Adding Up STEM Qualifications

An Intervention Analysis of Common Core’s Effectiveness on High School Readiness for STEM

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Abstract

The United States has an increasing need for workforce talent with an educational background in STEM, and the Common Core State Standards initiative was one of the many initiatives implemented to rectify the issue. An intervention analysis was conducted over time by measuring inbound high school senior’s average mathematical SAT score on a yearly basis across major groups, and measuring whether Common Core significantly increased or decreased a student’s higher education mathematical potential. The data is for the state of New York, which is provided by the College Board. Three separate time series analyses were conducted between 1998 and 2016: All New York, STEM-related degrees, and non STEM-related degrees. Each data set was fit with a time series structure, and forecasted values post Common Core standard implementation were compared to the actual values using Wilcoxon tests. Statistically significant results were not found. No significantly positive or negative effects on average mathematical SAT performance were found as a result of implementing Common Core State Standards.

*Keywords:* STEM, Common Core, Intervention Analysis, SAT

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The workforce of the United States, within the near future, will be facing struggles related to continuous automation of jobs that have previously existed for decades, as well as a need for repurposing workers to have the skillset for handling these technological workplace needs. These advancements and innovations in the technological sphere are resulting in an increased need for workers with experience in Science, Technology, Engineering, and Mathematics within their educational background, or “STEM” abbreviated. Based on multiple sources, the need for these skills has been growing, and will continue to exponentially grow throughout the next few decades. According to Noonan (2017) with the Economics and Statistics Administration, “Employment in STEM occupations grew much faster than employment in non-STEM occupations over the last decade (24.4 percent versus 4.0 percent, respectively), and STEM occupations are projected to grow by 8.9 percent from 2014 to 2024, compared to 6.4 percent growth for non-STEM occupations.” As the population of the United States continues to advance technologically, the population will need to be appropriately prepared to handle these STEM-heavy positions in the future.

However, there is a genuine concern that the talent pool feeding the workforce may not have an adequate skillset in STEM-related fields. According to the U.S. Department of Education, “few American students pursue expertise in STEM fields—and we have an inadequate pipeline of teachers skilled in those subjects.” The Department of Education further elaborates that “not enough of our youth have access to quality STEM learning opportunities and too few students see these disciplines as springboards for their careers” (“Science, technology, engineering, and math,” n.d.). There have been a variety of initiatives done at both smaller and larger scales to encourage students to pursue these kinds of learning opportunities, with one such initiative being the Common Core State Standards Initiative. Common Core standards are “designed to ensure students are prepared for today’s entry-level careers, freshman-level college courses, and workforce training programs” through “developing the critical-thinking, problem-solving, and analytical skills students will need to be successful,” according to the Common Core State Standards Initiative (n.d.). Common Core standards were implemented for english and mathematics courses in a large portion of participating states in 2013, in which the timing aligns with the Five Year STEM Strategic Plan by President Barack Obama. According to this plan, “maintaining America’s historical preeminence in the STEM fields will require a concerted and inclusive effort to ensure that the STEM workforce is equipped with the skills and training needed to excel in these fields” (“Federal science, technology, engineering, and mathematics (STEM) education 5-year strategic plan,” 2013). This strategic plan, as well as implementation of Common Core standards, was a direct influence of President Obama’s Race to the Top initiative, which “helped drive states nationwide to pursue higher standards, improve teacher effectiveness, use data effectively in the classroom, and adopt new strategies to help struggling schools” (“Race to the top,” n.d.).

Common Core standards, as well as the initiatives developed by President Barack Obama, have met controversy despite the positive goals promoted for education in the United States. According to Diane Ravitch (2016) from New York University, “the pursuit of a national curriculum is yet another excuse to avoid making serious efforts to reduce the main causes of low student achievement,” citing that poverty could largely be indicative of a student’s ability to succeed. Furthermore, states such as Oklahoma and Indiana have repealed the implementation of Common Core standards; NPR interviewed Oklahoma teachers after Common Core was repealed in the state, and concluded that “Even after the state spent hundreds of thousands of dollars on the Core rollout, teachers said they needed more training, more materials and more help” (Turner, 2014). Considering the success of Common Core standards alone is controversial, some argue that Common Core standards in relation to STEM is even more controversial. James Milgram and Sandra Stotsky (2013), professors of Mathematics and Education respectively, explain that “not one state board or department of education is on record as having sought (and obtained) the collective opinion of their own state’s higher education teaching faculty in mathematics, science, and engineering” when developing Common Core standards, and no “precalculus material appears in Common Core’s final mathematics standards.”

The SAT examination is currently utilized to test reading, writing, and math proficiency required for entry into most four year higher education institutions, as well as more selective STEM-related degrees. The College Board, who hosts the SAT examination, explains that “the SAT is an opportunity for students to show colleges they’ve got what it takes to succeed on campus” (“Content alignment,” n.d.). Each year the examination is conducted, the College Board creates a report of data including exhibits of intended majors for college-bound senior students, as well as the average scores for all areas of the examination within these major groups. Within the data available, the need for future STEM workers in the workforce can be measured by examining mathematics performance within intended STEM-related majors and non STEM-related majors specifically for proficiency, as well as overall aptitude within any intended major to handle the future workforce challenges that require STEM education. Furthermore, with total reports of data from the College Board on a yearly basis, an analysis can be done over time to see if the implementation of Common Core positively or negatively affected in-bound college student performance on the mathematics portion of the SAT.

The overall aim of this study is to analyze whether the implementation of Common Core standards had any effect on the average SAT mathematics score over time for inbound seniors in general, as well as inbound seniors looking to pursue either a STEM-related or non STEM-related college degree. Given President Obama’s Five Year Strategic Plan for improving society’s STEM workforce, the following time series analyses will show the nation’s future trajectory toward this goal, and if the mathematical skillset of college-bound seniors is at a higher level to pursue these future jobs society will require. The null hypothesis, or the hypothesis assumed to be correct unless proven otherwise, is that Common Core standards do not significantly change the average mathematical SAT score. The alternative hypothesis, or the hypothesis to accept if there are statistical numbers to support it, is that Common Core standards do significantly change the average mathematical SAT score.

**Method**

Data for this study was obtained from the College Board’s archived data, which is in PDF form through the College Board’s Research website (“Archived SAT data,” n.d.). Archived data was pulled for years 1998 to 2016 for college-bound seniors, and was pulled for the state of New York (Appendix A). New York was selected for this study for many reasons, including:

* New York features the 1st largest metropolitan city in the United States (“Largest cities in the United States by population,” n.d.).
* New York is the second most demographically similar state to the United States, according to demographics from the American Community Survey (Kolko, 2016).
* New York students favor taking the SAT, increasing the likelihood of larger amounts of available data (Saget, 2013).
* The state of New York’s college-going rate is 69.3%, which is a higher percentage compared to the rest of the country, meaning a larger sample size of students would be captured (“College-going rates of high school graduates,” n.d.).

Each PDF for New York was exported to Excel, in which all values for in-bound student numbers and mathematical scores in Excel were validated against the original PDFs from the College Board. Years 2007 through 2016 featured 38 records of major groupings, and years 1998 through 2006 featured 23 records of major groupings (Appendix B). Names of all major groupings were adjusted for spelling and consistency across years, and a column indicating the year was added. All together, with data from all years, there were 587 lines of data. Different students were measured within major groupings each year data was collected.

Each major group was objectively classified as STEM-related or non STEM-related by utilizing online major requirements from large universities, with Arizona State University as the primary resource. Courses required for majors within each grouping were explored, and major groupings where the majority of degrees required higher than a basic mathematical course (Calculus and above) were signified as STEM-related degrees (Appendix C).

A weighted mean was utilized to calculate the average mathematical SAT score per year in each data set. Each major in each year has an average mathematical SAT score in the data set already, but an average between majors alone cannot be used because each major has a different number of students. The number of students in a major plays a role in how much that score will affect the average. A weighted mean, therefore, allows the calculation to give more weight to majors with larger numbers of students. To do this for a single calendar year, the number of students in a major is multiplied by the average mathematical SAT score in a major. After this is done for each major, these values are added together and divided by the total number of students in that single calendar year. Resulting tables with mean scores per calendar year will be used to obtain numerical results (Appendix D).

The research questions being examined through this study are as follows:

* Does the implementation of Common Core in 2013 significantly change the average SAT score over time?
* Does the implementation of Common Core in 2013 significantly change the average SAT score within STEM-related majors over time?
* Does the implementation of Common Core in 2013 significantly change the average SAT score within STEM-related majors over time?

To address these three research questions, three different sets of data will be analyzed: All Data Available, STEM-related majors only, and non STEM-related majors only. Because the data from the College Board is a sample of a wider audience of students going to college, samples will not be taken within this data set.

An intervention analysis is an examination in how a change in policy can change the outcome of what is being measured over time (if at all). In this study, the intervention is the implementation of Common Core standards in 2013, and the average mathematical SAT score is what is being measured over time. In simplest terms, numbers are being analyzed to compare mathematical SAT scores before and after Common Core standards were implemented. The intervention analysis in this study was conducted through R Studio, which is a statistical programming software (Appendix E). Intervention analysis entails the following procedures:

* Observe and interpret time series plots.
* Fit time series structure to data before Common Core was implemented.
* Forecast predictions for average mathematical SAT score from 2013 to 2016, and compare to actual average mathematical SAT scores.
* Conduct a statistical test to see if there is a statistically significant difference between forecasted and actual values between 2013 and 2016.

**Results**

Each data set was imported into R studio and plotted to obtain initial information on patterns over time (Appendix F). Generally speaking, non STEM-related degrees did not display a positive or negative trend in terms of average mathematical SAT score after the implementation of Common Core standards. STEM related degrees displayed a positive trend in average mathematical SAT performance after the implementation of Common Core standards, as well as all data in the state of New York.

In order to conduct an intervention analysis, each of the three data sets were fitted with a time series structure prior to the Common Core standards intervention in 2013. A time series structure is a numeric model in which different methods of using past data assist in predicting future data values. Two particular components were fit to the three datasets, called autoregressive (AR) and moving average (MA) models. An autoregressive (AR) model uses a linear pattern in which a present value is predicted using a prior value in time, and this exact pattern applies to all values over time. A moving average (MA) model uses a linear pattern of past error values (or “white noise”) to predict future values. For both AR and MA models, the lag value indicates the specific prior values to use in order to calculate the present value. A time series structure might include one or both of these components, and may contain these components seasonally or non-seasonally. Using a variety of diagnostics (Appendix G-I), as well as testing a variety of different models, time series structures were successfully fit to each data set. The conclusion was that all New York data was fit with an MA component (lag 1), data for STEM-related majors was fit with an MA component (lag 1), and data for non STEM-related majors was fit with an AR component (lag 1) and an MA component (lag 2).

The data being fit with time series structures allows for forecasting average mathematical SAT scores after the implementation of Common Core standards in 2013 (Appendix J). The forecasted values for all New York Data and STEM-related degrees were found to have a similarly steady trend in its forecasted values for average mathematical SAT score, as both data sets were fit with an MA model with 1 lag. The forecasted values for STEM-related degrees had variation in the average mathematical SAT score’s movement over time, as the predicted values in red did not steadily increase or decrease. Forecasted values between 2013 and 2016 were then averaged and subtracted from the actual average between years 2013 and 2016 for comparison (Appendix K). The following conclusions can be interpreted from this calculation:

* Within the entire New York data set, students on average performed about 1.7 points better each year than what would have been forecasted as their performance.
* Students intending to pursue a STEM-related major, on average, performed about 4.1 points better each year than what would have been forecasted as their performance.
* Students intending to pursue a non STEM-related major, on average, performed about 2.1 points worse each year than what would have been forecasted as their performance.

While statistical significance was not tested thus far, there does not appear to be vast differences between the mean differences in actual versus predicted mathematical SAT scores.

With forecasted values obtained and stored for each of the three data sets from 2013 to 2016, assumptions were then tested to conduct a paired t test against the actual average mathematical SAT scores for these years, which is a statistical test to verify if two populations show significant differences between each other. However, because years 2013 to 2016 equated to only four observations to compare, the t test was not a satisfactory way to compare these populations. Furthermore, when testing these observations for normality, none of the observations for all three data sets followed a normal distribution. Normality means the values collected follow the shape of a bell curve if graphed into a histogram, and is required for a paired t test to give reliable results. Assumptions for normality and paired t tests were run, although the results will not be used to determine statistical conclusions in this study (Appendix L).

Because the sample sizes of this intervention analysis were small, the Wilcoxon test was conducted for each of the three data sets to test for statistical significance (Appendix M). The significance level was set at α=.05, which is standard number chosen for statistical studies; this value equates to 95% confidence that the analysis outcome is statistically correct. All output of the Wilcoxon signed rank test shows a p value greater than .05; the p values from the Wilcoxon test would need to be less than .05 to be statistically significant. Therefore, the null hypothesis was not rejected, and the conclusion of this study is that Common Core standards did not significantly change the average mathematical SAT score within the entire data set, STEM-related degrees, or non STEM-related degrees. This analysis did not have statistically significant results, and did not indicate positive or negative effects on average mathematical SAT performance as a result of implementing Common Core Standards.

**Discussion**

With the conclusion of the intervention analysis being that there is no statistically significant evidence of Common Core having a positive or negative effect on average mathematical SAT performance, this could have positive or negative ramifications on the interpretation of education’s goal of preparing for a future work force with more STEM qualifications necessary for society to thrive. On one hand, it is a reassurance that the funding toward Common Core has not had a negative impact on students, and that there does appear to be a minimal positive trend in SAT mathematical performance for in bound seniors planning to pursue STEM-related degrees. However, it is not reassuring to know that there are no positive changes as a result of the funding and difficulties with changing the curriculum in many states of the country. Furthermore, the results of this study show that more needs to be done in regards to improving the mathematical performance of students who are not planning to pursue STEM degrees, as the population of potential candidates to handle these future jobs with a higher education degree in STEM needs to grow.

There are some limitations to the intervention analysis conducted in this research. For one, this study measures what students are intending to major in upon beginning their higher education careers, rather than what degree they graduate with. One could argue that measuring the intention to major in a STEM-related degree is not preferred compared to measure those graduating with one, yet analyzing in-bound seniors allows for analysis in how prepared students would be given that they pursued a STEM degree in full. Furthermore, because this data was collected from the College Board directory, there was no opportunity to make this a controlled experimental study to narrow down potential causation in regards to the contributing factors of success and failure for a mathematical SAT score. If a similar study were reproduced in the future, it would be useful to control for qualities such as: Socioeconomic class, Title I School (or not), gender, race, suburban/metropolitan living, public/private/charter school, and ESL (English as a second language) students. Furthermore, with this data collected over time, perhaps some sort of generalized linear model could eventually be created to predict a student’s propensity for success on the mathematical portion of the SAT. This way, an analysis could analyze a student’s potential for success in STEM regardless of their intention to pursue a STEM-related degree.

Furthermore, if a similar study were conducted in the future, substantial results might be found with more granular and detailed data. While data with major groupings was appropriate for time series analysis, having all demographic information available for each in bound senior student taking the SAT could provide more information. For one, having specific major information for each student would allow our classification of a STEM-related degree to be more precise, rather than labeling an entire group as “STEM-related degrees” or “non STEM-related degrees”. Furthermore, analyzing the effects of Common Core standards may require more time in order to gauge whether or not the standards are having a statistically significant effect on the success of students. By collecting more years and having newer data available over time, a more conclusive answer on a student’s ability to handle the challenges of a STEM-related degree based on their mathematical SAT score could hopefully be captured.

If more resources were available, an analysis between states would provide the most pertinent information. New York was selected for this study due to its demographic similarity to the United States as a whole, yet there could be bias with only using one state’s data due to differing popularity in the SAT and ACT across states. Furthermore, it might be worth doing an analysis on ACT mathematical scores versus SAT scores within each state, while also keeping in mind each state’s preference for one exam or the other.

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References

Archived SAT data (n.d.). *The College Board.* Retrieved from https://research.collegeboard.org/programs/sat/data/archived

College-going rates of high school graduates – Directly from high school. (n.d.). *The National Center for Higher Education Management Systems.* Retrieved from http://www.higheredinfo.org/dbrowser/index.php?measure=32

Content alignment. (n.d.). *The College Board.* Retrieved from https://collegereadiness.collegeboard.org/about/alignment

Federal science, technology, engineering, and mathematics (STEM) education 5-year strategic plan: A report from the committee on STEM education. (2013, May). *Executive Office of the President of the United States.* Retrieved from https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/stem\_stratplan\_2013.pdf

Kolko, J. (2016, April 28). ‘Normal america’ is not a small town of white people. *Five Thirty Eight.* Retrieved from https://fivethirtyeight.com/features/normal-america-is-not-a-small-town-of-white-people/

Largest cities in the United States by population. (n.d.). *Ballotpedia.* Retrieved from https://ballotpedia.org/Largest\_cities\_in\_the\_United\_States\_by\_population

Milgram, J.R., & Stotsky, S. (2013, September) Lowering the bar: How common core math fails to prepare high school students for STEM. *Pioneer Institute.* Retrieved from http://pioneerinstitute.org/download/lowering-the-bar-how-common-core-math-fails-to-prepare-high-school-students-for-stem/

Noonan, R. (2017, March 30). STEM jobs: 2017 update. *U.S. Department of Commerce.* Retrieved from http://www.esa.doc.gov/sites/default/files/stem-jobs-2017-update.pdf

Paiz, J., Angeli, E., Wagner, J., Lawrick, E., Moore, K., Anderson, M., Keck, R. (2010, May 5). General format. Retrieved from http://owl.english.purdue.edu/owl/resource/560/01/

Race to the top. (n.d.). *The White House Barack Obama*. Retrieved from https://obamawhitehouse.archives.gov/issues/education/k-12/race-to-the-top

Ravitch, D. (2016, July 23). The common core costs billions and hurts students. *The New York Times.* Retrieved from https://www.nytimes.com/2016/07/24/opinion/sunday/the-common-core-costs-billions-and-hurts-students.html

Saget, B. (2013). Where the SAT and ACT dominate. *The New York Times.* Retrieved from https://archive.nytimes.com/www.nytimes.com/interactive/2013/08/04/education/edlife/where-the-sat-and-act-dominate.html

Science, technology, engineering, and math: Education for global leadership. (n.d.). *U.S. Department of Education.* Retrieved from https://www.ed.gov/stem

Turner, C. (2014, December 30). Common core repeal, the day after. *National Public Ratio.* Retrieved from https://www.npr.org/sections/ed/2014/12/30/371654882/common-core-repeal-the-day-after

What parents should know. (n.d.). *Common Core State Standards Initiative.* Retrieved from http://www.corestandards.org/what-parents-should-know/