

## **LEAN SIX SIGMA FOR MITIGATING HIGH SCHOOL DROPOUTS**

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### **Abstract**

In the United States, there is a need for smart cities to help manage an ever-growing population. The enhancement of smart cities will further require an educated and skilled workforce. Government officials take the lion's share in managing the education system in a manner that students leave high school with the skills and knowledge to be successful in post-secondary education or in a technical school. This study focused on dropout rates in selected high schools in Hamilton County, Tennessee. Lean Six Sigma's DMAIC was used so as to provide a unique and repeatable study framework. Data in the form of graduation rates and enrollment numbers were first collected and analyzed using Minitab. The initial data analysis was followed by further investigation based on a survey questionnaire distributed to high school teachers, which resulted in determining the root causes of the dropout rates. The results of the survey indicated that poor reading skills played a significant role, leading to higher dropout rates. The academic performance of high school students is oftentimes tied to how they performed while in elementary school. The students who struggled in their elementary education have a higher risk of dropping out of school even before reaching their senior year. Ensuring increased economic and societal advantages for future high school graduates demands an integrated approach that mitigates the root causes of dropout rates.

### **Keywords**

DMAIC, Dropout Rates, Lean Six Sigma, Secondary Education, Socioeconomic Perspectives

### **Introduction and Literature Review**

According to the 2018 PISA (Program for International Student Assessment), which is a series of tests centered on three main domains: science, reading, and math and has become the world's most influential education study, students from China came in first place while students from the U.S. came in tenth. All students need to be performing at higher levels in math, science and reading to compete in the technical world we live in today. In the United States many high school students graduate each year without the skills they need to function in the world outside the classroom. If this trend is allowed to continue, the United States will not have the educated workforce that is required for the management and function of its many smart cities and for the overall success in a technological driven world.

Moreover, it should be emphasized that good education is interlinked with good health (Freudenberg & Ruglis, 2007). Disparities in high school education caused by dropouts can adversely affect the future workforce and the enrollment in colleges and universities. Hence, high school dropout is a problem that needs to be noted, prioritized, and addressed with an integrated approach involving all stakeholders, including but not limited to local and federal government agencies and educators.

According to the U.S. Constitution, it is primarily the State and local government's responsibility to ensure that citizens receive an education. States and local communities establish schools, develop curricula, and determine requirements for enrollment and graduation. Curriculum is based around individual state's content standards. Standards are created based around students' individual needs, differing abilities and interests, as well as their social and prior experiences. Federal and state policies have shown to have both limits and potential for determining how

students are educated. Local communities also have a lot to do with policy and policy has much to do with how resources will be allocated. Policy also dictates what is a good education and how a good education can be best achieved (National Academic Press, 1997). The United States Department of Education (USDE) since its creation in 1867, has been gathering information on teaching and how the States can establish effective school systems. This gathering of information on what constitutes educational success and passing this information on to teachers and educational policymakers continues and has expanded over the last 130 years (USDE, 2021). Policy making and funding of education has great implications on the success of an effective classroom.

A strong economy has been the backbone that the United States was built upon. The inventions and innovations of the people who settled this nation were a major contributing factor to a productive economy. Today, various engineering, technological, and mathematical innovations continue to advance and grow the economy including in smart cities. The workforce's job qualifications have changed as well; many require specific academics and/or training. Thus, many of the advancing smart city innovations now require academia to adjust how they educate and prepare students prior to graduating.

Student performance in the classroom is oftentimes determined by how they performed at earlier grade levels. Many students drop out of school prior to even reaching their senior year. Students are required to read in every subject they take while in school. Educators observe the common trend that students who cannot read at their grade level struggle in many of their classes. Students facing this problem will eventually be considered at-risk students; meaning there is a higher possibility of these students failing, dropping out of school, and never graduating.

Although it won't be possible to answer them all within the scope of this paper, it is crucial to ask the following questions and pave the way for further emphasize on the problem of dropout. What do these students do when they do attend classes? Are these students able to perform on the same level as their peers? Are these students causing discipline issues while in class and preventing teaching and learning from taking place? Are these students motivated to learn? What happens to those students who become high school dropouts? It has been reported that students who drop out of school may go on to commit crimes, become incarcerated, have children out of wedlock, or continue to work in low-paying jobs. Government officials and administrators have been aware of these issues, but a solution has yet to be found. Hence, high school dropout is a severe problem that may hinder the advancement of smart cities. Without a skilled local workforce, how can the social infrastructures, physical infrastructures, economic infrastructures, and institutional infrastructures be sustained?

Students dropping out of high school is not just a contemporary issue. There have been numerous studies conducted on this subject, but a single consistently leading cause has not been identified as the causes can vary locally, for example, from one county to the other or even from one state to the other. Several of the studies that have been completed that support the idea that a student dropping out of high school is more a process than it is just a single event. Long-term studies of the first twenty years of a student's life shed light on the role of early family situations and school experiences that can contribute to the placement of a student in the category of at-risk for becoming a high school dropout. Some of the root causes may have begun even before a student began their very first year of school. Oftentimes, issues that began prior to a student starting their academic career are developmental due to physical or mental ailments (Dupéré, Leventhal, Crornoe, Archambault, & Janosz 2015).

Adverse Childhood Experiences (ACEs) or potentially traumatic events during a student's childhood are directly linked to increased risk of the student becoming a high school dropout. There is an indirect effect between poor reading levels and externalizing behaviors - disobeying rules, physical aggression, and threatening others - are some examples (Morrow & Villodas, 2018). The status of parents tends to be one of the highest indicators of dropout rates among high school students. Parents' income and educational level as well as job prestige have been shown to have both direct and indirect effects on later educational levels for students. Higher parental involvement has proven to be a key factor in keeping students in school, but parenting style played an even bigger role. Having a lower socioeconomic position and social relations, and not completing a secondary education increased the risk of a student leaving high school by 3-fold compared to students whose families were living among the highest socioeconomic positions (Winding & Andersen, 2015). Student-teacher relationships have also been shown to serve as a deterrent to students dropping out of school. For instance, it is indicated that students of knowledgeable teachers have gained stronger word reading skills (Piasta, Connor, Fishman, & Morrison, 2009).

The remainder of this paper is arranged as follows. First, the importance and applications of Lean, Six Sigma, and Lean Six Sigma are presented in the Methods and Materials section where the roadmap of this study is depicted. Second, the data obtained from various sources are analyzed and discussed in the Results and Discussion section. The Conclusions section summarizes the key findings of this study and outlines recommendations and decisions relevant to decision makers. Finally, the Future Research section describes directions for continuing this research.

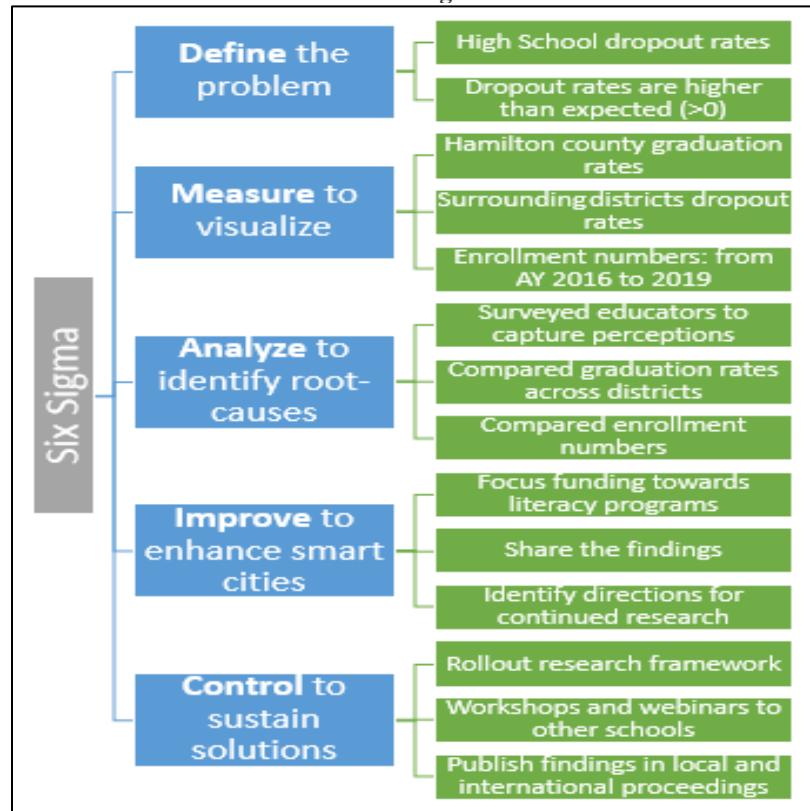
## Methods and Materials

The use of Lean or Six Sigma independently or in a synergic form as Lean Six Sigma is well versed primarily for improvement in manufacturing environments (e.g., see Abrha et al, 2015; Abrha, Alp, & Teklu, 2018; Abrha & de Anda, 2018). Evolving over the years, Lean Six Sigma has found its way to various sectors besides the manufacturing industry (e.g., see Yang, Sawhney, & Abrha, 2014), including education systems. However, not much work is published that provides a unique and repeatable framework focusing on the alignment of reduction of dropout rates or increasing graduation rates to developing a smart workforce for sustainable smart cities. The framework used in this study is Lean Six Sigma's DMAIC (Define, Measure, Analyze, Improve, and Control).

Since the problem at hand is the reduction of dropout rates in high school, the resolution plan for the problem began with a session of brainstorming with colleagues and that eventually led to the development of a project charter. The next step was the collection of historical data of graduation rates in the Hamilton County School District and surrounding districts. Student enrollment for Tyner High Academy in Hamilton County was acquired for the year 2016 for the 9<sup>th</sup> grade as well as for the sequent years of the 10<sup>th</sup>, 11<sup>th</sup>, and 12<sup>th</sup> grade enrollment. The information and insight gained from this step led to the visualization of an updated state of the previously defined problem and helped to narrow down the scope of the study.

Following the preliminary investigation of historical data, a survey and interview instruments were created to gain insight into the root causes of the problem and the possible correlation between high school performance of students and their previous level performances (both elementary and early level secondary education) as well as to investigate the role of increased graduation rate in attracting new businesses to the area. In the quest to determine the root causes of why students drop out of high school, a survey was created and consisted of questions related to student performance in the classroom. The response rate to the survey was 100%; all the participating teachers in a 2021 cohort of an NSF funded Research Experience for Teacher program responded. The questions were then presented to Hamilton County School District teachers for their responses. Finally, the identification of improvement opportunities and a replicable roadmap, shown in Exhibit 1, that can be used in other school systems was created.

Exhibit 1. Lean Six Sigma Framework.



## Results and Discussions

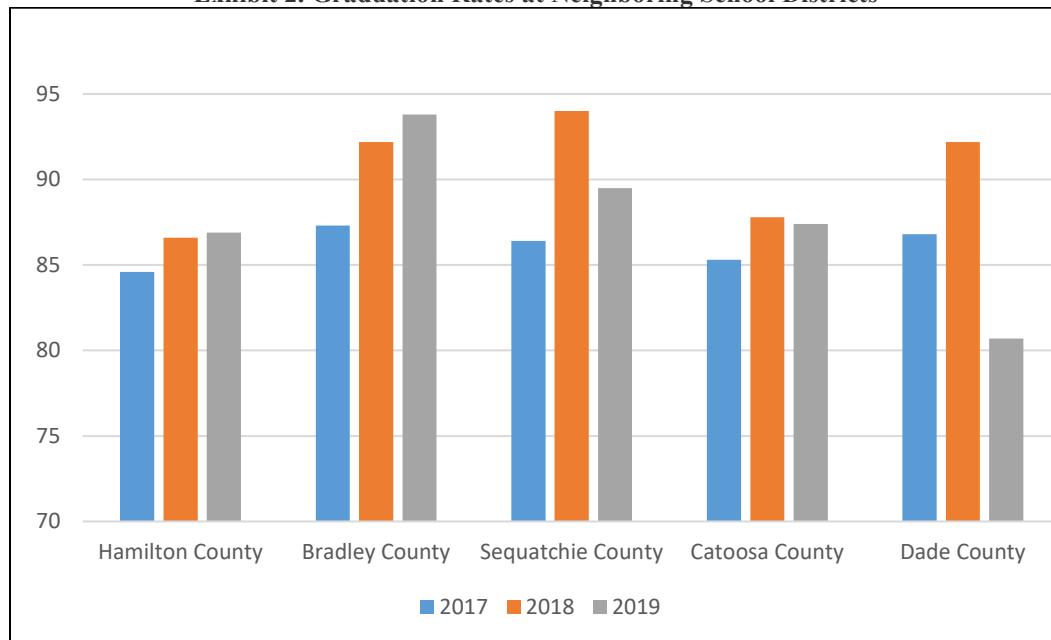
The historical data obtained from the Hamilton County School District and the surrounding school districts were analyzed to initially visualize the current state of the problem at hand, and later to serve as a reference for benchmarking with other outperforming school districts as well as capture additional information through the next step (survey). Graduation rates are for the years 2017 to 2019. The data indicated that the graduation rate for all districts was less than 100%. A comparison of the three years shows that it was 2018 when all four school districts were at their highest level of high school graduates. Looking at the average of all three years, Bradley County had the highest graduation rates. Exhibit 2 shows the graduation rates comparing Hamilton County Schools and the schools in the neighboring school districts.

Following along the research roadmap, the next step was to conduct a survey. The main insight gained from the survey of Hamilton County School District was that students' inability to read on grade level was the most significant hindrance to learning. Of the teachers who were surveyed 31% said that cell phone usage was another hindrance to student learning.

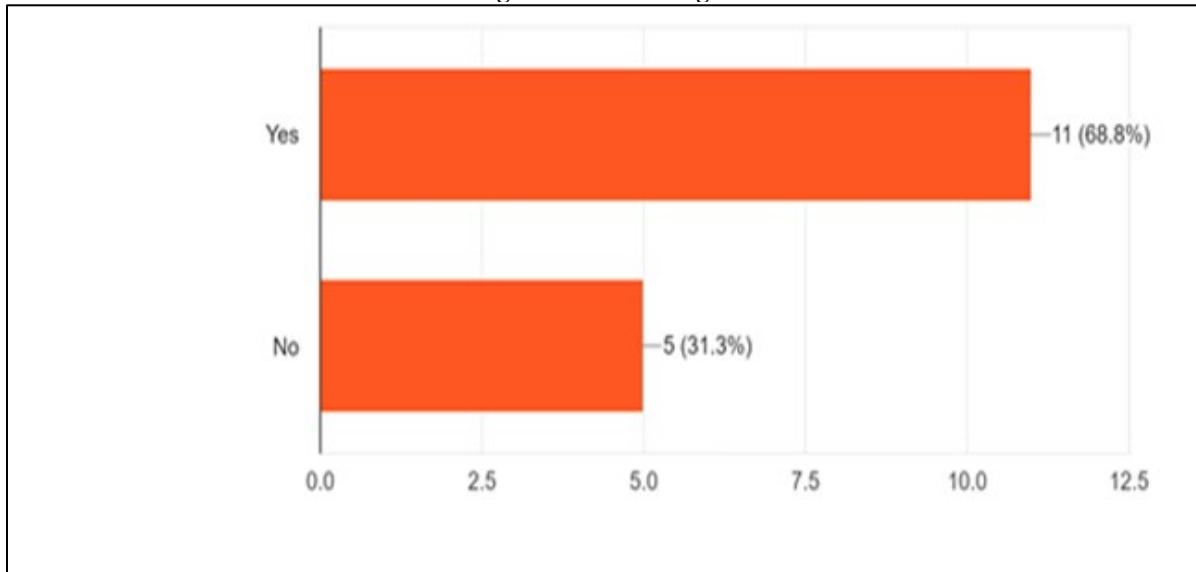
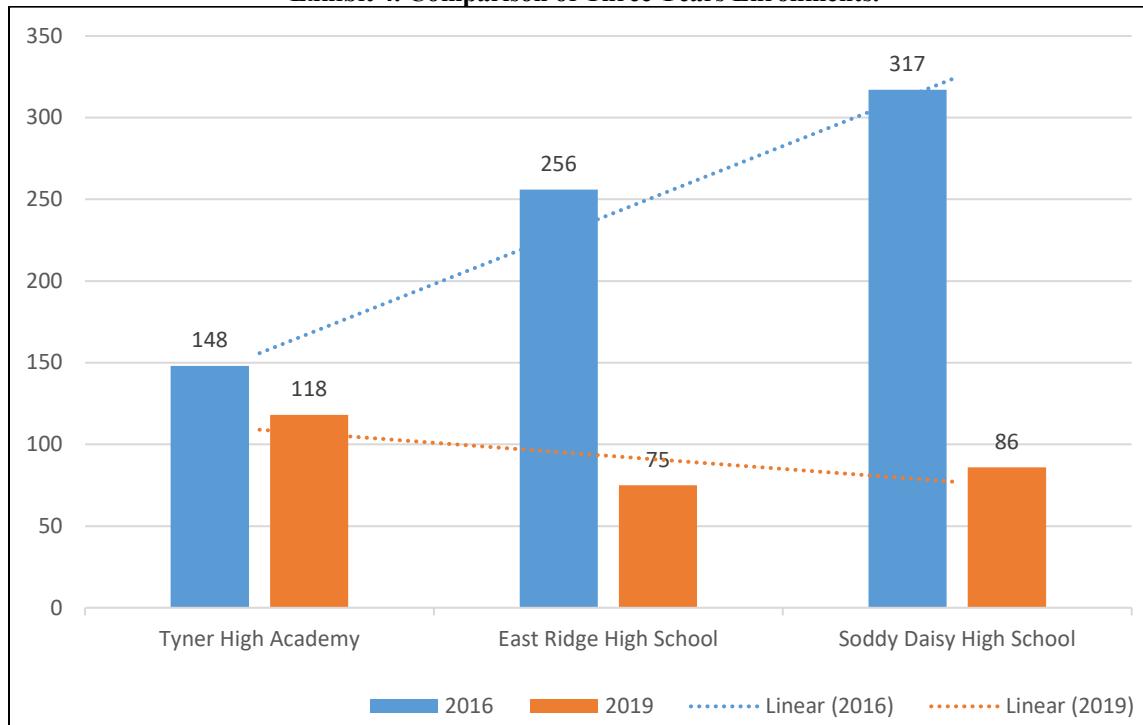
Information gleaned from the literature review also helped to reinforce the hypothesis that students' inability to read at grade level was one of the root causes of the problem of students dropping out of high school before graduating. For example, one method of addressing the revolving door of the prison system is proficiency in literacy skills (Reschly, 2010). When compared to those with typical reading skills, youth with poor reading ability are more likely to drop out of school, and making the problem worse, to develop a suicidal ideation (Daniel, Walsh, Goldston, Arnold, Reboussin, & Wood, 2006). Therefore, to prevent failure in a student's academic career requires the ability to read. The ability to read is important not only to the individual but to society in general. As such, poor reading skills are an example of hindrances to advancing learning. Exhibit 3 shows significant learning hindrances, where 68.8 percent of the respondents agreed that reading is a major hindrance to further learning. The remaining respondents did not consider reading a key contributing hindrance to learning but they still take it as an element of a combination of reasons.

Economic research has proven that school is an investment in human capital – that is, knowledge, skill, and problem-solving ability that have enduring value. Economic research has also proven that the greatest investment and the highest returns come from early school years when children are learning to read; without the ability to read, excellence in elementary, high school or post-secondary studies will be unattainable. Reading competency is critical in preventing increasing high school dropout rates and for ensuring students leave school with the skills necessary to function and grow in society. One means of predicting high school dropout rates is based on a student's reading level in the third grade. It is a proven fact that many high school dropouts, the unemployed, those living in poverty or receiving government assistance, and/or incarcerated are those with poor reading skills.

**Exhibit 2. Graduation Rates at Neighboring School Districts**



To give a deeper picture of the high school dropout problem, a comparison of enrollment and graduation rates of only three high schools situated in Hamilton County is shown in Exhibit 4. For instance, for Tyner High School Academy alone, of the 148 9<sup>th</sup> graders who enrolled in 2016 only 112 or 75.7% graduated in 2019. In 2019, there were 118 seniors; six did not graduate. The largest drop of students was from 9<sup>th</sup> to the 10<sup>th</sup> grade; from 148 to 124, which is approximately 16%. From the 11<sup>th</sup> grade to the 12<sup>th</sup> grade, there was an increase, from 112 students to 118 students. But six students did not graduate.

**Exhibit 3. Significant Learning Hindrances.****Exhibit 4. Comparison of Three Years Enrollments.**

## Conclusion

In this study, it was determined through a literature review and a survey and using Lean Six Sigma's DMAIC that there is a strong correlation between high school dropout rates and the ability to read on grade level. Students who fell behind in reading levels in grades 1-3 would later have the potential for becoming an elevated risk of dropping out of school prior to graduating. Enrollment numbers for three high schools in Hamilton County have shown that the enrollment numbers in the 9<sup>th</sup> grade were much larger than the graduation rates in the same student's senior year of high school. Determining these potential root causes of why students do not perform at higher levels or drop out before graduating delivers government officials and administrators with the information or knowledge that could lead to more focused solutions to these potential root causes thus producing more economic and societal advantages to future high school graduates and the economy for Hamilton County and throughout the United States.

For future graduates, the information discovered and reinforced by the results discussed above can lead to a more productive high school experience if government officials and administrators use the information to focus on addressing the root causes behind much of the high school dropout rates. There need to be short-term and long-term solutions put into place. Short-term solutions could be improved peer and teacher after-school tutoring sessions for struggling high school students and scheduling meetings between teachers, parents, and administrators to plan out better customized solutions. The long-term solutions could be the direction of funds to cover teacher training, hiring more tutors, and acquiring additional facilities, additional technology, and specialized learning and teaching materials. In addition, a greater focus needs to be on preschool and kindergarten programs and on first- through third-grade reading/literacy programs and tutoring.

## Future Research

Although it is encouraging that this study provided a unique and replicable framework using Lean Six Sigma and some preliminary root causes to focus on mitigating high school dropout rates, more work is needed to identify both academic and nonacademic factors that may be potential contributors to dropout rates. As part of future research, the authors are currently working on phase two of this study which deals with the underlying inferential statistics by looking deeper into socioeconomic factors, geographical variables, and other factors.

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## References

Abrha, W. D., Sawhney, R. S., Patlolla, D. R., De Anda, E. M., Reyes, J. C., Ruiz, E. R. Z., ... & Mei, H. (2015). Application of lean principles to improve productivity of maintenance function: A case study. In *IIE Annual Conference. Proceedings* (p. 1879). Institute of Industrial and Systems Engineers (IIE).

Abrha, W., & de Anda, E. M. (2018). Application of lean to reduce inter-plant logistics: the marine industry perspective. In *Proceedings of the International Annual Conference of the American Society for Engineering Management*. (pp. 1-10). American Society for Engineering Management (ASEM).

Abrha, W., Alp, N., & Teklu, T. (2018). Reducing steering gear handling damages – the six sigma way. In *Proceedings of the International Annual Conference of the American Society for Engineering Management*. (pp. 1-9). American Society for Engineering Management (ASEM).

Albliwi, S., Antony, J., Abdul Halim Lim, S. and van der Wiele, T. (2014), Critical failure factors of lean six sigma: a systematic literature review. *International Journal of Quality and Reliability Management*.

Daniel, S. S., Walsh, A. K., Goldston, D. B., Arnold, E. M., Reboussin, B. A., & Wood, F. B. (2006). Suicidality, school dropout, and reading problems among adolescents. *Journal of learning disabilities*, 39(6), 507-514.

Dupéré, V., Leventhal, T., Dion, E., Crosnoe, R., Archambault, I., & Janosz, M. (2015). Stressors and turning points in high school dropout: A stress process, life course framework. *Review of Educational Research*, 85(4), 591–629.

Freudenberg, N., & Ruglis, J. (2007). Peer reviewed: Reframing school dropout as a public health issue. *Preventing chronic disease*, 4(4).

Morrow, A. S., & Villodas, M. T. (2018). Direct and indirect pathways from adverse childhood experiences to high school dropout among high-risk adolescents. *Journal of Research on Adolescence*, 28(2), 327-341.

National Academies Press (1997). Improving Student Learning in National Academies of Sciences, Engineering, and Medicine: The Role of National Standards in State Policy. Washington, DC. Retrieved May 30, 2022, from <https://doi.org/10.17226/5844>.

Piasta, S. B., Connor, C. M., Fishman, B. J., & Morrison, F. J. (2009). Teachers' knowledge of literacy concepts, classroom practices, and student reading growth. *Scientific Studies of Reading*, 13(3), 224-248.

Reschly, A. L. (2010). Reading and School Completion: Critical connections and Matthew effects. *Reading & Research*, 85(4), 591-629.

US Department of Education (USDE). (2021, June 15). Federal role in Education. Retrieved May 30, 2022, from <https://www2.ed.gov/about/overview/fed/role.html>

Winding, T. N., & Andersen, J. H. (2015). Socioeconomic differences in school dropout among young adults: the role of social relations. *BMC Public Health*, 15(1), 1-11.

Yang, H., Sawhney, R., & Abrha, W. (2014, July). Application of discrete-event simulation in acute care's capacity analysis. In *International Symposium on Performance Evaluation of Computer and Telecommunication Systems (SPECTS 2014)* (pp. 528-535). IEEE.

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