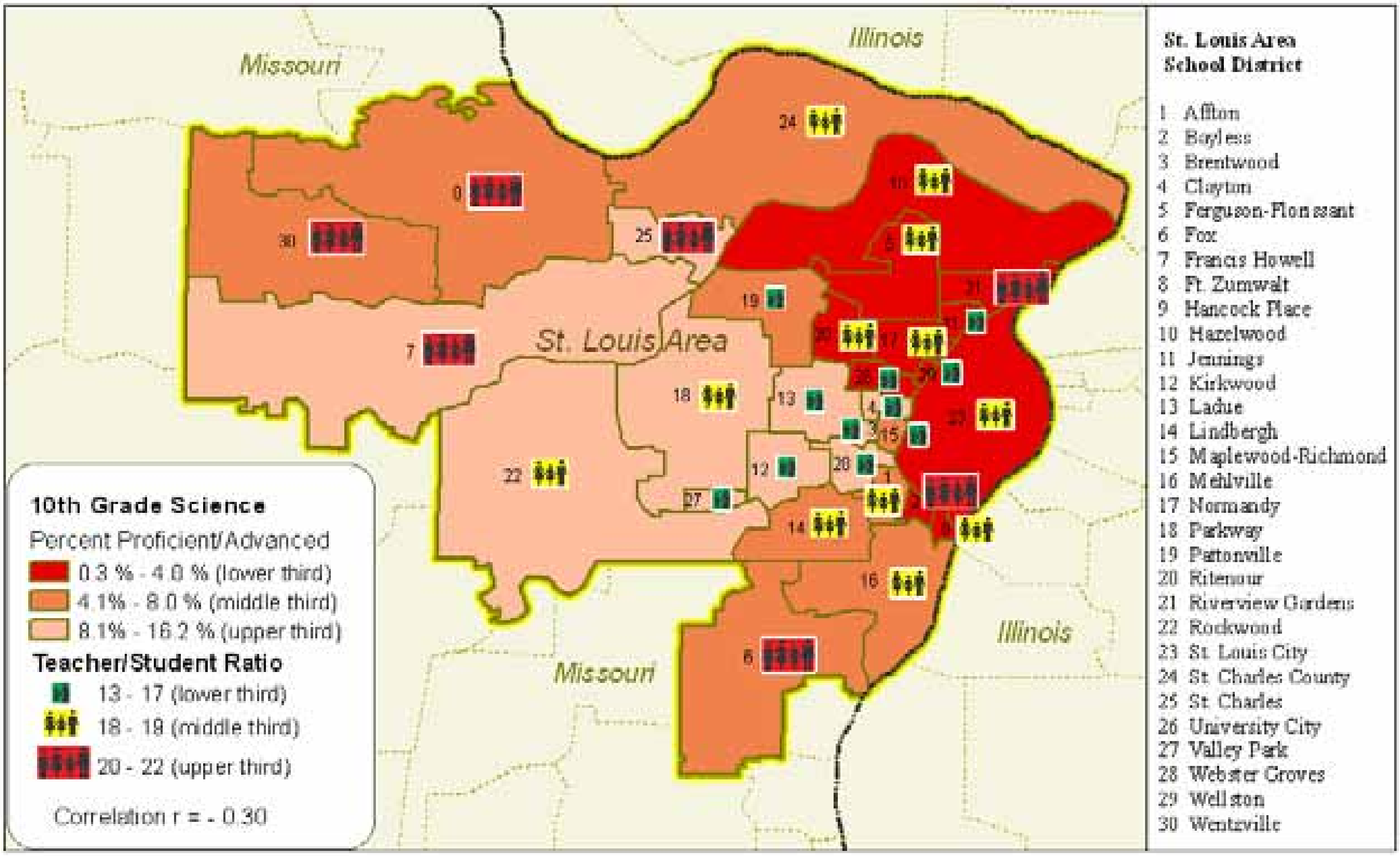


Figure 5. Teacher/Student Ratio and Percent of Student Proficient/Advanced on Science MAP Test for Tenth Grade, by School District



of Proficient/Advanced students at the third and tenth grade levels were used as the background to map the teacher variables.

In order to easily compare the three teacher variables within a district, they were represented together as a 3-bar graph (see Figures 6 & 7). The first bar was for percent of teachers with master's degrees, the second bar for teacher experience, and the third bar for teacher salary. The height of the bars corresponded to the lower third, middle, or upper third of the variable's distribution. In this way, the three variables simultaneously portrayed the district's teacher status.

When combined with the solid color district map, the 3-bar graph of teacher variables showed how each variable correlated with the percentage of Proficient/Advanced students in the district. For example, a low bar for each teacher variable in a red colored district indicated low teacher salary, experience, and percent master's degree associated with low percentage of Proficient/Advanced students. Using this approach, the teacher variables can be compared with each other as well as with the percentage of Proficient/Advanced students in the district. In addition, the profiles of the bar graphs can be compared across districts.

For example, the districts just west of St. Louis City in the upper third of percentage Proficient/Advanced students, were also in the upper third of teachers with master's degrees, teaching experience, and salary. The high bars in all three categories clearly show the geospatial relationship of teacher variables with the greater percentage of Proficient/Advanced students as well as to each other. In addition, low bars on all teacher variables were associated with two of the lower performing districts and two of the middle-third performing districts, but none of the higher performance districts.

Conclusion

The present study examined correlations of school and teacher variables with the percentage of Proficient/Advanced students in the district. A number of the variables were significantly related to the percentage of Proficient/Advanced students: instructional expenditures per student (10^{th} grade), teacher years experience (10^{th} grade), teacher salary (10^{th} grade), percentage of teachers with master's degrees (3^{rd} and 10^{th}), and percentage of students receiving free/reduced lunches (3^{rd} and 10^{th}).

Although these variables were related to student performance, direct causation cannot be assumed for any one variable. The variables were related to each other and to variables not included in this study, so changing one may not directly increase the percentage of Proficient/Advanced students. For example, hiring teachers with more years experience probably would not have a large impact on students' performance if other factors are not also addressed. Districts with a high percentage of students receiving free/reduced lunches have fewer students at the Proficient/Advanced levels, but reducing free/reduced lunches is not a logical way to increase student performance.

Figure 6. Teacher Education, Experience, Salary and Percent of Student Proficient/Advanced on Science MAP Test for Third Grade, by School District

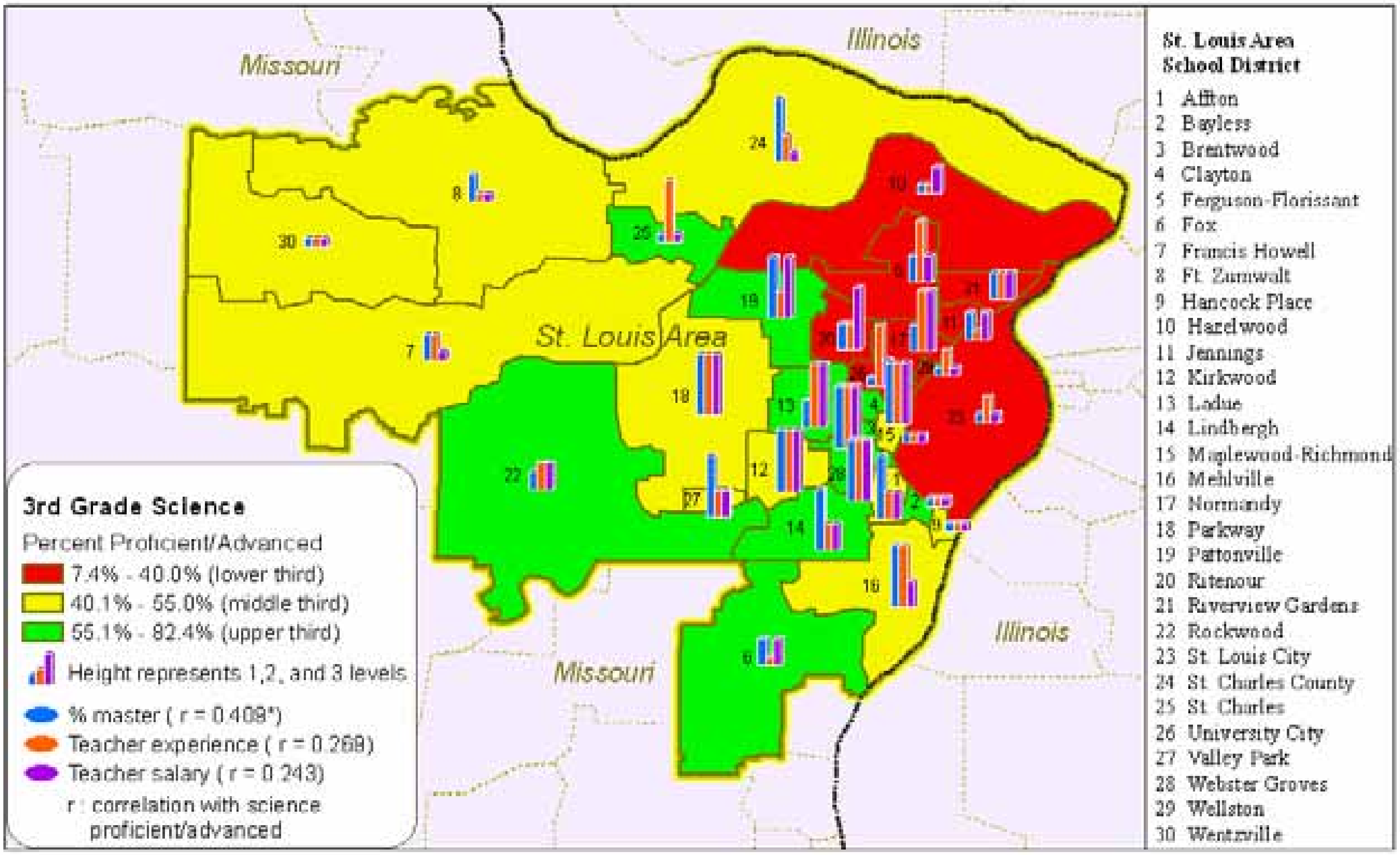
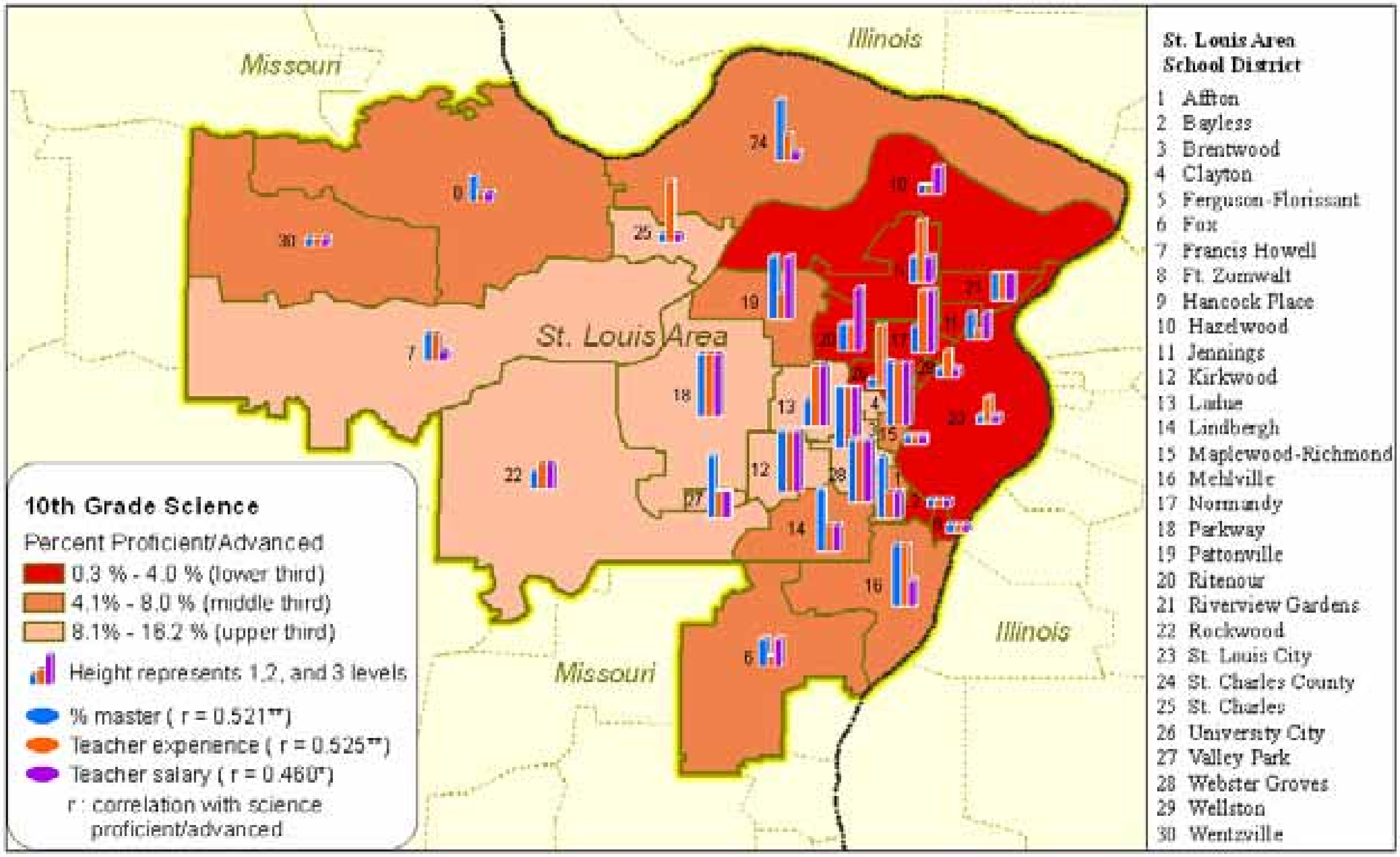


Figure 7. Teacher Education, Experience, Salary and Percent of Student Proficient/Advanced on Science MAP Test for Tenth Grade, by School District



The geospatial representation of the variable relationships gives a unique perspective on how the educational data is distributed across the region. It shows district variation in student science attainment in relationship to where greater school and teacher resources are located. For decision makers and policy planners in education, business, and the community, it is important to know the level of student attainment across the region and which factors are associated with it. When data are presented geospatially, demographic and educational patterns emerge that cannot be visualized from tables or summary statistics.

For example, districts located in the western part of the region have many new housing developments that attract younger families with children. The maps clearly show that these districts have medium to high percentage of Proficient/Advanced students in combination with: low participation in the free/reduced lunch program, low to middle range of teacher salaries and years of experience, mostly lower ranges of instructional expenditures per student, and higher teacher/student ratios in the classrooms. How can districts that are less favorable on these variables have higher student performance? The answer becomes clear when the data are represented from a geographic perspective and interpreted in the context of the higher concentration of younger families in these districts.

Analyzing educational and demographic factors through techniques such as geospatial mapping will lead to better understanding and sound decisions that promote policies beneficial to educational achievement, business and job growth, and ultimately all the regions' citizens.

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Appendix A

Science

Table 3

Correlation Coefficients for School, Teacher Variables, and District Science MAP Student Proficient/advanced Percentage

	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
(A) 3rd grade percent proficient/ advanced	1								
(B) 10th grade percent proficient/ advanced	.740**	1							
(C) Enrollment	-.032	-.046	1						
(D) Percent masters degrees	.409*	.521**	-.117	1					
(E) Teacher/student ratio	.068	-.300	.443*	-.100	1				
(F) Instructional expenditure/ student	.267	.545**	-.276	.470**	-.748**	1			
(G) Teacher years experience	.269	.525**	-.082	.355	-.375*	.585**	1		
(H) Teacher salary	.243	.460*	-.261	.662**	-.455*	.831**	.677**	1	
(I) Composite ACT score	.835**	.858**	.008	.612**	-.070	.438*	.399*	.457*	1
Percent students with free/reduced lunch	-.771**	-.781**	-.051	-.564**	-.109	-.233	-.237	-.281	-.910**

Appendix B

Mathematics

The Mathematics MAP test assesses six content areas or strands: Number Sense, Geometric and Spatial Sense, Data Analysis and Probability, Patterns and Relationships, Mathematical Systems, and Discrete Mathematics.

Table 5

School and Teacher Factors, and Student Mathematics Proficient/Advanced Percentage

Variable	Mean	SD	Minimum	Maximum
Percent of students with free/reduced lunch	40.21	26.94	8.7	97.2
Teacher/ pupil ratio	17.77	2.74	13.0	22.0
Enrollment	8231.27	8411.79	561.0	37166.0
Teacher years experience	12.37	1.86	8.9	15.5
Teacher salary	47,467.97	5,346.82	38,701.0	60,069.0
Percent master's degree	60.34	14.06	22.5	86.4
Composite ACT Score	20.77	2.62	14.6	25.4
Fourth grade percent Proficient/Advanced	39.58	16.03	1.3	69.8
Tenth Grade Percent Proficient/Advanced	13.42	8.90	0.7	37.9

Table 6

Pearson Correlation Coefficients for School and Teacher Variables with District Mathematics MAP Student Proficient/advanced Percentage

	Fourth Grade	Tenth Grade
Enrollment	-.022	-.093
Teacher/student ratio	-.110	-.402*
Percent of students with free/reduced lunch	-.879**	-.724**
Instructional expenditure/student	.482**	.584**
Percent masters' degree	.636**	.464**
Teacher years experience	.398*	.538**
Teacher salary	.496**	.497**
Composite ACT Score	.934**	.804**

** significance level of 1%;
* significance level of 5%

Table 7

Correlation Coefficients for School, Teacher Variables, and District Mathematics MAP Student Proficient/advanced Percentage

	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
(A) 4th grade percent proficient/ advanced	1								
(B) 10th grade percent proficient/ advanced	.781**	1							
(C) Enrollment	-.022	-.093	1						
(D) Percent masters degrees	.636**	.464**	-.117	1					
(E) Teacher/student ratio	-.110	-.402*	.443*	-.100	1				
(F) Instructional expenditure/ student	.482**	.584**	-.276	.470**	-.748**	1			
(G) Teacher years experience	.398*	.538**	-.082	.355	-.375*	.585**	1		
(H) Teacher salary	.496**	.497**	-.261	.662**	-.455*	.831**	.677**	1	
(I) Composite ACT score	.934**	.804**	.008	.612**	-.070	.438*	.399*	.457*	1
Percent students with free/reduced lunch	-.879**	-.724**	-.051	-.564**	-.109	-.233	-.237	-.281	-.910**

Figure 8. Free/Reduced Lunch and Percent of Student Proficient/Advanced on Math MAP Test for Fourth Grade, by School District

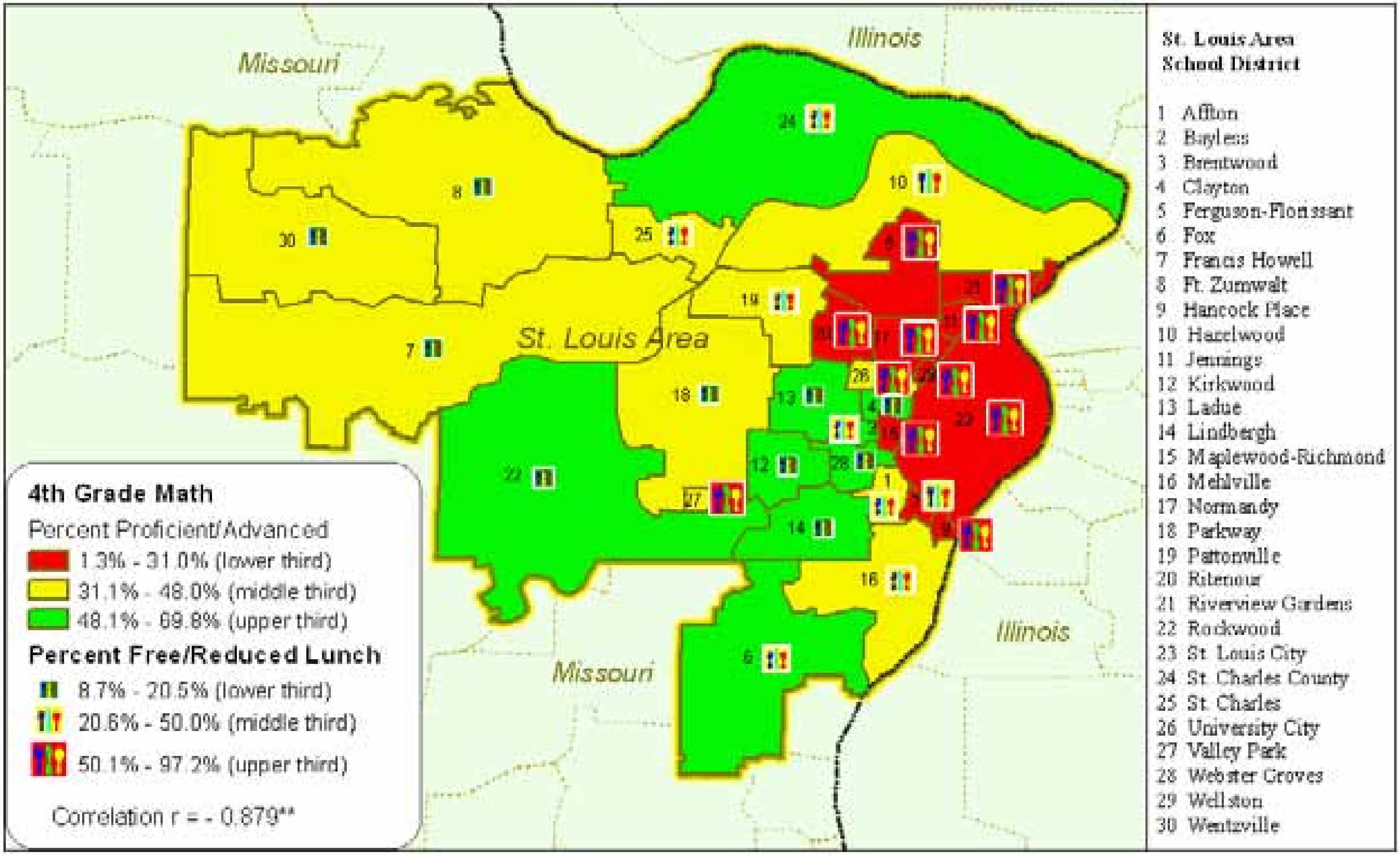


Figure 9. Free/Reduced Lunch and Percent of Student Proficient/Advanced on Math MAP Test for Tenth Grade, by School District

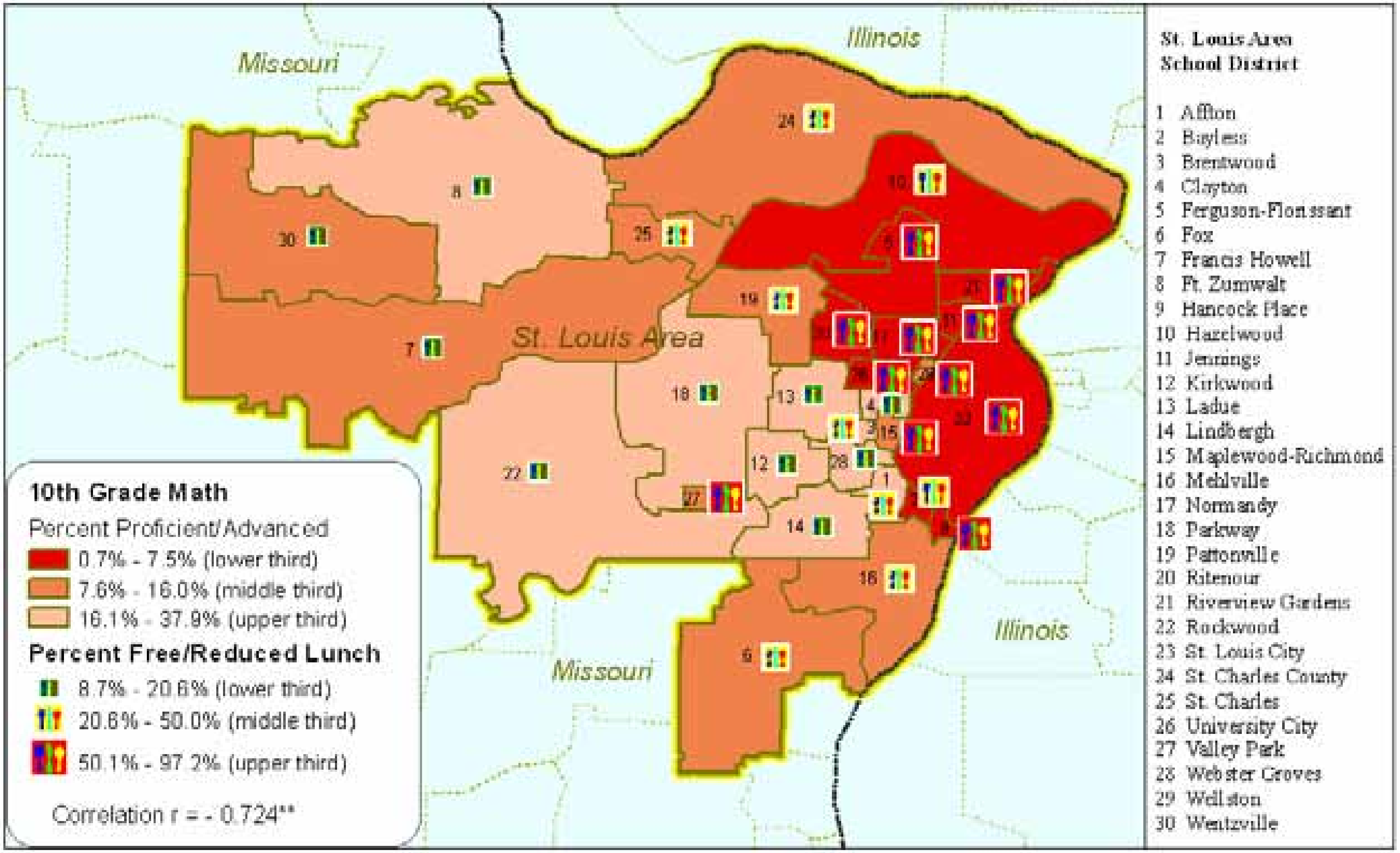


Figure 10. Student Expenditure and Percent of Student Proficient/Advanced on Math MAP Test for Fourth and Tenth Grades, by School District

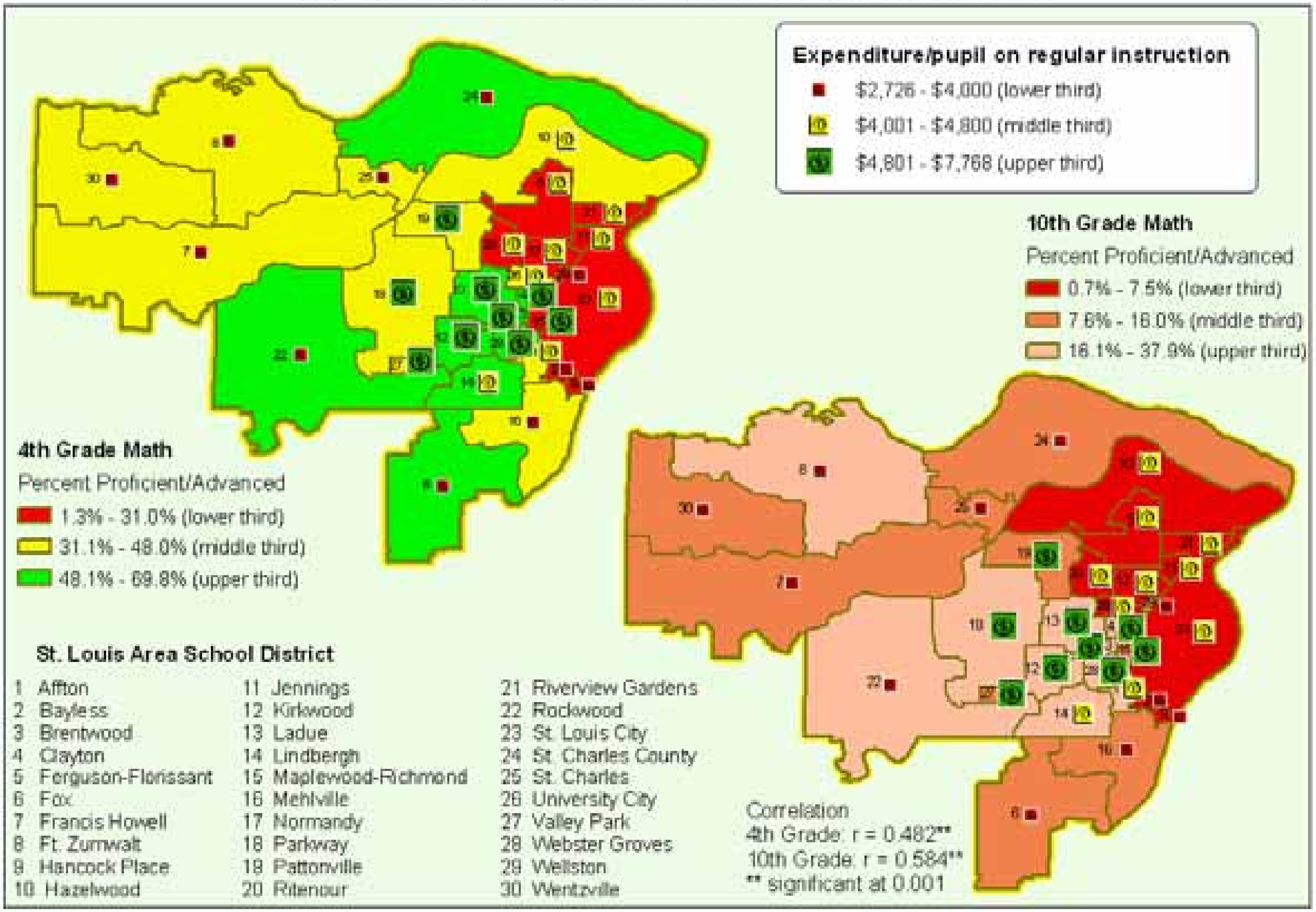


Figure 11. Teacher/Student Ratio and Percent of Student Proficient/Advanced on Math MAP Test for Tenth Grade, by School District

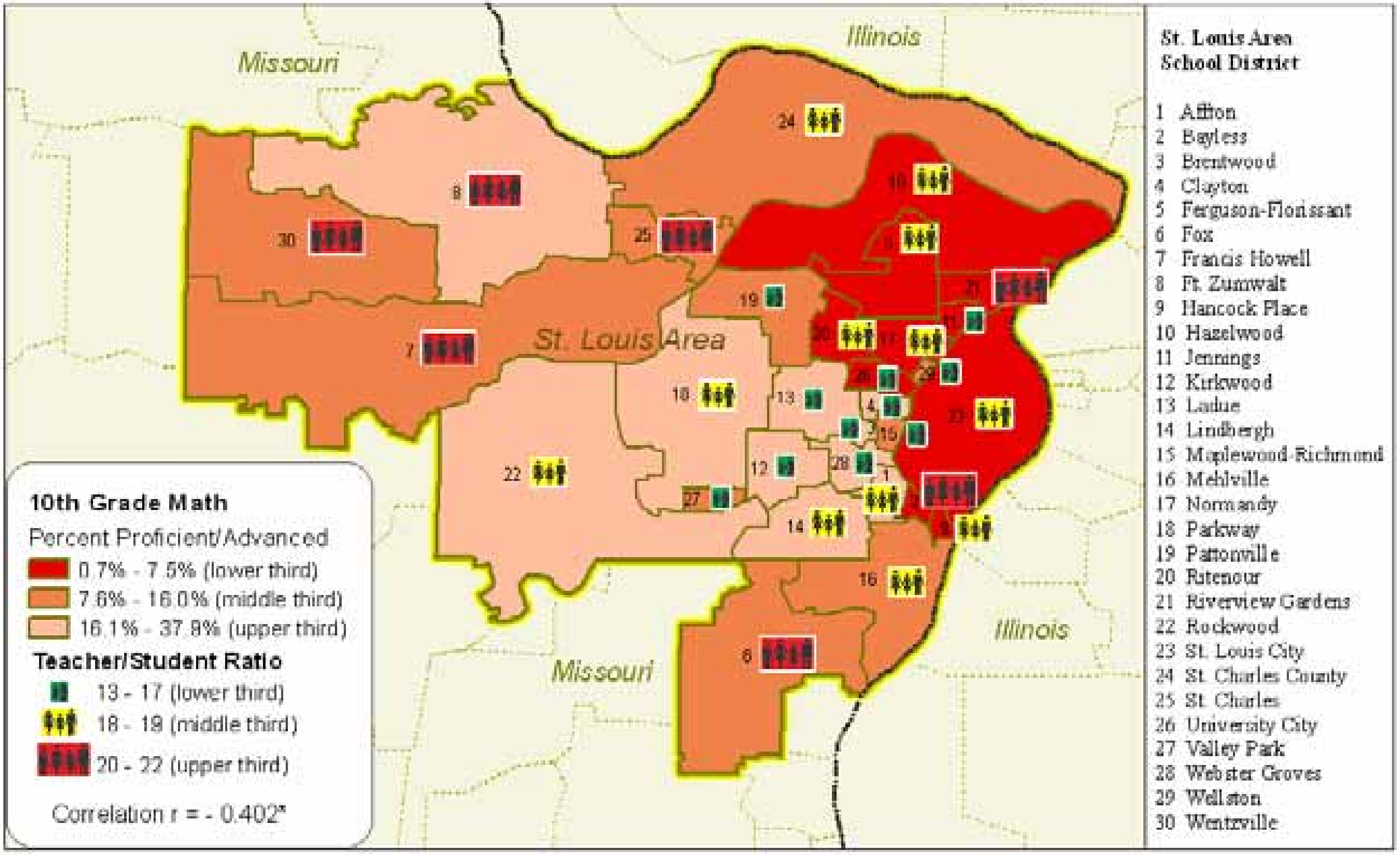


Figure 12. Teacher Education, Experience, Salary and Percent of Student Proficient/Advanced on Math MAP Test for Fourth Grade, by School District

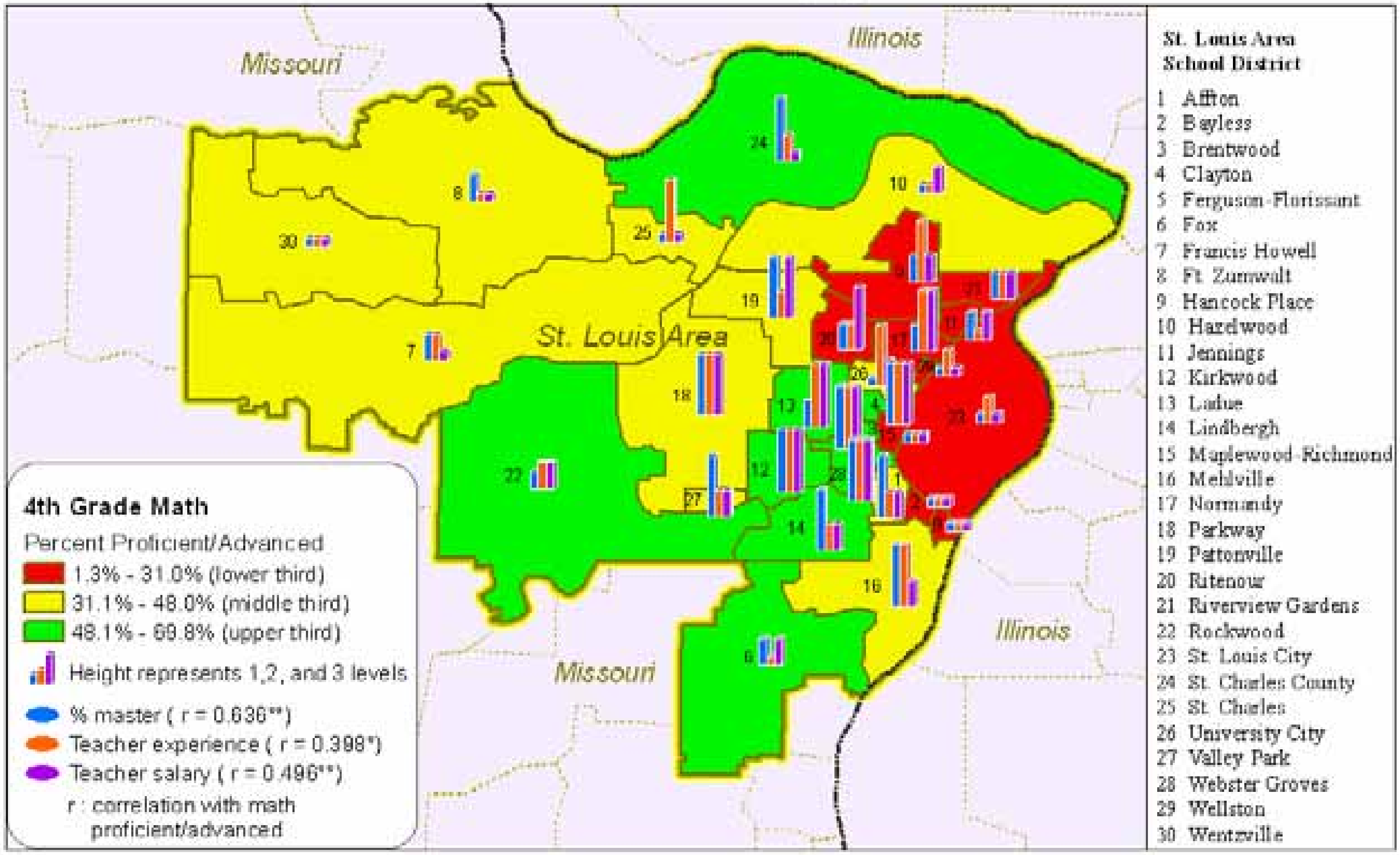
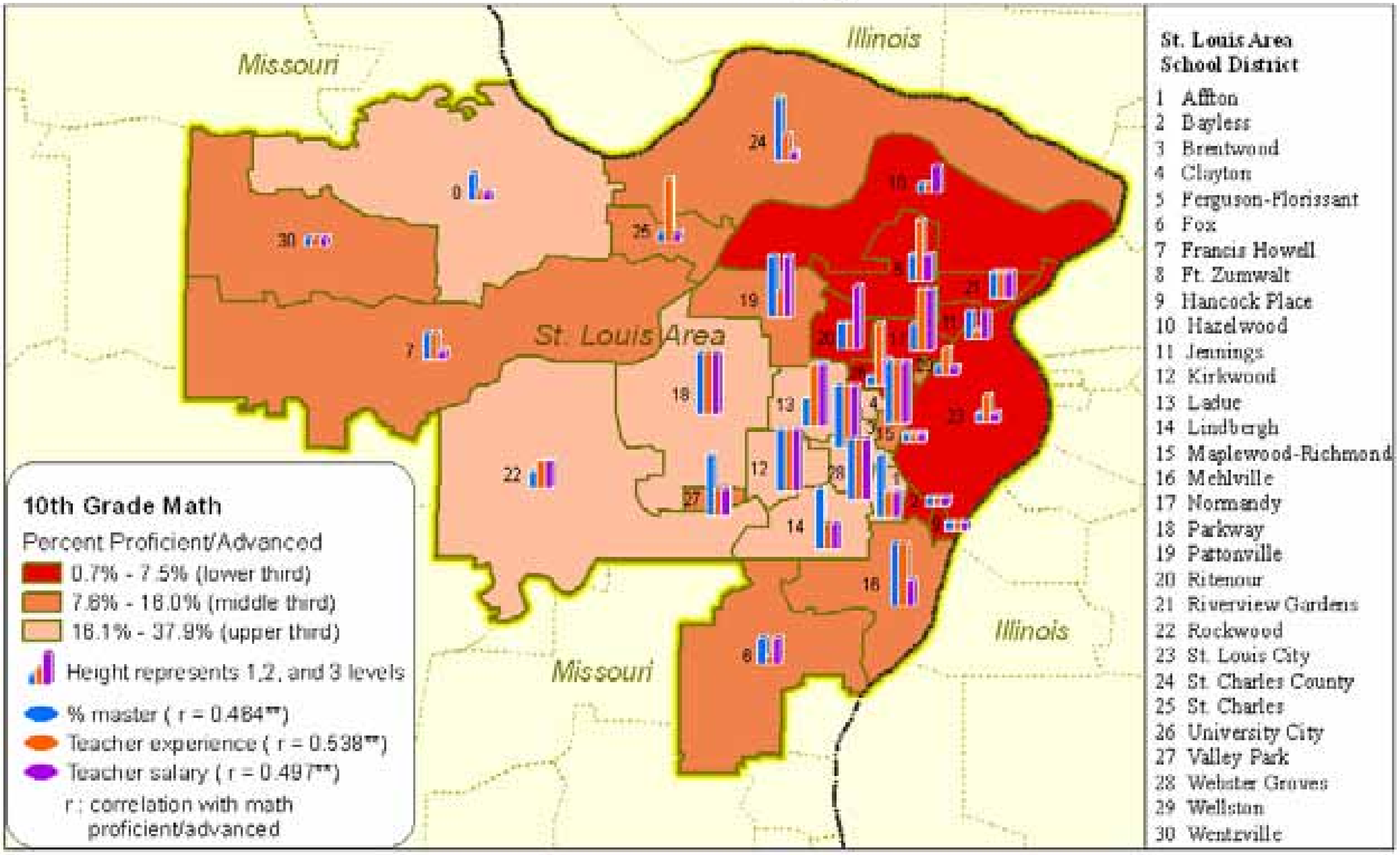


Figure 13. Teacher Education, Experience, Salary and Percent of Student Proficient/Advanced on Math MAP Test for Tenth Grade, by School District



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Authors

Mark Hogrebe, Ph.D.
Research Statistician
Center for Inquiry in Science Teaching and Learning
Department of Education
Washington University in St. Louis
Campus Box 1183
One Brookings Drive
St. Louis, MO 63130
314-935-9364
Fax: 314-935-6784
mhogrebe@wustl.edu

Lydia Kyei-Blankson, Ph.D.
Post doctoral Fellow
Center for Inquiry in Science Teaching and Learning
Department of Education
Washington University in St. Louis
One Brookings Drive
Campus Box 1183
St. Louis, MO 63130
314-935-4171
Fax: 314-935-6784
lkyeibla@artsci.wustl.edu

Li Zou, Ph.D.
Data Manager and GIS Analyst
Center for Inquiry in Science Teaching and Learning
Department of Education
Washington University in St. Louis
One Brookings Drive
Campus Box 1183
St. Louis, MO 63130
314-935-8832
Fax: 314-935-6784
LZou@artsci.wustl.edu