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SCIENCE EDUCATION IN THE UNITED STATES: A VIEW FROM PRE-COLLEGE CLASSROOMS

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ABSTRACT

A glimpse of pre-college science education in the United States, based on results selected from the National Survey of Science and Mathematics Education (NSSME), having implications for elementary and secondary science education and materials science education, is presented in this paper. Based on selected NSSME results reviewed, the condition of science, in pre-college classrooms in the United States is evidently mixed. The disparity in the median amount of dollars spent per pupil between the highest quartile and the lowest quartile of students eligible for Free or Reduced-Price Lunch (FRPL) raises equity concerns. However, an increase in the proportion of students eligible for FRPL taught by teachers historically under-represented in science is encouraging; Over 50% of classes in the highest quartile with a high proportion of FRPL students are less likely to be taught by teachers with a substantial science background, such as a degree or at least three advanced science courses compared to classes in the lowest quartile. Implications for Materials Science education are discussed.

Keywords: *Expenditure for teaching; Free or Reduced-Price Lunch; science; STEM; ethnicity and teaching; pre-college classroom; Materials education*

1. INTRODUCTION

We live in a world influenced by an information explosion, ubiquitous telecommunication technologies, and faster intercontinental transportation than ever before - due to unprecedented developments in science and its technological applications. Calls for a science-literate citizenry and a skilled work-force have been made by leaders in business and government. According to the “Pathways to Success” proposed by the Committee on STEM Education of the National Science and Technology Council of USA [1], priorities for education include building strong foundations for science literacy, and preparing a work-force having skills in science and technology and also in knowledge skills. Efforts to understand the condition of science education in U.S. pre-college (K-12) classrooms are timely and well worth pursuing.

2. METHODOLOGY

A review of (and analysis for) trends (if any) revealed by the National Survey of Science and Mathematics Education was undertaken for this paper, with implications for pre-college science education. The National Survey of Science and Mathematics Education (NSSME+) [2], involving school teachers and administrators, conducted by Horizon Research, Inc. is a reliable source of information for understanding the status of Science in U.S. pre-college classrooms. In addition to science, over the years, this survey has looked at Mathematics, and in 2018 added emphasis on Engineering and Computer Science in K-12 schools. The following discussion will review selected science items from the *Report of the 2018 NSSME+* [2], looking for trends, if any since the *Report of the 2012 National Survey of Science and Mathematics E*ducation [3], *Report of the 2000 National Survey of Science and Mathematics E*ducation [4], *Report of the 1993 National Survey of Science and Mathematics E*ducation [5], and, for identifying significance, the *2108 NSSME+: Trends in U.S. Science Education from 2012 to* 2018 [6], with implications for policy. A note should be made that the focus of this paper is primarily on pre-college education, mostly elementary and high school.

3. RESULTS

Outcomes of the review and analysis for trends of the science items from the results of the National Survey of Science and Mathematics Education listed above are discussed below.

3.1. Demographics

While 94% of elementary teachers are females and 6% males, at the high school level only 57% are females and 43% males. Compared to the NSSME 2012 survey there is no change at the elementary level, but at the high school level, the percent of male teachers and female teachers was 46% and 54%, respectively. In addition, when taking into consideration the percent of female science teachers at the high school level in 1993 (34%) and 2000 (50%) a trend in the closing of the gender gap and taking over by females is evident (Table 1).

Table 1. Elementary and High School Science Teachers by Gender (Data [2, 3, 4, 5, 7])

Grade	**Teacher Gender**	**1993**	**2000**	**2012**	**2018**
Elementary	**Male**	9	8	6	6
	Female	91	92	94	94
High	**Male**	66	50	46	38
	Female	34	50	54	62

The percentage of science teachers who are white dropped from 91% in 2012 to 88% in 2018 at the elementary level, and from 92% to 91% at the high school level (which was statistically significant) (Table 2). On the other hand, the percentage of science teachers who are African Americans increased from 5% to 8% at the elementary and 3% to 5% at the secondary school level. The percent of science teachers who were Hispanic/Latino increased from 8% in 2012 to 9% in 2018. At the elementary level, science teachers from groups that are Asian, and American Indian/Alaskan Native showed no change. At the high school level, there was an increase in Hispanic/Latino from 4% to 6% (statistically significant), Asian from 2% to 5% (statistically significant), and American Indian/ Alaskan Native from 0% to 2%.

Table 2. Percent of Elementary and High School Teachers by Ethnicity (Data [2, 3, 6])

Ethnic Group	Elementary		High	
	2012	2018	2012	2018
White	91	88	92*	91*
African American	5	8	3	5
Hispanic/Latino	8	9	4*	6*
Asian	2	2	2*	5*
American Indian/ Alaskan Native	1	1	0	2

*Note: *indicates a statistically significant difference between 2012 and 2018 [6].*

Another observation is an increase in the proportion of students eligible for Free or Reduced-Price Lunch (FRPL) in the highest quartile, taught by teachers from groups historically underrepresented in science, increased from 34% in 2012 to 42% in 2018. On the other hand, over all, 52% of classes in the highest quartile with a high proportion of FRPL students are less likely to be taught by teachers with a substantial science background in terms of having a degree or at least three advanced science courses, compared to classes in the lowest quartile (66%). This is an indication of an ongoing socio-economic divide in science education, - an issue needing immediate attention and constructive solutions.

3.2. Teaching Force

From 2012 to 2018, there was a negative trend in the percent of the science teaching force with undergraduate degrees in science education and Science/ Engineering/Science Education related fields at the elementary level; At the high school and middle school level, the trend was positive (Table 3).

Table 3. Science Teaching Force with Undergraduate Degrees at Elementary, Middle, and High School Level (Data [2, 3, 6])

Year	Percent Teachers with Undergraduate Degree								
	Science/Engineering			Science Education			Science/Engineering/ Science Education		
	Elem.	Middle*	High*	Elem.*	Middle*	High	Elem.	Middle*	High
2012	4	26	61	2	27	48	5	41	82
2018	3	42	79	1	36	57	3	54	91

*Note: *indicates a statistically significant difference between 2012 and 2018 [6].*

During 2012-2018, a drop in percent elementary teaching force with undergraduate degrees in science/engineering (4% to 3%), science education (2% to 1%, statistically significant), and science/engineering/science education (5% to 3%), and an increase in high school teachers with undergraduate degrees in science/ engineering (61% to 79%, statistically significant), science education (48% to 57%), and science/engineering/science education (82% to 91%) were noticed. There was also a statistically significant change in teaching force at the middle - school level in Science/Engineering (26% to 42%), science education (27% to 36%), and Science/Engineering or Science Education (41% to 54%). According to the American Association of Colleges of Teacher Education report based on U. S. Department of Education 2016 Title II Collection, elementary education (21%) remains the top most popular teacher education major and Science Education majors constitute only two percent in the United States [8].

3.3. Teacher Readiness

The 2018 survey showed that only 17% of elementary Science teachers and 46% of high school Science teachers developed the ability to engage in hands-on Science. These survey results are not encouraging, because, based on Science education research, especially at the elementary level, students need adequate hands-on experiences in Science to help them construct their knowledge structure. As teachers engage their students in doing science, they need to provide formative feedback by monitoring student understanding. Unfortunately, a negative trend was noticed at the elementary and high school levels in the percent of teachers who monitored student understanding during a lesson unit, from 46% to 33% (which was statistically significant) and 57% to 53% respectively. This item must be interpreted with caution since it is "related to instruction within a particular unit in a designated class," as reported in the 2018 survey report [3] (p. 38). Between 2012 and 2018, the percent of those who encouraged interest in Science and/or Engineering in students at the elementary level increased from 25% to 26%. It decreased from 53% to 43% among high school teachers. Considering nationwide efforts to realign Science education with competitive workforce readiness, we need teachers who are capable of teaching meaningful Science, engaging enough to create interest in Science fields among young learners.

With respect to official state standards, the percent of elementary teachers teaching to the standards dropped from 83% in 2012 to 79% in 2018, whereas at the high school level it increased from 81% to 84%. There is no immediate explanation why it might have dropped among elementary teachers, and whether this a short term trend or not. Based on the U. S. Department of Education *Secretary of Education's 10th Report on Teacher Quality* [9] only 30 states have set science standards for K-3 level, 32 states for 4-6 level and 43 states for high school level.

3.4. Per Pupil Expenditure

To engage students in hands-on Science, schools need laboratory equipment and consumable supplies. In high schools, there is a steady increase of approximately 33% in the median amount of dollars spent per pupil from $5.17 in year 2000 to $6.11 ($6.89) in 2012 and $6.88 ($6.75) in 2018. (Dollar value adjusted for inflation shown in parentheses.) The median amount of dollars spent per pupil per school at the elementary grades dropped 20% from $1.89 in year 2000 to $1.55 ($2.52) in 2012 and climbed back 28% to $1.98 in 2018.

In terms of schools eligible for FRPL, there is a disparity in the median amount of dollars spent per pupil between the highest quartile and the lowest quartile in 2018 and 2012 (Table 4).

Table 4. Free or Reduced Price Lunch (FRPL) Per Pupil Expenditure (Data [2, 3])

School Year	Median Amount (U.S. $) Spent Per Pupil Per FRPL Quartile	
	Highest Quartile (Adjusted for Inflation)	**Lowest Quartile** (Adjusted for Inflation)
2012	1.54	3.56
2018	2.05 (1.69)	5.62 (3.90)

Per pupil expenditure in 2018 in the highest quartile is $2.05 ($1.69) and lowest quartile $5.62 ($3.90) compared to 2012 where it is $1.54 and $3.56 respectively. Percent increase 33% (10%) in the highest quartile and 58% (10%) in the lowest quartile reveals a large socio-economic disparity that needs attention from stakeholders of education - if Science is truly a priority subject in U.S. schools as often touted by legislatures, leaders in business and government.

3.5. Time on Science

In self-contained elementary Science classes the average number of minutes per day spent teaching science differs considerably between K-3 and 4-6 grade levels and shows a steady decline since 1993. At K-3, an average 24 minutes per day was spent in 1993, 23 minutes in 2000, 19 minutes in 2012 and 18 minutes in 2018. At 4-6, an average 33 minutes in 1993, 31 minutes in 2000, 24 minutes in 2012, and 27 minutes in 2018. On an average 41 percent of class time was spent on “whole-class activities” involving discussions and lectures, 33 percent of class time was on “small groups work” and 18 percent of class time was on individual tasks such worksheets, reading and taking class tests at the elementary level in 2018.

3.6. Teacher Assigned Homework

Science homework assignments in high school classes that require two or more hours of student engagement per week is steadily decreasing from 14% in 2000, 9% in 2012, and 7% in 2018. In elementary classes, homework requiring 2 or more hours of student engagement remains at zero percent since 2000. Homework, especially at the elementary grades, has become a topic of controversy. For example, a meta-analysis by Cooper et al. [10] found that homework did not contribute to academic achievement. This is a complex issue and a fertile area for research in science education.

4. DISCUSSION AND IMPLICATIONS

The review of the National Survey of Science and Mathematics Education shows mixed results. Ever since the nineteen-fifties, and the launching of Sputnik by the then Soviet Union, there has been an increasing level of attention to Science in the U.S. school curriculum, but no concomitant level of support for Science education. The disparity in per-pupil expenditure between the highest and lowest quartiles of students eligible for Free or Reduced Price Lunch is discouraging. Science as a key component of pre-college education is of critical importance, and efforts to motivate students to study and comprehend Science still remain a challenge to teachers. As mentioned earlier, the median amount of dollars spent per pupil per school at the elementary grades decreased 20% from year 2000 to 2012 and increased 28% from 2012 to 2018, but when adjusted for inflation, dropped about ten percent in dollar value. It is quite disheartening to note that, starting in childhood, poverty has an adverse impact on the academic outcomes of school children [11]. A concerted effort by all stakeholders of education is greatly needed in order to address this chronic situation, which can adversely affect equity in the education of young children. Successful implementation of science education for all must remain a sincere objective of pre-college education.

We need to increase the number of teachers trained in Science at the elementary level. The same applies to Technology, Engineering, and Mathematics, where the training of teachers with adequate knowledge and teaching skills to deliver meaningful lessons is critical. Why candidates with qualifications in Science, Engineering and Science Education are moving away from elementary teaching force is an important question. In addition, considering the importance of Science learning experiences for the cognitive development of children at the primary school level, initiatives to develop strategies for reversing this negative trend by school districts, and teacher preparation programs are well overdue.

Teachers are key to Science classroom reform. Teacher education should provide prospective teachers with appropriate opportunities to discuss and develop cognitively engaging and motivating methods of teaching Science. Classroom teachers need suitable curriculum resources to facilitate the implementation of engaging and meaningful teaching and learning strategies. Both pre-service teacher education curriculum and in-service teacher development programs should address innovative teaching methods as well as learning skills for pre-college Science education, and the role of teacher education faculty, local school administrators and policy makers on this task is significant.

Although the gender gap is narrowing in the secondary Science teaching force, at present the size of this gap in Science education is unknown. The share of under-represented minorities in the Science teaching force at the elementary and high school levels has increased, indicating cautious optimism for more minority teachers in the science teaching force.

Another encouraging trend is an increase in the number of Science teachers from under-represented minorities teaching students in the highest quartile eligible for FRPL. But a discouraging trend is that more than fifty percent of highest quartile FRPL students are less likely to be taught by teachers with an adequate Science background. This means that there is a high possibility, that this socio-economic divide will increase when it comes to teachers qualified to teach Science integrated with Technology, Engineering and/or Mathematics with sufficient coursework and training in Science, Technology, Engineering and Mathematics, and the associated pedagogy to integrate these disciplines.

Recognizing that quality of teachers is the most influential schooling factor impacting student learning, and in order to ensure a robust supply of demographically diverse, high-quality Science teachers into pre-college classrooms across the country, the National Science Foundation Robert Noyce Teacher Scholarship program provides support for training teachers of Science, Technology, Engineering and Mathematics (STEM) to teach, specifically in high-need districts [12, 13]. According to the National Science Foundation [14], a high-need school district as defined in "Section 201 of the Higher Education Act of 1965 (20 U.S.C. 1021):

- has at least one school in which 50% or more of the enrolled students are eligible for participation in the free and reduced price lunch program;
- has at least one school in which - more than 34% of the academic classroom teachers at the secondary level (across all academic subjects) do not have an undergraduate degree with a major or minor in, or a graduate degree in, the academic field in which they teach the largest percentage of their classes; or more than 34% of the teachers in two of the academic departments do not have an undergraduate degree with a major or minor in, or a graduate degree in, the academic field in which they teach the largest percentage of their classes;
- has at least one school whose teacher attrition rate has been 15 percent or more over the last three school years." (n.p.)

In this situation, it is evidently necessary to diversify teacher demographics as teachers are prepared to teach in high-need schools.

The results of an inventory of selected NSF funded Robert Noyce teacher education programs [15] in four public universities in Texas and Florida would highlight teacher development, and particularly the importance of change in demographics. In the beginning, there were 267 scholars with the following distribution by demographics: Whites 47.2%, Hispanics/Latinos 31.1%, Asians 9.7%, African-Americans 9.4%, and Native Americans or other ethnicities 2.6%. By gender, 61.4% females, and 38.6% males. Of the 236 scholars who graduated or remain in the program, Whites 49.1%, Hispanics/Latinos 31.3%, Asians 8.5%, African-Americans 8.5%, and other ethnicities 2.6%. The percentage of leavers within each ethnicity follows: Whites 8%, Hispanics/Latino 11%, African Americans 20%, and Asians 23%, The only Native American scholar left the program. All scholars of the other ethnicities remained in the program.

Based on the NSSME results reviewed, a socio-economic disparity is evident in the amount of dollars spent per pupil between the highest quartile and lowest quartile among FRPL student groups in Science classes. The enormity of this problem is unimaginable in similar classes where Technology, Engineering, and Mathematics disciplines come into play when integrated with Science needing considerable funds. For example, classes implementing Robotics to teach Science in an integrated way will cost more in terms of materials, facilities and teacher training. It is a known fact that teachers spend their own money every year on school supplies. According to a report by the U.S. Department of Education [16], on average, a public school teacher spends $479 of his/her money on classroom supplies. Noticeably "a higher percentage of teachers of elementary grade levels (95% percent) spent their own money on classroom supplies than teachers of secondary grades (93% percent)" (p. 1). This does not minimize the responsibility of school administrators, school board members, and legislators to assuring that science classrooms are adequately funded to deliver engaging science lessons.

The amount of time spent per day in K-3 grades decreased 33% from 1993 to 2018. A similar trend, but a decline of 14%, is evident in grades 4-6. If this is the situation with time spent on Science education, will there be enough time to teach Science as an integrated curriculum? This is an important question. In the absence of survey information on the amount of time spent exclusively on hands-on Science activities, it is assumed that it was not a priority, due to a lack of adequate resources such as equipment, consumables, and especially Science-qualified teachers. Hopefully, a sufficient amount of time will be dedicated to teaching Science education through including hands-on lessons if twenty-first century global workforce skills are to be developed through Science education. Lan [17] calls for giving students the time and space they need to engage in Science activities and explore by themselves. Research in Science education shows that students receiving quality Science instruction early on in schools have a higher possibility of pursuing higher education and careers in Science and related fields [18]. So, we must plan a sufficient amount of time to teach hands-on Science in the elementary grades - without compromising the same at higher-grade levels.

In the context of the selected NSSME results reviewed and analyzed in this paper, the following note with regard to Materials Science education is made. Pre-college Science disciplines Chemistry, Physics and Biology, along with Mathematics and Engineering form the pillars of the field of Materials Science, and also its branches Nanoscience and Nanotechnology. However, during the review and analysis, a lack of information on the status of Materials Science education implementation in pre-college classrooms was noticed. A plethora of funded and non-funded activities at the college as well as pre-college levels, in curriculum developments and teacher workshops in Materials Science education, especially in Nanoscience and Nano-technology education is reported in the literature [19]. The US National Science Foundation funded report *The Future of Materials Science and Materials Engineering Education* [20] recommended that "existing K-12 MSME curricula should be assessed to determine their effectiveness, barriers to adoption and use, and means to overcome those barriers" (p. 29), but fell short of calling for a status study of Materials Science education in pre-college classrooms.

A national level study of the status of Materials Science education in pre-college classrooms is overdue. Results of a thoughtfully developed and implemented status study will enable policy makers, educators, and administrators, to make informed decisions in curriculum development, implementation, teacher education, and allocation of fiscal and materials resources essential for successful implementation of Materials education in pre-college Science classrooms.

5. SUMMARY

In summary, the condition of pre-college education as viewed from U.S. pre-college science classrooms, based on selected NSSME results reviewed and discussed in this paper is not very encouraging. Qualified human resources, suitable curriculum and instructional material resources, generous fiscal resources, in addition to effective policies to address equity concerns affecting students eligible for FRPL are critical to the successful implementation of science education in U.S. pre-college classrooms. Similarly to the NSSME survey, a status study of Materials Science education in pre-college classrooms is recommended.

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