

# Implementation of STEM Policy: A Case Study of a STEM-Focused Urban Charter School

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## Abstract

This case study explores policy implementation of a Science, Technology, Engineering, and Mathematics (STEM)-focused charter school over a three-year period. Gateway Science Academy of St. Louis (GSA), a K-12 district, has applied the STEM-focused curriculum model for seven years. This case study uses the Fullan Change Theory's seven core principles to investigate GSA district's implementation and integration of the New Generation Science Standards (NGSS) and Project Lead The Way (PLTW).

The purpose of this study is to explore the GSA school district's STEM policy implementation within the lens of the Fullan Change Theory. The researcher interviewed teachers and administrators and conducted classroom observations in order to collect data to investigate policy implementation. The study also reviewed relevant literature on effective policy implementations. In addition to interviews and classroom observation data, additional data was collected and analyzed, including teacher lesson plans, standardized test scores, and monthly activity logs. Findings indicated that the most successful STEM-policy implementation depends on staff motivation, administrative support, professional development, and team-lesson planning.

*Key Words:* STEM, Policy implementation, Urban schools, NGSS, PLTW

## Introduction

Based on research from the U.S. Department of Labor (2015), there are many jobs that require STEM skills. According to the National Science Foundation (2010), nine of the ten fastest-growing occupations that require at least a bachelor's degree will depend on significant math or science training. Many science and engineering occupations are projected to grow faster than the average rate of all other occupations. The Office of the Chief Economist (OCE) (2017) notes, "[STEM employment will grow] 8.9 percent between 2014 and 2024. Non-STEM jobs are projected to grow about 6.4 percent" (p. 2). The OCE (2017) data further substantiates more STEM workers earning college degrees than non-STEM-workers. In 2016, President Barack Obama emphasized STEM as a priority for the United States, noting,

"Science has always been the hallmark of American progress. It's the key to our economic success. I can't think of a more exciting time for American science than right now, because we are busy reigniting that spirit of innovation to meet so many challenges."

Many schools across the U.S., especially elementary and middle schools, eliminated science courses and student access to technology as a result of the No Child Left Behind Act (NCLB) and budget cuts. Two in five high schools in the U.S. do not offer physics courses (Heiten, 2016). As a result, elementary and middle schools place focus on math and reading curriculums (Dillon, 2006). Science scores have reflected this shift. In the 2015 Program for International Student Assessment (PISA), the United States ranked 25<sup>th</sup> out of 70 countries in science, 40<sup>th</sup> out of 70 in math, and 24<sup>th</sup> out of 70 in reading.

PISA test data demonstrated science scores went down following NCLB implementation. NCLB decreased and shifted science class time to more math and reading class time for elementary schools. This shift contradicts the demand of STEM skills jobs in the U.S. Department of Labor's Bureau of Labor Statistics (2008), which indicated that more than 80% of the fastest growing occupations in the United States are dependent on STEM skills, and many of these positions are being filled by talent from abroad. Asunda (2011) indicated that President Obama assured preparation of 100,000 STEM teachers by the end 2021. This pledge supported the National Science Board's (2007) recommendation that the U.S. needed 2.2 million new STEM teachers in K-12 schools and community education settings over the next decade.

State legislators further noted,

"Legislators are beginning to focus on policies related directly to STEM education, H.R.5031 - STEM Education Act of 2014, design and testing of innovative

STEM learning models, programs, and other resources for informal learning environments to improve STEM learning outcomes and increase engagement for K-12 students, K-12 teachers, and the general public, including design and testing of the scalability of models, programs, and other resources."

This initiative indicates the need for more STEM-focused K-12 schools in the U.S., which has received attention from stakeholders and is crucial to creating a pipeline from K-12 schools to college for future STEM workforces.

## Research Question:

This study explores the GSA district NGSS/ PLTW STEM implementation process in K-12 classrooms, focusing on the following research question:

What are the qualities and components of successful NGSS/PLTW STEM-policy implementation in the GSA district?

## Literature Review

The implementation of any new policy at the secondary level is often challenging for staff and school administrators (Brundrett & Duncan, 2014; Hooghuis et al., 2014; Lowrie, 2014; Rekkor, Ümarik, & Loogma, 2013; Ryder, 2015). This also brings challenges. Today's school curriculum is often in a state of flux, subject to policy changes at state and federal levels, and this is even more common in STEM subjects. STEM-curriculum integration is derived from the considerations of many researchers, and it exists at the college level as well (Beane, 1995; Czerniak et al., 1999; Jacobs, 1989). A recent report from The National Research Council (NRC) (2016) shows barriers to earning a STEM-related bachelor's degree, with more than two-

2015 PISA science score-496

2012 PISA science score -497

2009 PISA science score-502

Table 1. U.S. PISA Science Scores

thirds of those intending to earn a STEM-related associate's degree failing to earn these degrees within four to six years after their initial enrollment. This suggests STEM educational pathways are less efficient than other fields of study (NRC, 2016).

School administration values and behaviors can effect organizational change (Oreg & Berson, 2011). The implementation of any new program requires an engaging learning process for everyone, at all levels. As such, a new approach is needed for administrators and staff. Elmore (2004) points out that improvement typically translates to new learning. While that is not necessarily a new issue, it undergirds that in order for change to occur, the new policy must strive to improve the non-functioning parts.

A recent report from the NAE et al. (2017) unambiguously indicated that teachers' roles as leaders and policy makers in STEM policy integration are crucial for implementation success. National Science Education Standards from the National Research Council (NRC) and Benchmarks for Science Literacy from the American Association for the Advancement of Science (AAAS) are intended to guide the development of current state science standards. This standard has been around for fifteen years; however, there have been some new advances in the science world. The NGSS standards will address major advances and new approaches to teaching science standards (Next Generation Science Standard. (n.d). The intent is that NGSS should increase student engagement in the classroom. For example, instead of teachers presenting the core concept, students will explore this concept through activity-based learning in order to gain mastery of the concept. Sometimes there are time concerns noted with this type of process, but teachers must get in the habit of feeling okay not covering everything (Colson & Colson, 2016). In other words, it is okay to try something new and fail at it -- which tends to be the opposite mindset of traditional schooling. NGSS-friendly lesson plans are bringing a new dynamic to the classroom where it is now encouraged for teachers to say, "I don't know; let's find out." This new NGSS approach makes both students and teachers think more deeply and ask more questions. As of February 2016, NGSS was adopted by 18 states (National Association of State Board of Education (n.d)). NGSS necessitates curriculum modifications, and in order to make the change seamless, it is important to offer professional development for K-12 teachers and administrators (Altuger-Genc & Issapour, 2015). Professional development for K-12 teachers is even recognized by higher education institutions, who have established custom-designed training materials and workshops for K-12 teachers. In addition, professional development of STEM implementation can be found via research and paper presentations at national conferences with regards to sample teacher lesson plans for NGSS standards (Buhr Sullivan et al., 2013; Passow, 2013; Morrow et al., 2013). Bergen et al. (2014) presented a sample curriculum design with a specific focus on el-

ementary, grades three through six.

While research has addressed the need for increased STEM curriculum in K-12 schools, gaps exist regarding what specific qualities and components make for successful STEM-implementation. This study seeks to address those gaps.

## Theoretical Framework

This study used Fullan's evidence-based theoretical framework. Fullan's (2006) Change Theory is centered on evidence-based educational reform, which is based on seven "core premises" that embrace the theory: (a) motivation; (b) capacity building focused on results; (c) learning in context for those enacting reform; (d) capacity to change the larger context; (e) reflective action; (f) tri-level engagement; and (g) persistence and flexibility.

According to Fullan (2006), change cannot happen without motivation. There are several key steps that must be followed in order to encourage motivation. The most crucial steps are the creation of short-and-long-term goals, which is necessary to keep followers on track. Fullan (2006) notes moral purpose is the foundation of motivation, and he is not alone -- most researchers agree on the impact of motivation in learning. Spitzer (1996) asserts that no matter how excellent any instructional program is, learning will be no greater than the student's level of motivation. That being said, following only motivational behaviors will not be enough to successfully implement policy. There must be other factors that support the policy implementation. The second "core premise" is capacity building, which concentrates on producing results. Applying pressure to produce results can be a positive tool (Fullan, 2006). Capacity building is a crucial key for moral support and a motivation of successful policy implementation. According to Fullan (2006), "Most theories of change are weak on capacity building, and that is one of the key reasons why they fall short" (p. 9). The third step is learning in context for those enacting reform. This core premise refers to all stakeholders open to learning during the process of change or new implementations. The fundamental message is that stakeholders must buy-in to do the "right" things during the implementation process, even when faced with a new set of expectations (Elmore, 2004). The process of such a change in climate depends fundamentally on modeling the new values and behaviors you expect to displace from administrators to teachers to support staff (Elmore, 2004). The fourth core premise is the capacity to change the larger context. Once the implementation of new policy is established in a small group, such as in an individual science teacher's classroom, then this can be duplicated with the rest of the building and, subsequently, the district. According to Fullan (2006), it is important to note that changing the larger context also may spur potential barriers such as unnecessary bureaucracy, collective bargaining conflicts, and managerial issues.

Fullan notes that a reflective action for all stakeholders is a necessary process to the previous four premises. All stakeholders to the implementation process need to open minded and nonjudgmental, unified over a shared vision of collective ownership and changes in behavior (Fullan, 2006).

In addition, collaboration must exist between state, district, and school/community stakeholders with a collective aim of "mutual interaction and influence within and across the three levels" to reach a common goal (Fullan, 2006, p. 11).

The last premise is persistence and flexibility in staying the course, which Fullan (2006) calls "resilience-persistence plus flexibility" (p. 11). The last premise is where critical checks-and-balances must be performed, balancing theory with action. So being reflective or flexible with this process is the way of learning and implementing.

## Methods

### Research Design

Merriam (2016) states, "A case study is an in-depth description and analysis of a bounded system" (p.37). Merriam (2016) notes the phenomenon of interest as "intrinsically bounded" so that it can be called a case study (p.39). In determining the research design, the researcher sought to define understanding of the components of STEM-integration in the GSA district using an inductive analysis of data including interviews, observations, and miscellaneous documents and artifacts, resulting in a descriptive account. The researcher was the sole collector of data. The researcher's goal was to reach all science teachers and administrators in the GSA district. As Merriam (2016) states, "There are two reasons for selecting a wide sampling: 1) document diversity and 2) identify the common pattern" (p.257). The researcher used maximum variation sampling to select interview candidates within a bounded system. Such sampling procedures enable the researcher to hear voices from different backgrounds and grade levels, as well as their involvement in the STEM-implementation process. All science teachers and administrators were asked to be part of a research study and were provided with a consent form allowing the collection of data using human subjects (Appendix A). All participants were informed that they could withdraw their consent to be a part of research at any time. Participants who agreed were then asked to sign informed consent forms, acknowledging their participation was voluntary. No data was collected from science teachers and administrators who wished to be excluded from the study. There are three parts of this study.

### Selection of Site and Participant

The site chosen for this study was the GSA district because it has a STEM-focused curriculum for all subjects,

Interview participants	School type	Grade level	Student population	Gender	Race	Years as STEM School
Teacher #1	Urban	K-5	400	Female	White	7
Teacher #2	Urban	6-8	250	Female	Caucasian	7
Teacher #3	Urban	6-8	250	Female	White	7
Teacher #4	Urban	9-12	250	Male	Caucasian	7
Administrator #1	Urban	6-8	250	Male	White	7

**Table 2: Demographic information of interview participants**

and it is in its seventh year of operation with such a curriculum. In addition, the GSA district was honored as the 2015 Missouri Charter School District of the Year. Also in 2013, Stanford University's Charter Organization Management Studies recognized Concept Schools, the district's management organization, as a top organization. Furthermore, the researcher, who is an administrator in the district, intrinsically values STEM-focused education, and has access to the participants and data necessary for such a study. Finally, because the district is comprised of three schools: elementary, middle, and high school, there is a wider pool from which to collect data. In total, the three campuses serve 1,400 students in grades K-12. Because this study addresses STEM-policy implementation, the researcher chose to recruit both science teachers and administrators from each campus of the GSA district as they would be able to describe the process from policy to the classroom.

## Setting

The sites chosen for this study were high school and middle school science and PLTW classrooms. The researcher chose these classrooms because these teachers had previously been interviewed about their STEM-policy implementation in the classroom.

The middle school classroom was comprised of seven lab tables, around each of which were four students. The observed lesson's objective was chemical and physical property changes. This particular class was the highest class level in the seventh grade; the students are in the "honor-student" category. The observed class period was 45 minutes. The student population was very diverse as there were many international and multi-linguistic students present. The classroom was equipped with a projector mounted to the ceiling interfaced with a Smart Board and document camera. Students had access to individual Chromebooks. As part of their lab activity, they used invis-

ible ink-vinegar, beakers, baking soda, cotton swabs, and a journal to take notes.

The high school 9<sup>th</sup> grade "honors" chemistry class consisted of 29 students. The classroom had lab tables with four students able to sit at each table. The classroom was diverse, there were also many international and multi-linguistic students present. The lesson objective was to determine why noble gases are not included in a discussion on electronegativity. The observed class period was 45 minutes. The classroom was equipped with a projector mounted to the ceiling, interfaced with a Smart Board and document camera. Students had access to individual Chromebooks, and they were assigned to compare two elements in terms of atomic radius, ionic radius, ionization energy, and electronegativity. The students repeated the exercise with metal and nonmetal materials, ultimately leading to writing general statements summarizing the trends revealed by these comparisons.

## Participation and Positioning of Researcher

The researcher is an employee of the GSA school district. As such, the researcher's positionality must be considered. The researcher is an assistant principal in the GSA school district, and therefore has "insider" status. Potential implications of such status include the possibility of participants' interview statements reflecting what they believed the researcher wanted to hear rather than their actual values and beliefs. Additionally, observation data faced the same threat -- the potential for humans to perform differently when they feel "under the microscope." As a result, data was cross-validated by analyzing data for emerging codes and themes stemming from multiple participants' interviews, observations, and documents. The researcher's perspective, as an administrator at the GSA high school, deeply values STEM-focused education, which can also serve as a benefit to this study as the researcher has a more experienced and synthesized

approach in interpreting findings.

## Data Collection

Participants included three science teachers, one PLTW teacher, and two administrators, all of whom participated in semi-structured interviews. The researcher e-mailed information to potential participants describing the study and explaining the purpose. Participants were sent structured interview questions and replied via email. Interview questions were based on Fullan's (2006) Change Theory, and were asked in order to generate an understanding of participants' experiences during the implementation process so that the researcher could derive themes most likely to lead to successful STEM integration. For example, the researcher asked participants to describe the process of NGSS/PLTW policy implementation in their school or district level, and to explain to what extent flexibility existed in how such policy was incorporated into daily and unit planning. Questions were designed to develop a deep understanding of science teachers' PLTWs, teachers', and administrators' experiences towards the STEM/PLTW implementation process and integration in classrooms, as well as to enable the researcher to hear voices from different backgrounds, grade levels, and involvements in STEM-structures. The average duration for interviews was 30 minutes. The researcher employed member checks to follow up with each interview participant and discuss classroom observation findings and document analyses. As Merriam (2016) notes, taking findings back to participants and asking for validation is important for validity and reliability of qualitative research. See Appendix B for interview transcript.

The researcher also observed four classrooms (grades six through twelve), utilizing the same classroom observation protocol used by the GSA district, so as not to create an uncomfortable situation with teachers. The observations were conducted following each of the science teachers' and PLTW teacher interviews. The purpose of the classroom observation was to follow up post-interviews with the classroom observation in order to observe findings from interviews and to observe evidence of STEM integration in science and computer classrooms. For example, this created the benefit to cross-validate findings between the interview and observation. It also provided the opportunity to observe participants in their natural setting -- their classrooms and/or school buildings. The researcher set up a ten-minute post-meeting with teachers after each classroom observation to provide further elaboration of findings.

Documents collected include science and PLTW teachers' lesson plans, monthly science activity logs, and standardized test scores.

### Lesson plans.

From 2015 - 2017, yearly and weekly lesson plans were reviewed and analyzed by the researcher. Each year,

GSA science teachers discussed science curriculum via local school administration and the district's director of science. From that feedback, final yearly plans were made, and curriculum was revised. The scope and sequence of science curriculum included weekly and monthly recommended hands-on activity and lab activities.

### Monthly Activity Log.

In addition to yearly and weekly lesson plans, a monthly activity log was created to assist with the implementation during the 2016–2017 school years. An additional purpose of the monthly activity log was to collect and measure data to share with science teachers and school administrators. The monthly activity log evolved as the 2016–2017 school year progressed. The ultimate goal of the monthly activity log is to observe an accurate number of hands-on lab activities in science classrooms. Individual science teachers enter data into the monthly activity log after completing activities. The log is managed by a district STEM coordinator, whose role is centered on coaching and mentoring individual science teachers and leading the NGSS/ PLTW district implementation, while working closely and collaboratively with the district superintendent. The coaching includes working with each science teacher in the district and supporting them in class during hands-on and lab activities, which is a crucial part of effective implementation of policy.

### NWEA Test

The district also used Northwest Evaluation Association (NWEA) standardized test scores to measure students' growth and overall class growth from fall to spring each year. NWEA is a non-profit organization that has assessed over 4.5 million students, and it has a presence in 49 foreign countries, 50 states, and 3400 districts (NWEA measuring what matters (n.d)). The researcher analyzed test science scores from the last three years. The

NWEA district science scores (grades three through eight) are below. The students' growth data support hands-on activities and NGSS implementation increased students growth in science.

The collection of these documents provided the researcher with the possibility of validating findings through additional means from which to derive themes. As the researcher was specifically seeking demonstration of STEM implementation, these documents provided another pathway to possibly find such data. Merriam (2016) notes, "A qualitative study of classroom instruction would lead to documents in the form of instructors' lesson plans, student assignments, objects in the classroom, official grade reports and school records, teacher evaluations and so on" (p.175).

### Validity and Reliability

To establish internal validity, the researcher used triangulation, including member checks for each participant, multiple types of data collection, and multiple methods of data collection. Regarding member checks, the researcher followed up with each participant to debrief extrapolated themes found in observation and interview data. Participants agreed with the extracted themes and validated the researcher's findings. Regarding multiple methods of data collection, the researcher checked findings from interviews with observation findings and document analyses. For example, participant Ashley states administrative support is crucial for STEM integration in classroom. She received coaching for lab activity from DCS and both the classroom observation notes and monthly activity logs show effective STEM integration within her lesson.

Merriam (2016) notes that reliability refers to the possibility of whether results can be replicated. More specifically, Merriam (2016) says, "The more important question for qualitative research is whether the results are consistent with the data collected" (p.251). The researcher

collected and analyzed a variety of data, and though human behavior is not static, the researcher believes results to be consistent and dependable and could be applied to other districts and even individual schools seeking to implement STEM.

### Data Analysis

Braun and Clarke's (2012) six-phase method for thematic data analysis describes the following six-step method: "Phase 1: Familiarizing Yourself With the Data;" "Phase 2: Generating Initial Codes;" "Phase 3: Searching for Themes;" "Phase 4: Reviewing Potential Themes;" "Phase 5: Defining and Naming Themes;" and "Phase 6: Producing the Report."

The researcher re-read all the documents, interview transcripts, classroom observations and field notes, monthly lab reports log, and NWEA test scores to acquaint him with all data. In Phase 2, the researcher began generating initial codes of interview transcripts, with the focus on aspects of STEM-policy implementation. In Phase 3, the researcher began to make connections between initial coding from transcribed interview and documents. During Phase 4, the researcher looked for potential categories. The researcher derived four categories after careful coding in the first three phases. Categories include: motivation, administrative support, lesson planning, and continued support. In Phase 5, the researcher took a closer look at the categories in Phase 4, arriving at the following four themes: policy implementation requires high motivation; administrative support is fuel for the policy engine; team lesson planning leads to teacher buy-in; and, professional development is the pulse of successful implementation. The final phase is to produce the report while remaining engaged in the process of analysis and maintaining focus on your research questions during the process.

Although this case study focused on a specific school district, the extrapolated concrete universals can be generalized to other districts. While other school districts may be their own unique system, the universal properties of quality STEM-implementation (motivation, administrative support, professional development, and team-lesson planning) can still be applied, demonstrating transferability of findings.

### Findings

Using Braun and Clarke's (2012) guidance for thematic analysis, the researcher constructed four themes as described above in view of this:

- Policy implementation requires high motivation
- Administrative support is the fuel of the policy engine
- Team lesson planning leads to teacher buy-in
- Professional development is the pulse of successful implementation

The themes below have been extracted from data analysis

	Fall 16-Fall 17		Fall 14-Fall 15		Fall 13-Fall 14	
Grade level	percent met projection	count met projection	percent met projection	count met projection	percent met projection	count met projection
4	52	70	66	72	59	61
5	53	56	55	54	38	26
6	60	56	65	43	56	40
7	76	59	62	46	38	24
8	48	29	47	28	64	32
Average scores	57.8	54	59	48.6	51	36.6

Table 3: GSA district NWEA growth target reports

documents and are supported with previous literature.

## Stakeholder motivation and capacity building

For any successful implementation or change, the foundation is motivation. Successful educational change is prompted by motivating stakeholders (Fullan, 2006). The role of stakeholder motivation will make the implementation process successful. All participants of this study commonly indicated the belief that the NGSS will bring more hands-on experiences and lab activities into science classrooms. This will increase student engagement and generate more participation in classroom discussions. Increasing student engagement was a driving motivation for teachers and school leaders. Participant Justin said, "I would like to engage students in practices to build, deepen, and apply their knowledge of core ideas and crosscutting concepts."

Participant Lopez said, "My students most display active engagement when they are completing hands-on activities/experiments on content that is of interest to them. For example, students have been learning about plants and animals since kindergarten, however, when you conduct hands-on activities/experiments, the students are the most engaged."

Participant George said, "It is my belief that, while it is difficult to control which direction it goes, hands-on and open-ended activities create a deeper understanding of a wider range of skill sets/standards for students. Students may not learn as many facts, but they will learn how to think and how to apply thinking to concepts." For educators, witnessing students learning and succeeding continues to drive educator and student motivation alike. Both comments undergird that stakeholder motivation is vital for any educational policy implementation, which the literature supports.

Data from classroom observations and documents analysis support the collective group effort such as working as team during lesson planning, especially for details concerning lab activities and hands-on activities which have the benefit of motivating science teachers to do more lab activities in classroom (Altuger-Genc & Issapour, 2015). Further research suggests STEM integrated co-planned lessons should be implemented by STEM teachers (Roehrig et al., 2012). It is crucial for schools to create a time for teams to create weekly and yearly lesson plans. Data from weekly lesson plans and the monthly activity log provide support that co-plan lesson plans and lab activities were observed more in classrooms than individually planned lessons. Teachers and administrators need motivation that the policy will enhance student learning in STEM activity (Shen et al., 2015; Ramli, Nur Farhana, Talib, & Othman, 2017).

Capacity building with a focus on results is the driving factor during the policy implementation process (Fullan, 2006). The role of full-time personnel is important to col-

lective motivation and giving timely necessary support. The absence of full-time leaders will slow down capacity building and motivation (Johnson, 2012). Participant Jennifer said, "Our administration is on board and is very supportive in the transition to implementation of NGSS." The support of leaders during the process of implementation will make the process smoother, if done well, or slower if lacking. The research on school leaders' roles during educational policy implementation shows that providing staff development will eliminate misunderstanding and give necessary support for all stakeholders (Hope & Pigford, 2001).

## Change and learning with persistency and flexibility

In order for teachers and administrators to learn new concepts, a willingness to change and adapt is imperative. Without change, learning will not occur. Resistance to change has the potential to upset successful implementation. Research on successful STEM implementation policy suggests that lack of persistency in training and the flexibility to change will negatively affect coherence of policy implementations (Foley, 2015; Johnson, 2012; Ramli, Nur, Farhana, Talib, & Othman, 2017). All participants in this study pointed out, "During the policy implementation, teachers were looking for more support and flexibility, such as professional development about embedded NGSS hands-on and activities in our lesson plans." This theme has been observed in all teacher participants. Participant Steven reflected on his reaction with his students: "if a student is unable to meet the behavior expectations, he/she may be removed from the activity and asked to complete an alternative assignment." This illustrates a teacher who did not demonstrate flexibility and persistence-- ultimately a threat to successful implementation.

The goal of the NGSS policy implementation is increasing students' engagement; so it is reasonable to expect science teachers to remain flexible during the change and learning process in their classrooms. When students are more engaged, learning increases. All stakeholders must be willing to buy into the process and understand that hiccups will occur along the way, but the commitment to flexibility must remain a constant.

Professional development such as summer workshops for preparing science teachers is crucial. As Altuger-Genc and Issapour (2015) indicate, providing the science teachers with hands-on project material, worksheets, and support materials are expected to help with smooth transitioning from the existing science standards to NGSS. Participant Kelly reflected on resource choice used by data analysis. "There is data available from MySci that shows growth in 5th grade MAP science testing in the schools in which MySci is used." It makes the decision easier once the new sources have some kind of data. As key role players for policy implementation, teachers who have a decision making role can be expected to model effective imple-

mentation (Bergen & Chen, 2014; Brundrett & Duncan, 2014).

## Tri-level engagement and reflective action

The policy implementations require multiple levels of engagement and responsiveness. Policy implementation is a dynamic process and needs reflective action during the process. All participants, teachers, school-level and district-level administrators indicated that, "The school and district level support during the NGSS and PLTW implementation are important." Teachers mentioned they were happy to see support from both levels. Reflective action supports two-way communication and eliminates immediate problems that otherwise could occur during the policy implementation. Ricento et al. (1996) argued that policy is re-explained and modified as it travels through layers of legislation and political processes, states and supranational agencies, institutions and classroom practitioners. This supports the finding that behavior and social aspects of classrooms can constrain policy implementation if the policies are seen in conflict with behavior and social roles of classroom culture (Ricento et al., 1996). The issue lies with having both a top-down and bottom-up approach to policy implementation. Teachers have a key role during policy implementation. Teachers' ways of introducing the new policy in this study is to employ a new approach to teaching science in the classroom. The ultimate goal for NGSS policy implementation is engagement of students and discovering concepts; but the effect of classroom culture may have a more direct and pervasive influence on classroom teaching than policy statements or reforms, as supported in Ricento et al. (1996). The school leaders' roles are key for understanding the dynamics of the change process and the action that must be taken during the phase of the implementation process (Hope & Pigford, 2001).

## Visual Model of Themes and Interactions

The following visual model (Table 4) demonstrates the process of analyzing codes in order to generate interpretative themes that represent demonstrations of STEM-policy implementation.

## The Study's Limitations and Future Study

The study focused on STEM focused K-12 school NGSS/PLTW implementation and the integration process. This study's findings are limited in that the only sample was a STEM-focused school, with only one K-12 district policy implementation. In order to best confirm external validity and better generalize findings, it is recommended that future research employ a duplicate study in a non-STEM focused school district, and then compare findings between these two districts. In addition, it is recommended for future research to duplicate this study using three or more school districts who have implemented NGSS/PLTW in a retroactive study. This would allow the

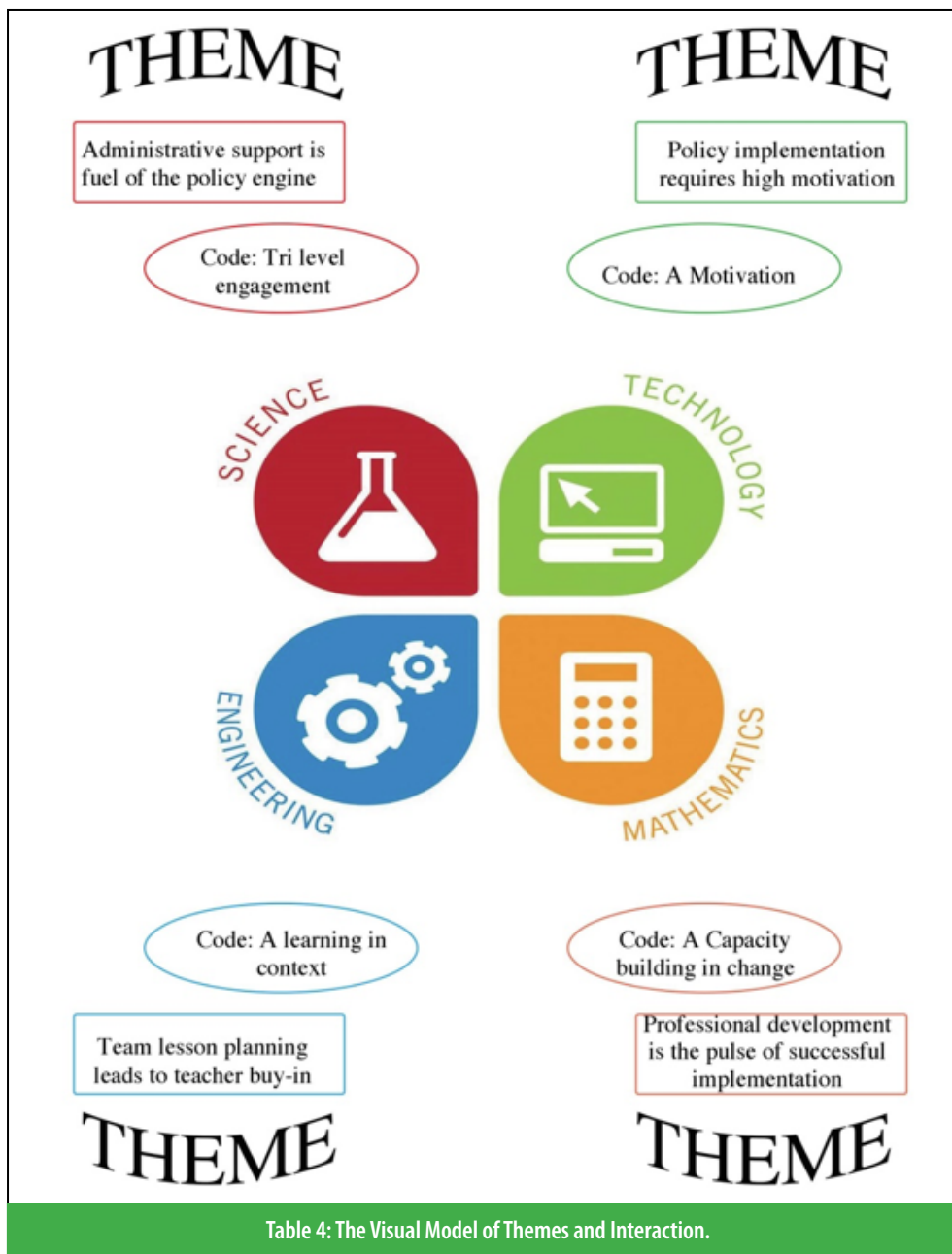


Table 4: The Visual Model of Themes and Interaction.

sample size to be increased. Finally, the researcher was the primary instrument of data collection and analysis. Other than member checks, results were not validated by outside sources or additional investigators.

## Discussion and Conclusion

This study focused on how to explore STEM policy (NGSS and PLTW) implementation and integration in science and PLTW classrooms. The study used Fullan's (2006) evidence-based theoretical framework, which is centered on evidence-based educational reform. The seven core principles discussed in the literature review were investigated on the GSA district's NGSS and PLTW implementation and integration process. The study's findings highlight a few important outcomes worthy of future discussion.

Motivation is the most essential factor for effective policy implementation and integration. Stakeholder mo-

tivation research supports the effects of policy implementation and integration (Fullan, 2006; Mariage & Garmon, 2003; Shen et al., 2015; Ramli, Nur, Farhana, Talib, & Othman, 2017). Professional development (PD) is another factor that affects motivation. Research shows that providing staff development will eliminate misunderstanding and give necessary support for all stakeholders (Hope & Pigford, 2001). Participant Ashley indicated, "I have been teaching science for years and using hands-on activities and experiments as much as possible during my instructions. Students were always showing more interest to hands-on activities and experiments-- more than listening to the teachers lecturing." Motivation like Ashley's can be self-driven-- such as how Ashley understood the means to the end. The new NGSS policy will assist her to do more hands-on and lab activity in the classroom, which will increase student engagement and, subsequently, student mastery. As Fullan (2006) mentioned

in his seven core principles for policy implementation, capacity and leadership are prerequisites for collective motivation. According to Fullan (2006), capacity building is often ignored by policy makers; yet, capacity building is concentrated on following up on production of result. The role of the District STEM Coordinator (DSC) was noted on interview data and documents analysis as a way to assist with building capacity and subsequently collective motivation between all stakeholders.

Team planning and administrator support is another essential factor for effective STEM implementation. This study found that teachers notice that co-planning and having a designated person for various roles are significant for a smoother process. Participant Ashley indicated, "Working with my administrative team has been helpful. My administration understands what needs to be done, what is lacking in our elementary science and has fully supported me." The support is also essential to continuing motivation during the implementation process. The research also found team planning and full administrative supports are relevant factors of effective policy implementation and integration (Altuger-Genc, G., & Issapour 2015); Johnson, 2012). The data from classroom observations, lesson plans, and monthly activity logs illustrated that team lesson plans are the most effective lessons for teacher to integrate into their classrooms, also supported in Roehrig et al. (2012).

The finding of this study demonstrates necessary components of effective NGSS/PLTW implementation and integration in K-12 classrooms. In the age of golden STEM skills, all students regardless of their background should prepare for STEM skills jobs. To reassure prosperity for a STEM workforce, all students must have opportunities in K-12 schools which emphasize a demanding STEM curricula. This study highly recommends using the Fullan (2006) change theory as a framework for any STEM policy implementation and integration in K-12 schools in U.S. The study investigated a STEM focused K-12 public charter school district. The study proved that the school district which used the Fullan (2006) change theory as a framework during the NGSS/PLTW policy implementation and integration can be successful. To improve success of implementation and integration, staff motivation, administrative support, professional development, and team-lesson planning are the most influential elements of process.

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