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# Systems Thinking as a Method for Leveraging Smart Classrooms

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SYSTEMS THINKING AS A METHOD FOR LEVERAGING SMART CLASSROOMS


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## Dedication

To my parents and husband, and family who have provided me with utmost support and encouragement.

SYSTEMS THINKING AS A METHOD FOR LEVERAGING SMART CLASSROOMS

by

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**Abstract**

Digital technologies have revolutionized enterprises across our personal lives, and most major industries. The digital transformation can be considered a strategic response to digital trends (Vial, 2019), encompassing substantial changes in society and industry caused by technology development (Taj, et al., 2010). It's a complex journey that needs to be guided by clear strategy. Digital transformation is more about people, than it is about technology (Frankiewiczz, B., 2020). It requires organizational changes that are backed by leadership and driven by challenges to culture (Abbu, H., 2022). Digital transformation requires leaders to build trust (Mugge, Abbu, and Gudergan 2021; Gudergan et.al. 2021; Abbu et al. 2020). Existing research suggests that organizations need to develop a digital transformation strategy to find innovative applications of technology, manage the changes triggered by technology and coordinate the implementation of the digital transformation (Hess et al., 2016). This digital transformation is revolutionizing the way enterprises support, improve, and fulfil their processes and activities. This revolution is introducing innovative technologies such as the Internet of Things (IoT), cloud computing, analytics, and other advanced technologies to provide a fully connected SMART network that can optimize workloads and improve performance.

One of the main industries that this digital transformation is affecting is the manufacturing domain. Incorporating the technologies that this era of digital transformation has brought upon has deeply affected the manufacturing enterprise operations and production processes in terms of increased efficiency and flexibility (Björkdahl, 2020; Pereira & Romero, 2017). Sectors of the private industry and engineering centers in the United States Department of Defense have embraced this transformation, implementing digital engineering activities to great benefit (DOD Strategy, 2019). As for the healthcare industry, adopting novel technology and embracing the potential of this digital revolution has become a necessity for every health center. For example, endoscopes produce video data, but these are not recorded beyond still images (Zimmerman, H.D., 2021). It would be beneficial to use the entire video for evaluation and other purposes. The

education domain can also reap the fruits of this digital transformation. The digital transformation started with a defined strategy that leveraged opportunities presented by new technology while meeting the objectives of system stakeholders (Demartini, C. G., 2020). That strategy has been leveraged for education connecting everything to support tomorrow's digital world and creating strong strategic partnerships able to build an ecosystem connecting people, processes, and things into a powerful, and secure, system of systems.

While it is apparent that there is much to gain from this digital transformation in any domain or industry, there is still a lack of knowledge available to Small to Medium enterprises looking to leverage SMART capabilities within their facilities. With the use of our tools, methods, research, and resources, we aim to provide Saint Patrick's Cathedral School with a baseline of what is needed to leverage SMART capabilities in classrooms. This digital transformation is essential for adoption because it will prepare students to enter a workforce where digital literacy is essential. Not only do SMART classrooms enhance collaboration, but they also prepare students for in-demand careers. In an economy that's increasingly driven by data, analytics, cloud computing, and other advanced applications, technological literacy forms the foundation of many careers — including some of the most lucrative. From electrical and civil engineering to biotechnology and nursing, many jobs demand a high level of technological proficiency. By familiarizing students with educational technology at a young age, teachers can help to establish the skillset that will later be utilized to grow into fulfilling career.

This thesis analyzes the need to adopt novel technologies, tools, methods, and practices the K-12 learning enterprise, and explores the foundation needed to leverage the concept of creating a SMART enterprise.  Our case study examines educators of Saint Patrick's perceived barriers to technology integration and the leveraging of SMART classroom capabilities. Educators and administrators from Saint Patrick's pK-8$^{th}$ grade levels in El Paso, Texas were observed in their classrooms during an 8-week period. A discipline of Systems Engineering called systems thinking was utilized, and the systems engineering lifecycle applied to approach this case study and create an architecture for leveraging the baseline necessary to support a digital transformation within an

enterprise. To achieve our goal, we asked stakeholders what they would like to achieve. To better understand our stakeholder's needs, we conducted an in-depth observation. We then used that information to determine what processes and socio-technical activities, such as workforce training, need to be completed to leverage SMART classroom capabilities, and what is feasible for the enterprise.

Our approach involved the Systems Engineering practice systems thinking to view the system as a whole and understand how the social and technical aspects of the system can work together to leverage SMART classrooms. To merge these two entities our case study involves the installation of a reliable internet network along with training the workforce to better utilize digital technologies. A variety of systems engineering tools such as an enterprise architecture, a systemigram, and functional flow block diagrams were developed to better visualize the socio-technical aspects of the system. The results from this literature review and case study implicate that a reliable internet connection is the basic requirement needed for using this technology. Moreover, our thesis also identified the important role that enterprise members and administrators play in carrying out and influencing the work. A major area of focus during this site observation was teachers attitudes toward technology capabilities and their guiding principles, goals, and visions for adopting SMART technologies. Mission and vision communication from administrators, along with sufficient workforce training is pivotal to adopting digital transformation and leveraging the concept of SMART classrooms. Our students will inhabit a digital workforce; thus, it is morally imperative that teachers adopt technology. We are responsible for shaping how our students interact in their surrounding environment and the world.

**Keywords:** *Digital Revolution, Education, IoT, Systems Thinking, SMART capabilities*

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# Chapter 1: Introduction

Digital technologies have emerged in all facets of our lives – business, production, education, and many more paradigms. Education systems are undergoing a massive transformation in response to social, economic, and technological changes. In response to these tremendous changes, different approaches and reforms have been proposed. Auther Ekiz-Kiran describes the extent of engineering being integrated into the K-12 science standard documents and provides implications for integrating digital engineering elements during this transformation. Education is being transformed into context by new digital technologies. The results showed that the United States had placed a particular emphasis on engineering during this digital revolution. Information technology is a driving force for educational reform. If the enterprise goal is to increase innovation and productivity, structural changes supported by technology must be made instead of simple "Evolutionary Tinkering" (Burbules, N.C., 2020).

The technological revolution in education can no longer be captured simply by looking at computers in classrooms (Burbules, N.C., 2020). Most discussions have described computers as tools for conventional instruction. Recently, educators have begun to use digital technologies that have influenced not only the teacher's work nature but have also expanded the use of digital tools in education. Today, children grow up in a society with rapid technological developments and encounter a wide range of technologies in their everyday lives. To enable children to develop an understanding of the nature of technology, technology education as part of schooling from the early years is considered essential. Given these changes in our society, workforce, and everyday lives, a new type of education and capacity is arguably needed. What this requires is open to debate and depends upon perspective standpoints and educational paradigms (O'Brien, K., 2014).

## 1.1 MOTIVATION

The United States education system is facing a digital transformation. The demand for technology utilization and adoption is dramatically changing the skills needed in the labor market, from technology skills to performing tasks that require high-level capabilities (Conference Proceedings ICSNS XI, 2020). Leveraging SMART classroom capabilities from this digital transformation is not as simple as one may assume. One possible way to address current challenges is by understanding the education system as an enterprise where multiple systems operate with one another. Nevertheless, the implementation of a holistic perspective is not reflexive, as the perspective introduces new risks and potential challenges. To leverage smart classrooms in a school setting, further research efforts are needed to address social aspects, technical aspects, and the holistic understanding of the school. This involves the interworking elements of a school and how certain actions or changes could create a ripple effect.

## 1.2 PROBLEM STATEMENT

Currently, there is no clear rationale that explains the apparent difficulty with leveraging the use of educational technology from a systems thinking perspective and the baseline that needs to be established to adopt novel technologies during this era of digital transformation. According to the Innovation Diffusion Theory (IDT) (Jayawardena, C., 2020), adoption is a decision to maximize use of technology innovation as the best course of action for an enterprise available. It is pivotal to analyze the effectiveness of the changes that have taken place, if not completely, then at least from several sides – how formation and assessment of understanding are carried out when using digital tools in education, and to what extent digital tools facilitate the educative tasks of the teacher. In this thesis, a systematic literature review is conducted to identify the foundation required to support a SMART learning environment, and the architecture adopted across the enterprise to enable them to benefit from novel technologies such as the IoT.

The works of this thesis explore the activities, tools, methods, and processes that presented themselves upon leveraging the concept of a SMART classroom. In “You say you want a revolution? Transforming education and capacity building in response to global change”, O’Brien et. Al. highlights the importance of recognizing that there are different approaches and understandings of education. This diversity of perspectives on a revolution in education indicates that this transformation is not only about adjusting the external system from one assumed point of view, but that it is also about changing the way that actors perceive and interact with the system (O’Brien, K., 2014). This is potentially relevant to not only those directly involved in education, but also a broader spectrum of society that engages indirectly with education (e.g., parents, policy makers, businesses). A revolution in this sense involves transforming the teachers and administrators as well as the students. It can be considered a process of continuous change.

The goal of this thesis is to present areas of opportunity to leverage SMART classroom technologies to revolutionize teaching methods to ensure the development of 21st century skills, and in doing so, prepare students for the demand of the job market. The adoption of digital technology in K-12 classrooms has been gaining tremendous momentum across the United States since the 1990s (Cheung, A. C., 2013). To support the adoption of educational technology, the U.S. Department of Education provides grants to state education agencies. For example, in fiscal year 2009, the Congress allocated $650 million in educational technology through the Enhancing Education Through Technology (E2T2) program (SETDA, 2010) (Cheung, A. C., 2013). Given the significance of educational technology and the role it plays in shaping the future of students, it is pivotal to know how best to leverage SMART classroom technology to enhance learning.

The purpose of our literature review is to examine evidence from rigorous evaluations of the digital transformation in education, innovative technology applications, components of a SMART classroom, and the current and future state of education to determine how to best leverage the concept of SMART classrooms in the K-12 learning enterprise. To the best of authors' knowledge, currently there is hardly a holistic systems thinking view of factors that affect successful acceptance and adoption of digital transformation engaged in educational process. Understanding the socio-technical aspects of leveraging SMART classrooms can be beneficial to the improvement of educational practices. Hence, this concept-centric review aims at addressing this concern with the following research question:

**RQ1.** What processes and activities are needed to leverage the concept of a SMART classroom and what are the challenges faced?

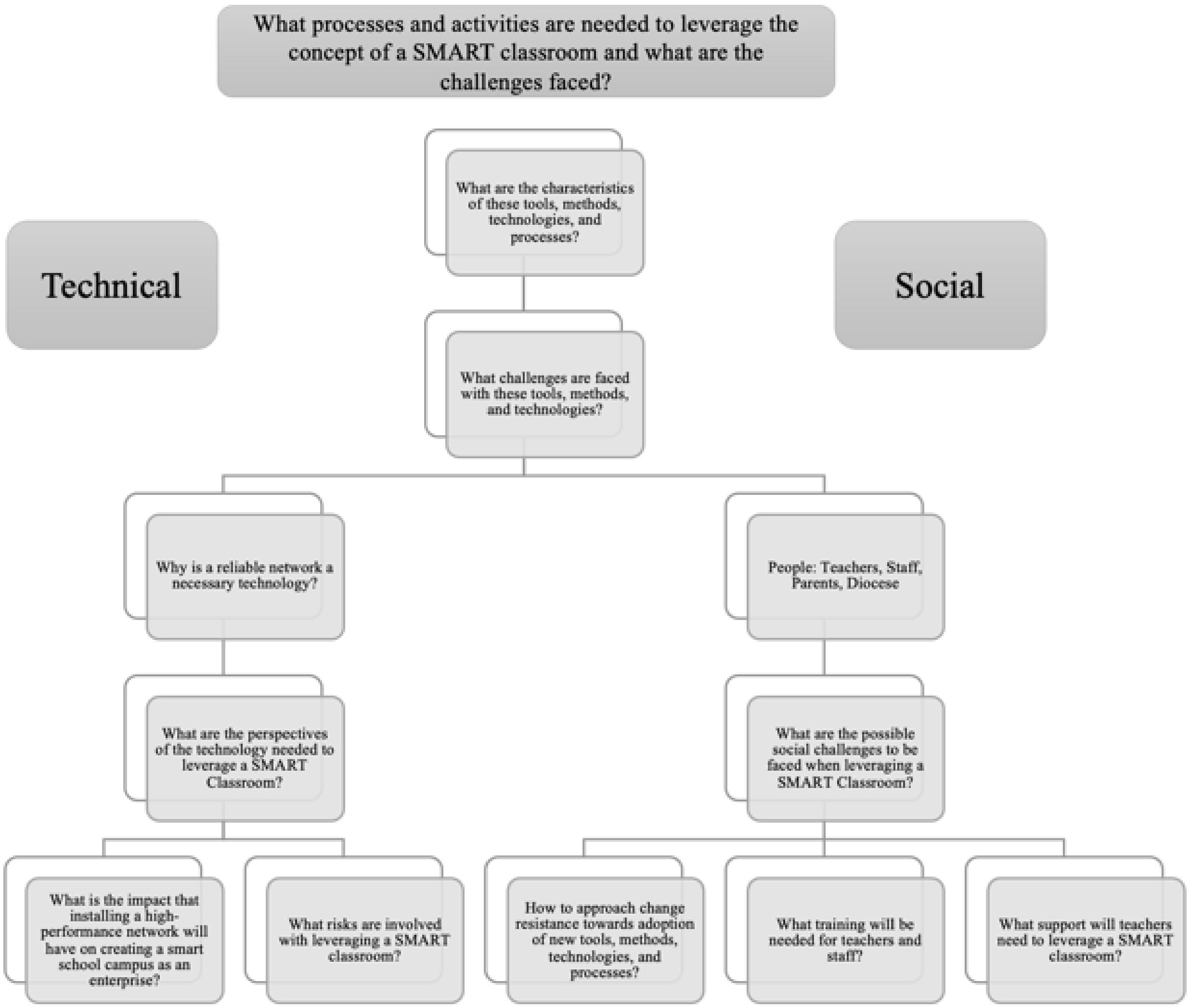


Figure 1.2.1: Thesis Question Map.

Moreover, the questions pondered upon investigating the concept of leveraging a SMART classroom, are shown above, and their implications explored throughout the findings of this thesis.

### 1.3 Thesis Organization

This thesis describes the digital transformation initiatives needed to leverage emerging technologies that support the SMART classroom shift for the K-12 learning environment. Chapter

2 covers extensive literature reviews on the digital transformation, systems thinking, the Internet of Things (IoT), Education as IoT, the current and future state of Education, an Analogy of IoT in Classrooms, components of a SMART classroom, and the advantages and challenges of digital transformation adoption in K-12 during this digital transformation. Next, Chapter 3 discusses the case study a newly installed Wi-Fi network, and the workforce culture change and training required to better prepare a school campus for the leveraging of SMART classrooms. Chapter 4 describes the case study procedures and research tools that allowed us to investigate the implications of the socio-technical activities in our quest to leverage the digital transformation. Chapter 5 presents a conclusion of these works with a summary of the work conducted and proposed future work. The thesis concludes with insights on limitations to be considered, and future work to be conducted.

### 1.4 BACKGROUND

The term digital transformation was first adopted by the private sector and is mostly associated with the need to use new technologies to stay competitive in the digital era, where services and products are delivered online (Mergel, I., 2019). Digital transformation is enabled through the application of smart devices and tools that enable real-time monitoring, updating, and services that transform processes and activities (Mergel, I., 2019). It is urgent to utilize emerging technology to realize digital transformation within enterprises. A revolution often referred to as Industry 4.0 facilitates a significant positive relationship between digital technology adoption and digital transformation performance (Awan, U., 2021). Li et al. (2020) argue that digital transformation is a complex process that organizations must develop to build digital capabilities to take full advantage of the benefits offered by Industry 4.0 and stay competitive.

## 1.5 Thesis Objective

In this paper, we suggest systems thinking as a powerful tool to amplify the understanding of how the digital transformation can enable educators to connect technology to build an integrative curriculum for students preparing to enter a workforce where digital technology aptitude is essential. More specifically, we aim to identify the activities needed to leverage the concept of SMART classrooms, what that is, the advantages, and challenges that are faced. There are several studies and public policies addressing the necessity of the preparation, training and improvement of the current workforce. (National Research Council, 2010). According to Mendes (2015), competences become skills and those skills can become a competitive advantage.

## 1.6 Benefit of Study

The rapid changes in internet technology could help in achieving SMART classroom implementation and effective application in both teaching and learning. Advances in teaching methods and tools have created a revolution in curricula and classrooms (Shudayfat, E.A., 2022). The global job competition has dictated the progress in educational systems and has made the adoption of novel technologies necessary in order to gain competitive advantage (Oztemel, E., 2020). SMART classrooms could arguably help students improve academic competence, develop employability skills, and enhance a student's knowledge and development of 21st century skills. Moreover, this study on leveraging the concept of SMART classrooms for the pK-12 learning enterprise can be used as a learning paradigm for small to medium enterprises looking to adopt emerging technologies into their activities, methods, and processes.

## 1.7 Methods

The systematic literature review portion of this thesis will also be used to analyze the architectural framework needed to be put into place for leveraging SMART classrooms. This systematic review is essential to analyze smart classrooms during a digital transformation. From this literature review, an architectural framework for leveraging SMART classrooms and technology was developed, as well as a heatmap of network coverage on a school campus. This network heatmap data will be used to improve performance in things like fixing wireless dead zones, creating adjustments, and improving wireless coverage. The goal of the proposed architectural framework is twofold: (1) provide concepts that aid the understanding of leveraging SMART classrooms and the infrastructure required to implement them; (2) present a Wi-Fi network which enables teachers, faculty, students, and parents to leverage a SMART classroom learning environment.

# Chapter 2: Literature Review

A systematic data collection method and analysis was implemented to let the topics related to the digital transformation and SMART classroom leveraging. To be included in this review, the following inclusion criteria were established, the studies evaluated any type of educational technology applications, including computer assisted instruction, integrated learning systems, and other technology-based programs, used to improve learning, and the studies involved students in grades K-12. The university database, and web-based repository, Google Scholar, were used to find related articles. A comprehensive literature search of articles written between 2010 and 2022 was conducted using different combinations of key words (e.g., Digital Revolution, Education, IoT, Systems Thinking, SMART capabilities.). The majority of studies and articles from the literature review come from four educational databases, JSTOR, ERIC, EBSCO, and Dissertation Abstracts.

To aid in investigating our thesis research question a five-step methodology was utilized. The literature review of the digital transformation in education serves as a basis for exploring examples of case studies, innovative policies, the leveraging of SMART classrooms, and other initiatives designed to overcome barriers for implementing digital education initiatives in the United States and other parts of the world. This literature review produced best-practice overviews, lessons learned and a set of recommendations for actions at organizational and systemic levels of digital transformation leveraging.

## 2.1 LITERATURE REVIEW PROCEDURE

The collection of articles was conducted by a step-by-step process to identify the relevant literature in the field. The literature review considered the following keywords and searched for terms:

*Digital Transformation, Education, IoT, Systems Thinking, SMART capabilities.*

These keywords were searched in Miner Quest through The University of El Paso's library databases for relevant literature. After discussing and analyzing the titles and abstracts of all resulting papers from initial search, 127 potential focused papers were identified. However, after critically reading the identified 127 papers entirely in a second iteration, 100 papers relevant to this research were determined. These one hundred papers were entered into an excel spreadsheet to be used to perform an in-depth analysis, assessing challenges, methods, processes, and benefits, among others. This process has been summarized below in Figure X.

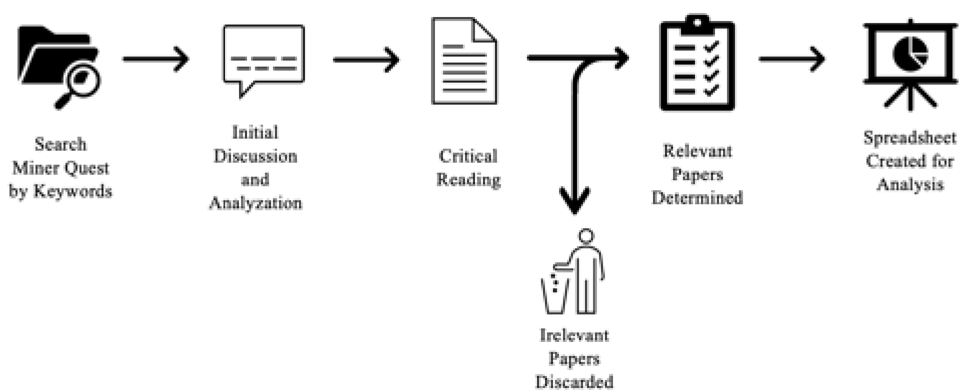


Figure 2.1.1: Literature Review Screening Process

Through this systematic literature review we were able to determine the current and future state of education, as well as the implementation of IoT in K-12 education, with its advantages and challenges. Moreover, this literature review helped define a consensus of the components necessary for a smart classroom, and the definition of Systems Thinking. Through this literature review, the need for a reliable Wi-Fi network to implement the IoT in a smart classroom presented itself. A robust Wi-Fi network with a reliable connection lays the groundwork for the architecture of a smart classroom.

The following sections within this literature review portion serve to inform and walk us through the setting of the problem, how we will be approaching the problem, the elements of a SMART classroom, current and future state of K-12 education, and the advantages and challenges of a SMART classroom. Our systems thinking approach to leveraging SMART classrooms during the digital transformation is a discipline and way of thinking that will benefit this project because it examines the enterprise as a whole and identifies the system, subsystems, functions and capabilities independently, then studies their interconnections and interactions.

### 2.2 Digital Transformation

Digital transformation is about leveraging technologies to maximize productivity, value creation, and social welfare (Almeida, F., 2020). This term encompasses the comprehension necessary to take the required actions when enterprises face new technologies; it is not to be confused with reflexive change (Singh & Hess, 2017). At a high level, digital transformation is comprised of the changes taking place in enterprises and industries using digital technologies (Agarwal et al., 2010; Majchrzak et al., 2016). Digital transformation is opening the doors for technology innovation, collaboration, and new enterprise models. Digital transformation is a megatrend across industries driving technologies such as data analytics, cloud storage and services, virtual and augmented reality with visualization and simulation, pattern recognition, machine learning, and AI. Digitalization also provides productivity improvements, cost reductions, and innovations (Hess et al., 2016).

The increase in the use of digital technologies within economies has called attention to the importance of digital transformation and how it can help businesses stay competitive in the market

(Kraus, 2021). Research highlights that digital transformation should be considered in architectural enterprise perspectives, as this topic addresses much more than just the digital transformation (Bouncken et al., 2021). Successful enterprise technology leveraging is achieved by concurrently exploiting and exploring what is offered through achieving organizational agility (Hess et al., 2016). According to Li (2020), novel technologies facilitate the development of a wider range of new business models and not only transform them, but also serve as a new means to communicate and interact with stakeholders. However, not all individuals possess the knowledge and skill set to adopt this digital shift, making it pivotal to train employees properly, as they may be affected by the new working environments created by this digital transformation.

## 2.3 Systems Thinking

As the world of technology evolves, and new capabilities, and devices emerge, systems are becoming more complex and interconnected. SMART classrooms are considered a system in this context. Through the application of systems thinking, one is better able to understand the deep roots of these behaviors and how they have the potential to affect the entire system. The understanding of these behaviors can help one predict, maintain, and take preventative measures to ensure the system is running optimally. Systems thinking consists of three main components: elements, or characteristics, interconnections and their feedback and relations, and a function or purpose (Meadows, D.H., 2008). Barry Richmond, the prime mover of the concept of systems thinking, defines this as the art and science of making reliable interpretations about behavior of a system of interest by developing a deep understanding of the system structure (Richmond, 1994). He emphasizes that people embracing Systems Thinking position themselves such that they can see both the forest and the trees; one eye on each (Richmond, 1994).

From a systems thinking standpoint, it is feasible to holistically view a transformation, and propose a real understanding of impacts, allowing the development of strategies that contemplate new needs and requirements of this paradigm (Oliveira, B.G., 2020). The term has been defined and redefined in various ways since its coining by Barry Richmond in 1987. After conducting a literature review on systems thinking, and the ideas surrounding this topic, a consensus on the definition of the term was drawn. Systems thinking focuses on the way that a system's constituent parts interrelate and how systems work overtime and within the context of larger systems. This set of skills allows the user to take a holistic approach to analyze the system with the capability of identifying and understanding sub systems and predict their behaviors. This in turn allows the researcher to use inferred reasoning to suggest changes to produce desired effects.

In 2015, Arnold and Wade set on an academic quest to approach systems thinking as a system by identifying its goal and then elaborate upon both its elements and the interconnections. To do this, they conducted an extensive review on systems dynamics literature and were able to create a list of Systems Thinking Characteristics from their findings. This list included: identifying interconnections, avoiding working in silos, synthesizing methods or tools, recognizing feedback loops, understanding causality, identifying and understanding non-linear relationships, differentiating types of flows and variables, understanding dynamic behavior, reducing complexity by modeling systems conceptually, and understanding systems at different scales. A systems thinking approach to interconnections identifies that processes, tools, and people are connected.

Another component of systems thinking is synthesis, which is the harmonization of two or more things to create something new. “Sometimes you are combining old ways to harmonize a new way. In some instances, you may gain new information and create something new,” Marticek says. Feedback loops are a critical part of systems thinking because they illustrate feedback between various parts of a system via models and diagrams. Moreover, this approach looks at how one element influences another in an interconnected system. Systems mapping, such as a systemigram, is the system visualization that will inform decision-making. “If you hand this to an executive, this flow diagram will help them understand what is needed to make the change,” Martiček says. In this paper, we suggest systems thinking as a powerful tool to amplify understanding how technologies of this digital transformation can be leveraged to create a SMART classroom that enables educators to connect technology to building an integrative curriculum for students preparing to enter a workforce where digital technology aptitude is essential.

### 2.4 Internet of Things

The Internet of things can be described as a group of interconnected devices, and infrastructures that allow access to their management, and the access to data they generate. P. Helmiö describes the IoT as being “built for bigger ‘things’ than simply home and Alexa devices. IoT in classrooms makes students more productive. IoT devices have the potential of keeping students safe in their classrooms. IoT devices such as wireless locks, RFID cards, etc. can work together to enhance a school campus’s security. The IoT transforms our students digital and technical world (Iivari, N., 2020). By 2025, more than 75 billion IoT-enabled devices will be installed around the globe (Yadav, C.S., 2022). Internet of Things is commonly percievedregarded as the evolution of the internet. The internet of things shows promise to revolutionize several areas, such as being able to interconnect objects through networks, whether they are from internet or not, transmit and share important information, which will allow companies to streamline many of its processes. (Evans, 2012).

The IoT has the ability to rapidly transform the traditional education system into a more flexible and adaptive means of educational instruction (Balog, K., 2020). Therefore, the influence of IoT technologies on our educational systems is inevitable. There is significant potential for IoT technology to improve the process of teaching and learning and make “anytime, anywhere” a reality (Mingsiritham, K. 2020). However, the educational use of the IoT is still in its early stages of development (Dai, Z., 2021), and only a limited number of articles have focused on applying the IoT in education, particularly within the context of developing countries (Shayganmehr, M., 2021). For example, in a recent systematic review, observed that the acceptance and potential usage of the IoT in education are still rare, especially in developing countries (e.g., Saudi Arabia)(Al-Abdullatif, A. M., 2022). This leaves plenty of room for researchers to study the issues impacting the educational applications of IoT, particularly in developing countries. Research in this field is scarce and relatively new.

### 2.5 Digital Transformation in Education

Digitalization affects not only the content of education, but also its delivery, organization, and culture. Adopting novel technologies possesses the potential to transform things in almost every area of the digital age, in conjunction with Industry 4.0. These rapid changes in the world affect education both as an organizational enterprise and as a revolutionary learning environment. One of these values has been the digital transformation. Students are born in a digital world where technology usage becomes more and more prevalent in our everyday lives. Digitalization within educational learning environments coincides with the use of digital technologies for learning and development. When considering digital transformation caused by emerging technologies it is important to explore the impact of school connectivity and the opportunities that the appropriate use of technology can bring to education.

The digital transformation is one of the most crucial challenges for education during this day and age (Erstad, O., et al., 2018). The digital transformation that we are currently facing is reshaping the job market and posing new challenges to education, yet there is little research that specifically examines the goals of school administrators to adjust leadership styles in order to influence digital development in K-12 schools. This goes beyond the integration of technologies, and also requires changes with regard to school curricula and the overall approach and delivery for educators so that students are better prepared for different job markets and societies. An important part of this technological adoption is that school leaders must highlight the underlying goals prior to other steps of implementation like adapting the curriculum, and empowering teachers to adjust their teaching accordingly. Providing suitable support, adequate training, and professional development opportunities so that technology becomes a meaningful part of the school culture is essential (Ruloff, M., 2022).

### 2.6 EDUCATION AS IOT

The core of Industry 4.0 is the IoT, which enables the connection of systems, people, machines, and products (Gilchrist, A., 2016). Industry 4.0 can be seen as the revolution that has facilitated the digital transformation of the manufacturing sector, with embedded sensors in product components and manufacturing equipment, and analysis of all data. Engaging students is seen as crucial for student learning in various environmental settings, educational stages, and school subjects (Wang, J., 2022). Recently, many emerging technologies (e.g., Internet of Things, Big Data Analytics, Augmented Reality, Virtual Reality) have been sugested for the transformation of traditional classrooms into classrooms with SMART capabilities that can be effective and engaging when it comes to stimulating the student learning environment (Wang, J., 2022).

However, even while we live in a world that surrounds us with these technologies, the reality is that these cutting-edge technologies are unavailable in most learning environments

(Wang, J., 2022). Therefore, the founding framework of digital devices and resources is the starting point of this study aimed at encouraging technology-based teaching and learning. As smartphones become increasingly popular, this technology helps to establish better communication and interaction with teachers and students (Halili, S.H., 2019). The conventional educational enterprise can be transformed into a more efficient e-learning platform, with many virtual interacting objects involved in the learning process (Bajracharya et al., 2018).

### 2.7 CURRENT AND FUTURE STATE OF EDUCATION

Digital classrooms use technology as a means of education. There are several benefits of a digital classroom. Unlike traditional teaching, where access to information is limited course content, and. Compared to real-life classrooms, data from a digital classroom provides the opportunity to combine the high methodological rigor of a standardized environment with an authentic representation of a classroom situation with all its accompanying dynamics. The transition from traditional classroom learning environments to smart classroom learning environments presents significant implementation challenges.

Digitalization of education as a useful instrument is a mediator between a teacher and a student. It is necessary to understand that any instrument at the "output" gives what was originally put into it, and in any formal system, a formal indicator designed to reflect something that is not fully amenable to formalization tends acquire a self-sufficient character and distort value judgments regarding the process characterized by this indicator. This fully applies to the formation and assessment of understanding when using the considered digital tools.

The International Society for Technical Education (ISTE) is a non-profit organization that serves educators who use technology in education and seeks to promote the integration of technology in teaching and learning. In 2016 ISTE set standards for students to make them capable and ready to get involved in a world that is digitally connected. Students and teachers in this digital transformation should be made ready to live in a regularly evolving technological atmosphere. The standards set by ISTE are designed to empower the voice of students and to ensure that learning is a process that is to be done by the student (Darling-Hammond, L., 2020). ISTE envisions a student of this digital transformation, as an empowered student, digital citizen, innovative designer, knowledge creator, creative communicator, and a global collaborator (Ghozlan, A., 2020).

According to Mohamed et al (2018), Industry 4.0 is identified as the fourth industrial revolution that can be characterized by a combination of new technical components to achieve horizontal and vertical integration or value networks. Thus, Industry 4.0 can be defined as the conceptualization of the rapid changes found among technology, industry, and societal patterns (Kozlovska, M., 2021). Moreover, industry 4.0 describes the realization of new practicality, principles, and values that have not been seen before. These new values and standards will shape the qualifications of the workforce demand for a digitized future.

### 2.8 Analogy of IoT in Classrooms

The digital transformation that Industry 4.0 has brought forward has not only launched novel technologies for educational use, but for many other domains and enterprises as well. For example, Industry 4.0 is revolutionizing the way companies manage, improve, and develop their processes and products. This fourth industrial revolution is introducing cutting-edge technologies such as the Internet of Things (IoT), cloud computing, analytics, and AI and machine learning into their production facilities and throughout their operations. Industry 4.0 is comprised of technologies such as IoT, big data, cloud computing that can be used to provide a fully connected SMART network to reduce task computation time while enhancing production within smart manufacturing systems.

To realize the benefits of Smart Manufacturing, a rationale is needed to lay the foundation of standards that Industry 4.0 enabled smart manufacturing systems need for successful adoption. Standardization is a key factor in the implementation of Industry 4.0 emerging technologies, as it proposes the shift from traditional methods and tools towards a data-driven system interconnected by the Internet of Things. The foundation of standards required can be described as sets of criteria within an industry relating to the standard functioning and carrying out of operations in their respective fields of production (Tortorella, G.L., 2019). In layman's terms, it is the generally accepted requirements followed by the members of an industry. Standards provide an orderly and systematic formulation in a particular industry or sector of the economy. To explore this topic the corresponding required standards, interoperability, interface, technology implementation, management challenges, application, and development are explored.

## 2.9 Components of a SMART Classroom

The concept of a SMART classroom has been around for decades, and many definitions for it have surfaced over the last few years as the popularity of this approach has grown. A SMART classroom can be defined as a learning environment for students and teachers that is enhanced by technology to improve the learning experience. Technology, people, processes. Learning management system, interactive control center, on-demand collaboration, on-demand visual learning, lecture recording equipment, learning applications, integrated learning technologies, projectors, interactive whiteboards, smart storage, interactive projector, etc.

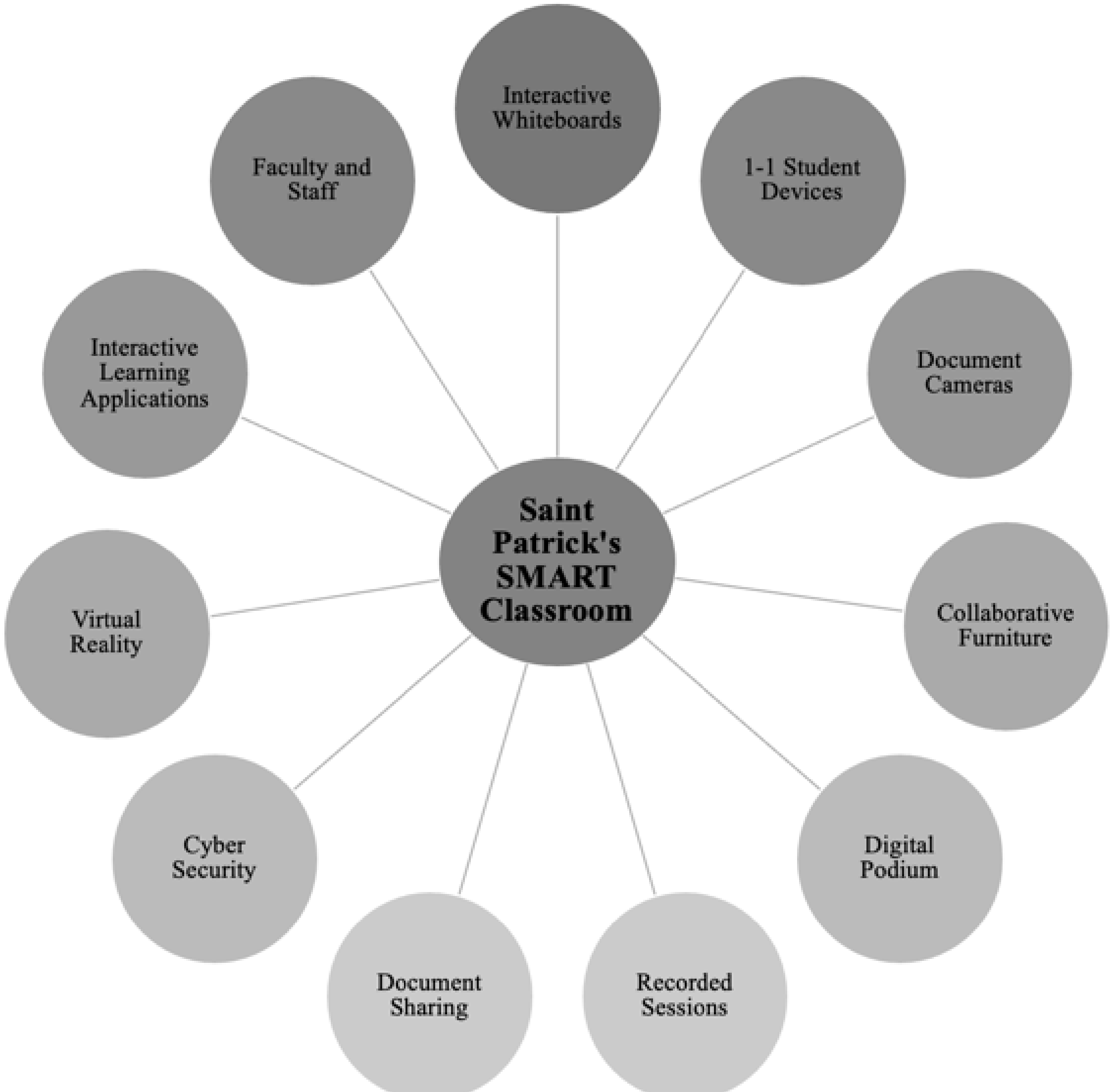


Figure 2.9.1: Opportunities for SMART Classrooms

Not only should we investigate technology integration in the classroom, but the physical classroom environment should also be investigated to facilitate students' engaged learning. Research on the SMART classroom environment has shown that the physical arrangement can affect behavior of both students and teachers (Yang, J., 2013), and that a well-structured classroom tends to improve student academic and behavioral outcomes (Yi, H.S., 2017). martmartAn adaptation of The SMART Classroom model developed by Huang et. al. (2019), is shown in Figure X.

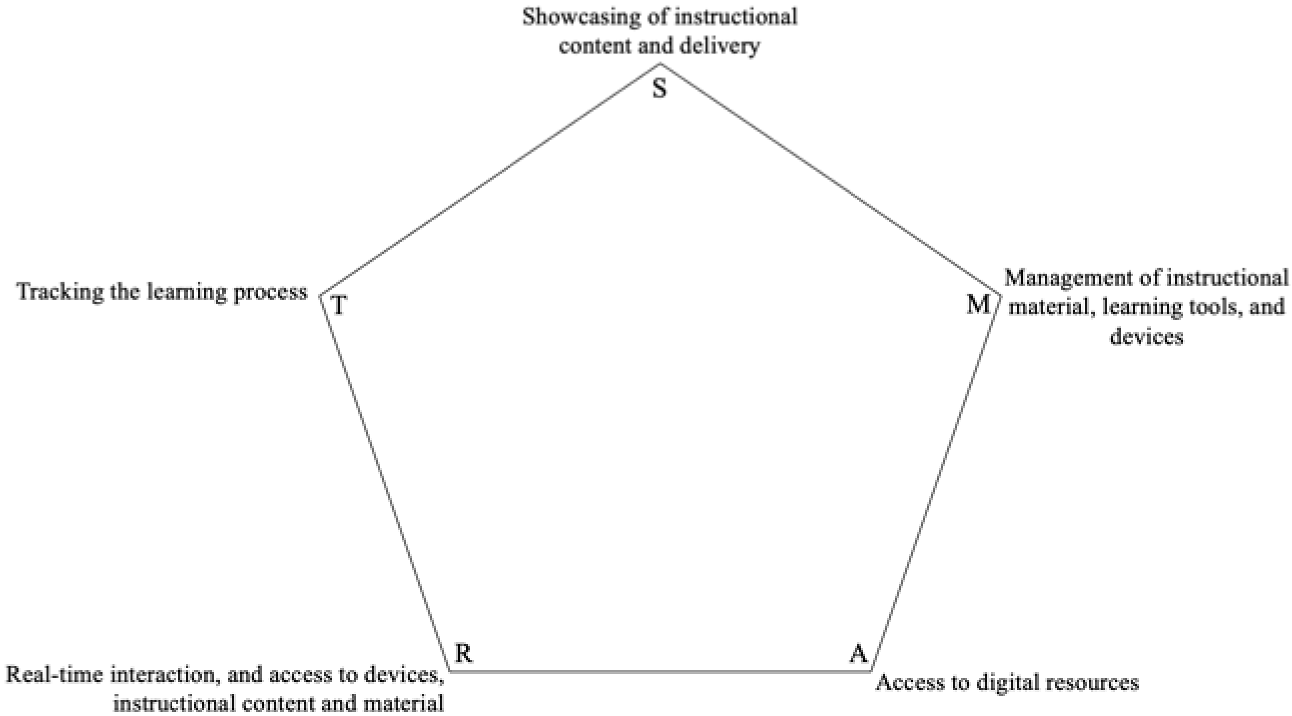


Figure 2.9.2: Ideal SMART Classroom

The ideal future SMART classroom involves a great deal of collaboration and interaction and is student-led. Moreover, the concept of SMART classrooms includes 1-to-1 devices; every student can access educational technologies whenever possible. In this SMART classroom environment, students control the course study and explore curriculum independently. These spaces include all the technology needed, such as VR headsets, tablets, and laptops.

### 2.10 ADVANTAGES

They are capable of engaging the students in learning and keep inspiring them to learn more (Halili, 2019). The latest advancements in technology for teaching which may bring enormous vicissitudes in every aspect of life from manufacturing to daily life, from learning to social commitment are listed Orak, S.D., 2021). Cloud computing enables students to keep their study material in the cloud and access it from anywhere without any cost (Kaliraj, P., 2022). A multitude of insights can be obtained from student data if they are analyzed using the right tools. With innovations such as adaptive instruction, an educator can work collaboratively with technology and data experts to help design learning environments that pinpoint identify learner difficulties and suggest instructional interventions that can help remedy them (Burbules, N.C., 2020).

New teaching and learning technologies, like the use of social media and other resources, are powerful tools for data collection and tracking of learner activities, and difficulties. Big data technology enables an institution to use this data and analyze it to determine the academic performances of students, drop-out patterns, attendance patterns, and the like (Kaliraj, P 2022). The delivery of visual presentations is a fundamental part of the teaching and learning process. The use of interactive screens with multi-touch are programs are a great way to enhance skill development and create interactive content, that aids students in acquiring knowledge in a curious manner. Augmented Reality can be applied to classroom learning in subjects like physics, biology, and chemistry and can be adopted to augmented books (K. Lee, 2012).

Teachers and administrative staff can use this data to guide their own decision-making and planning. These novel tools and capabilities offered by the digital transformation in education provide other potential uses for leadership and governance as well: sparking communication with parents about school performance, discussion of goals and priorities, keeping parents informed about the learning curriculum, and engaging them in reinforcing learning goals at home. Another aspect of this leveraging of novel technologies is to break the gap between "schoolwork" and "homework"—to create a more continuous flow of teaching and learning, whether it be at home, the library, school, etc.

## 2.11 Challenges

As we transition into emerging technologies, researchers and policy makers are advocating for students to learn a broad set of skills, often referred to as "21st century skills," such as collaboration, critical thinking, design, and evidence-based reasoning (NRC, 2010). With the development of the internet, cloud computing, and other emerging technologies, the concept of SMART classrooms has been proposed and put into construction by many educators. Unfortunately, classroom environments have not completely evolved to support students in the new modes of collaboration. Classroom furniture that could be leveraged to support new modes of collaboration include swivel chairs, floor cushions, and ottomans for flexible seating options to promote idea sharing that characterize many of our research-based innovations.

The center of digital innovation lies in value creation, and value creation includes two categories: enhancing the existing value and creating new elements (Kraus et al., 2022), which coincide with digital innovation activities. In the digital context and under the pressure of transformational needs, this understanding of activity evolves into a process of adoption of digital technologies (Usai et al., 2021). While some educators have clear perceptions about educational opportunities surrounding digitalization, some struggle to cope with adopting new practices. Providing support to educators can make teachers confident in adopting technologies into their teaching routines. In effort to support teachers in managing a SMART classroom, it is important to first understand the challenges they face when engaging with these activities. The use of digital devices has the potential to change the physical and psychosocial classroom environments in either negative or positive ways.

Despite all the advantages of digital education, its weaknesses have emerged, and need to be worked on in order to bring the domestic education system to the leading edge. To achieve these goals, it is necessary to take into account that digital education is not limited to distance education but can act as an integral part of full-time education in the form of presentations at lectures, automated homework checking and testing works, information support for modules of the studied disciplines. There are a considerable amount of barriers to consider when making transformative changes in education, not because of a lack of tools, approaches and technical solutions, but due to culture change resistances. (O'Brien, K., 2013). It should be also noted that the students who have been trained using digital technologies will be able easily find themselves within the framework of future "Digital Economy", develop their propensity for further self-education. All these facts point to great prospects for digital education in a modern university (Filimonova, E. G., 2020).

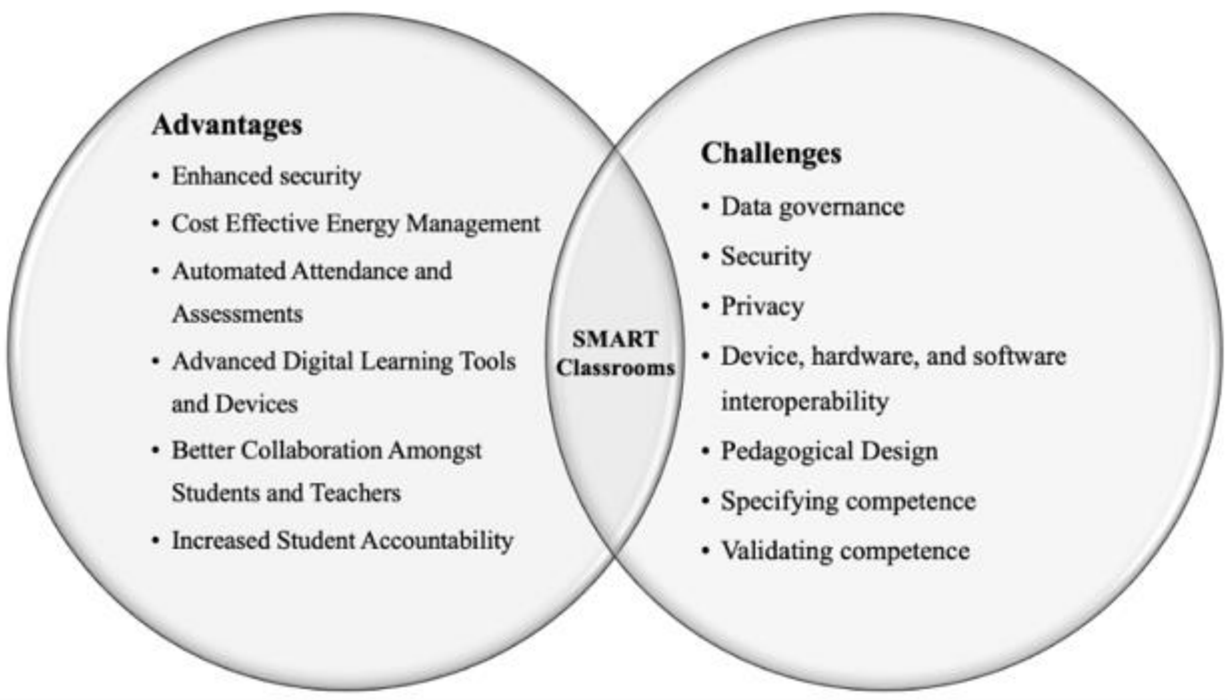


Figure 2.11.1: Advantages and Challenges of SMART Classrooms

While the benefits and challenges of leveraging a SMART classroom are presented in the figure above, we need to realize that the question of whether to adopt SMART classrooms or not, isn't the right frame of mind here. It would be to our benefit that we embrace the advantages while preparing ourselves for the challenges to be faced upon leveraging a SMART classroom. We need to make sure our students do not to walk into the workforce inexperienced and underprepared. Technology does not have an expiration date. Whether SMART classrooms leveraging is viewed as advantageous or disadvantageous, it does not change the fact that technology is not slowing down. Our students and students of the future will inhabit a digital world, thus it is a morally imperative that teachers adopt technology because we are responsible for shaping how our students interact in their surrounding environment and the world.

## Chapter 3: Case Study

In this age of digital information, wireless networks have become one of the most important infrastructure facilities and the Internet has become an essential technology and service for everyone. For teachers, students, and staff, a reliable Wi-Fi network is critical to their success. Many student devices are Wi-Fi-only in their ability to connect, whether it be for connectivity during classroom instruction or individual study. When Saint Patrick's began the process of leveraging a SMART classroom, we quickly realized that Wi-Fi network optimization is a crucial factor in adopting new technologies. To achieve this, Cambium Networks and advanced optimization tools from Ekahau were utilized to explore possible improvements to their digital infrastructure. In this case study, Cambium Wi-Fi network performance, and the Access Point (AP) location suitability was studied for a medium sized wireless network belonging to a Pre-K through 8th grade private school campus. To achieve optimal network connectivity from a user point of view, the access points should also be placed allowing for optimal network performance and not merely the coverage area.

While conducting our site observation for our case study, it was determined that a lack of communication and understanding of teacher, infrastructure and organizational needs were some of the most counterproductive factors when attempting to leverage the concept of SMART classrooms. Teachers, and administrators are trying to leverage SMART classrooms by a single approach instead of creating synergy between the social and technical aspects and viewing the entire system as a whole with interworking components. It is for this reason that we decided to approach this socio-technical problem with a systems engineering lifecycle and systems thinking perspective.

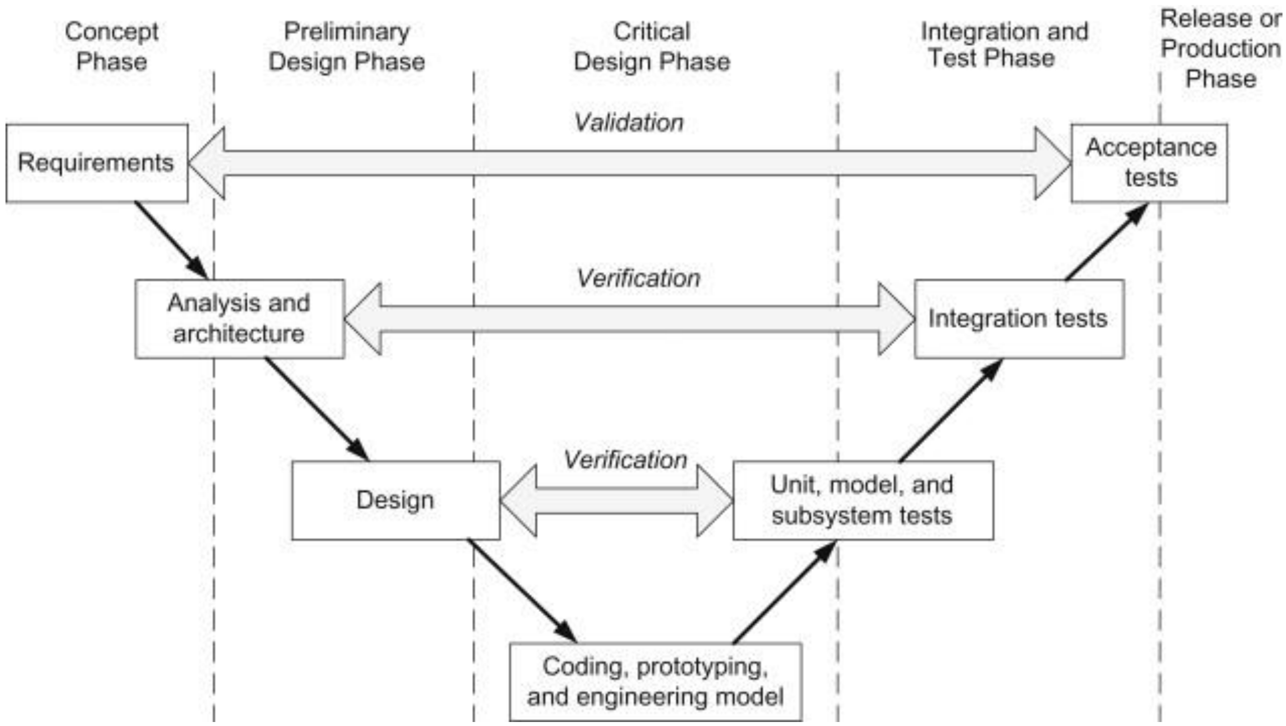


Figure 3.1: Systems Engineering INCOSE SE V Process

We used systems thinking and then approached the problem with Systems Engineering processes. In the development of a competency framework for Systems Engineering (SE), the International Council for Systems Engineering (INCOSE) includes systems thinking as one of three main categories (the other two being holistic life cycle view and systems engineering management) of the framework (Frank, M., 2012). The application of systems thinking to leverage the concept of a SMART classroom for Saint Patrick's will allow us to understand all the components of the system and how they work together. This systems thinking approach allows us to identify needs, determine stakeholder requirements, project planning and operations development, and perform an analysis of the system. Systems thinking is commonly accepted as the backbone of a successful systems engineering approach.

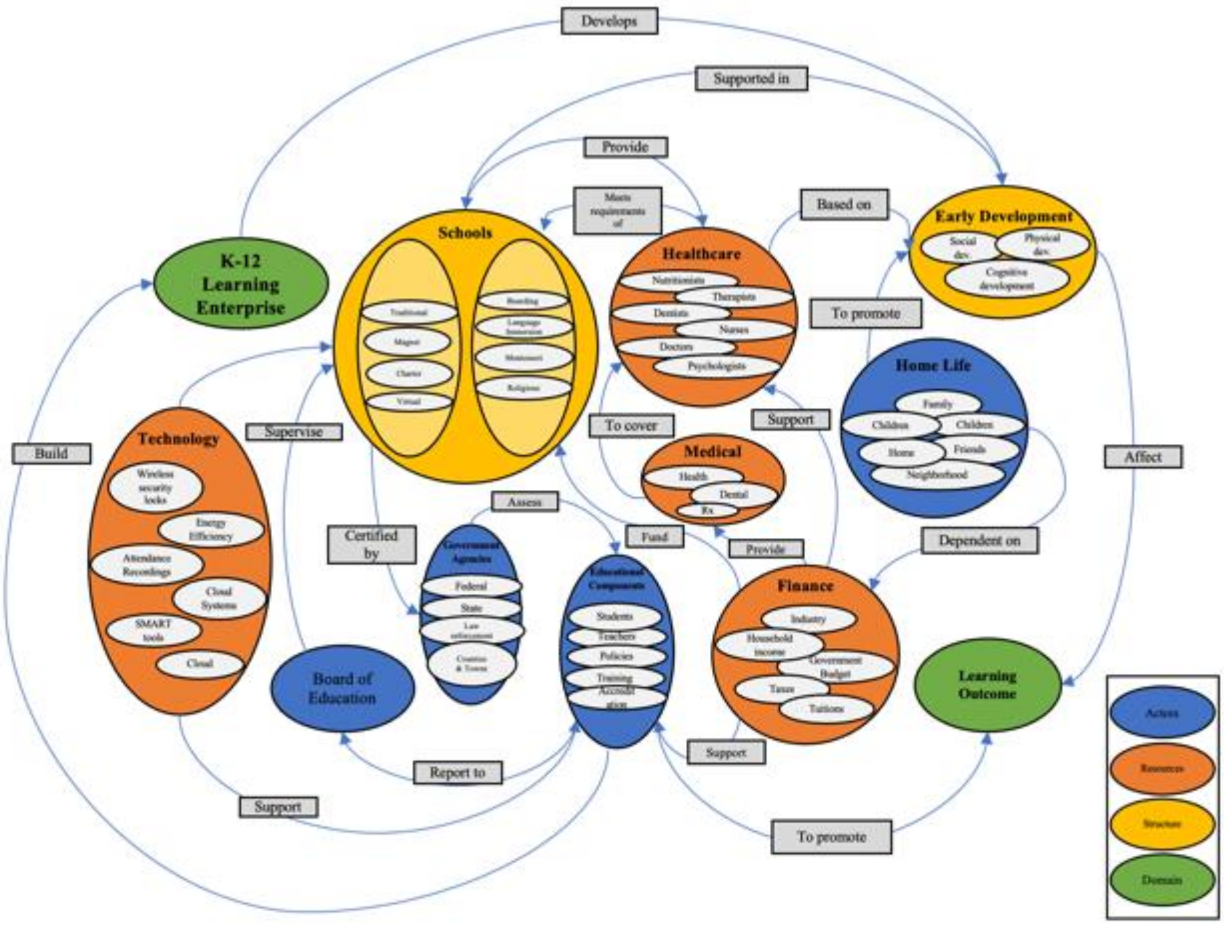


Figure 3.2: K-12 Learning Enterprise Systemigram

To further our systems thinking approach, a systemigram was developed. Systemigrams are useful learning tools for visually representing natural language descriptions of complex systems. The development of this systemigram helped us better understand the traditional K-12 learning enterprise. It is important to understand these interconnections and interacting subsystems to recognize how the enterprise interacts with different components. Systemigrams are a useful way to engage system stakeholders in conversations that help them visualize deeper insights into a system's overall construction and operation (Mehler, J.A. , 2011). The development of this systemigram allowed us to identify the social and technical entities of our system.

For a better understanding of the flow between these entities we took our investigation a step further and adapted a block diagram from "A Theory of Enterprise Transformation," by W.B. Rouse et. Al., as shown below. Within this step we considered the architecture of private schooling within the Catholic Diocese shown In Figure X. The performance execution that can be satisfied at the lowest level, Work Practices are limited by the next level Delivery Operations. Work can only be accomplished within the capacities provided by processes.

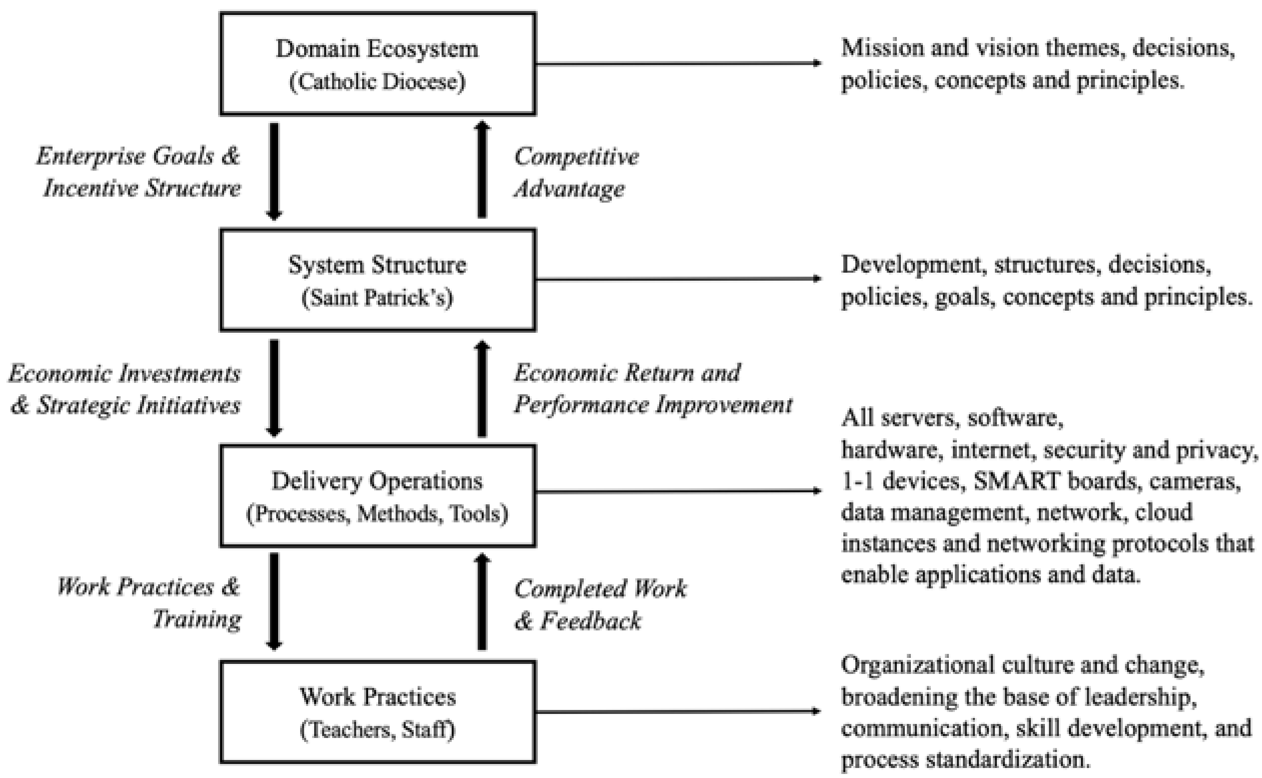


Figure 3.3: Functional Flow Block Diagram

Performance execution that can be gained from improved operations is dependent on the performance of the level above, System Structure. Potential efficiencies in system structure are limited by the ecosystem in which these organizations operate. The Catholic Diocese, economic conditions, and government regulations and policies will affect the processes that the enterprise is willing to invest in to enable Work Practices, whether these people be teachers, staff, or administrators.

### 3.1 Case Study Procedure

First we spoke to our stakeholders about the broad concept of what they would like to achieve. For us to understand our stakeholder's needs, we conducted a classroom, and teacher instruction observation – not from the curriculum standpoint, but from delivery viewpoint. Upon identifying requirements, we then decomposed them into lower and lower levels of detail. In this case, since leveraging a SMART classroom is the enterprise goal, we identified the tools needed, the type of capabilities a SMART classroom would be able to provide. Upon decomposition of this big picture, we determined that the first step and crucial baseline for leveraging a SMART classroom, is to establish a reliable and robust network for devices to operate on, and material to be shared, saved, and worked on collaboratively. Moreover, we also realized that sufficient training for teachers would need to be provided to teachers using novel technologies in order to fully execute and leverage a SMART classroom.

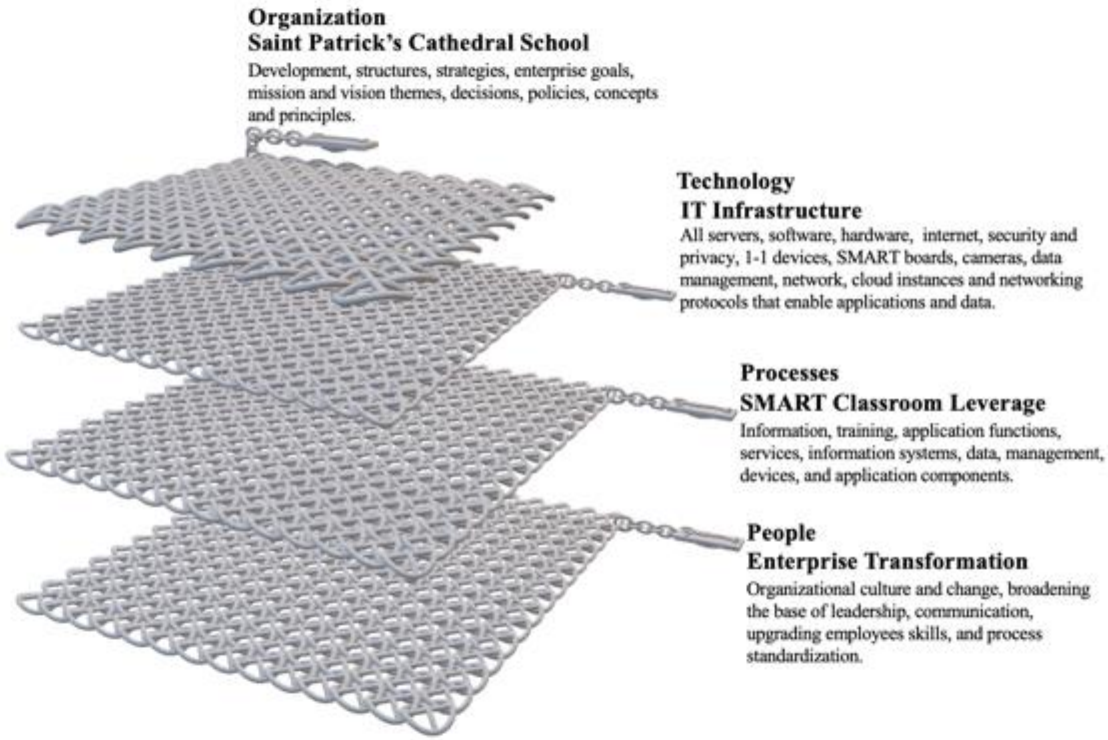


Figure 3.1.1: Enterprise Architecture for Saint Patrick's

This enterprise architecture applies architecture principles to guide organizations through the alignment of these architecture domains: organization, technology, processes, and people. Enterprise architecture is a visual aid that can be used to align an enterprise's strategy and operating model. Enterprise Architecture outlines and presents opportunities on how to manage technology, processes, and people to achieve mission and vision themes. In short, an enterprise architecture can be developed as a blueprint to support the transformation of the enterprise through its socio-technical journey. 4 primary architecture layers ensure this cohesiveness:

1. Organization architecture: This layer describes the enterprises strategy, the organization, the mission and vision themes, and the policies and principals that affect the organization.

2. Technology architecture: This layer identifies the servers, cloud instances, software and hardware that support the applications and data and understand how they are deployed. Additionally, devices such as SMART boards, document cameras, and 1-1 devices are also included in this layer.
3. Process architecture: This layer defines the enterprise's application, integration, and how these IT assets support the processes and services delivered. This layer also includes the process of educating teachers and administrators on the value of the mission and vision themes of the enterprise.
4. People Architecture: This layer defines the enterprise's organization culture and change, the skills required to deliver services, the training that helps ensure employees are educated to support enterprise needs.

Next, we began exploring how we could take these requirements and turn them into a system. We looked at the physical and organizational architecture of the enterprise to understand the ability to install a new network in a 100+ year old school and understand the operations of the enterprise. After investigating the architecture of the school campus, we looked into the specific design of the school. This includes the materials that the school campus was constructed with, the thickness of the walls, the mapping of the school, and other physical components of the campus.


Illustration 3.1.2: Aerial View of School Mapping

Illustration 3.1.3: View of Thickness of Wall

The historical nature of the development of this campus is very unique. The Sisters of Loretto at the Foot of the Cross opened St. Patrick Cathedral School in the fall of 1923 with 220 students in grades 1st through $7^{th}$ (Saint Patrick Catedral, 2023). The first stone was laid on July 31, 1914 (Saint Patrick Catedral, 2023). The style is a blend of inspired by the churches of medieval Byzantium and Romanesque architecture, and is composed of materials such as reinforced concrete, and pressed brick. This makes the walls of the campus very thick, requiring a strong connection and multiple access points in order to create a reliable network for students and teachers to utilize the internet while on campus. Moreover, there are a limited number of ports and wiring available within the classrooms, as much has changed since 1914, when the campus began being built.

In this research we aim to identify the challenges this campus faces when leveraging this digital transformation, and then propose opportunities to introduce a SMART classroom learning environment for their students, teachers, staff, and administrators.

The procedure of this case study can be summarized as follows:

i. Conduct an observation of classroom environment from the perspective of teacher delivery. Use observations to assess if digital resources can be accessed conveniently, and what digital technologies contribute to facilitate teaching and learning. During this observation we assess the requirements of our stakeholders.

ii. Upon completing our site observation and assessment of requirements, we use that information to determine what processes and socio-technical activities, such as workforce training, need to be completed in order to leverage SMART classroom capabilities, and what is feasible for the enterprise.

iii. Apply Systems Engineering practice systems thinking to view the system as a whole and understand how different entities of the system work together. Systems thinking is also used to understand that a reliable internet connection and school network is the basis for leveraging the concept of a SMART classroom. Within this step of applying systems thinking it is also understood that people and work cultures are an entity within this enterprise that also must be addressed. Thus, communicating goals, visions and the need for change must take place. Proper training for teachers, staff and administrators is needed as well in order to form a cohesive system.

iv. Apply Ekahau and cnMaestro tools to adjust the network access points to reduce interferences and modified the channel plans following both Cambium and the school campus's recommendations. Use Ekahau heatmapping tool to provide raw data to inform us on where routers should be placed for the best internet access for faculty, teachers, staff, and students to make this digital transformation and leverage SMART classroom capabilities.

### 3.2 RESEARCH TOOLS

Research tools that made a significant impact on our study include systems engineering tools such as a context diagram, systemigram, V-process model, functional flow block diagram, and a system architecture model adapted from Rouse W.B., et. al. 2005. Other technical research tools that we used for our case study include Ekahau tools that allow us to observe our Wi-Fi network signal coverage and ensure requirements are being met. One of Ekahau's main features is its Wi-Fi site survey tool that provides a comprehensive validation of Wi-Fi network coverage and performance. Furthermore, this Wi-Fi site survey tool also allows for identification of coverage holes, interference issues, roaming problems and all performance bottlenecks. There are a variety of Wi-Fi routers, and the quality of coverage they provide varies greatly. A Wi-Fi heatmapping tool can help identify the limitations of a Wi-Fi network. The use of a Wi-Fi heatmapping software application allows us to visualize frequency bandwidth coverage and configure routers accordingly.

Physical obstacles, such as walls or furniture, impede Wi-Fi signal strength and reliability. Even metal objects and can have a significant impact on wireless signal, which is why it is not recommended to install a Wi-Fi router near metal appliances. In some cases, physical obstructions create dead zones, which can be clearly reviewed on a Wi-Fi heatmap. Unfortunately, not all physical obstacles such as walls and other building infrastructures can be removed. You can improve your Wi-Fi signal by installing a Wi-Fi extender or additional access points. Radio frequency interference, also called RFI, refers to the disturbances in the Wi-Fi frequency caused by radio frequency interruptions. Devices that can cause interferences include microwave ovens, mobile phones, security cameras, and Wi-Fi routers in certain cases and circumstances. Radio frequency interference can be displayed on a Wi-Fi heat map as an area of signal weakness, and usually correlates with the presence an electronic device.

A Wi-Fi router has many settings and configurations that can be adjusted to improve the quality signal. One of the most important settings to pay special attention to is the Wi-Fi channel. In the 2.4 GHz band, there are 11 channels (at least in North America), with channels 1, 6, and 11 being the only non-overlapping channels. You should also pay attention to your router security settings, because the last thing you want is to let other people access your internet connection without your approval. Majority of Wi-Fi heat map solutions available on the internet can gather information about the configuration of your router, as well as other routers in the area. One final and very important tool used for our case study is Cambium network to establish internet connection and a network for the school campus, and cnMaestro, which allowed us to manage the network. CnMaestro is Cambium network's cloud management solution that can manage a variety of networks and all Cambium devices conveniently. It is the simplest and most cost-effective way to manage, configure, and trouble shoot your equipment over the cloud. After creating an account, you are able to navigate through administrative tasks such as updating software, adding administrators, and configuring devices.

# Chapter 4: Data Collection and Analysis

Data collection techniques include observations, process analysis, internet speeds, amount of network users, and relevant artifacts such as the rendering of a Wi-Fi heatmap. Upon collecting the data, we used a variety of approaches to analyze qualitative as well as quantitative data. The data from the case study observation was categorized, tabulated and cross checked to address the initial propositions of leveraging SMART classrooms. Systems thinking techniques like the development of a systemigram was used to identify the main components and relationships that are critical to a learning enterprise.

Moreover, this illustration helped us approach the data from different perspectives and scenarios and thus aided in avoiding making premature conclusions. The data collected to realize leveraging SMART capabilities, along with the data collected to understand the socio-technical private school enterprise was analyzed and then synthesized to develop a structured approach that can be applied to small to medium enterprises in the early stages of a digital transformation. While technology is a huge contributor to this digital transformation, it is pivotal to understand the properties, gaps, and dynamics of the socio-technical components of this transformation.

## 4.1 Site Observation

To gather insight on school leadership, practices, and instruction a site observation was conducted for a total of 8 weeks (about 2 months). One major area of focus during this site observation was teachers attitudes toward digital technology but also on their thinking, ideas, guiding principles, goals and visions. The basic structure of the observation included inspecting the status and use of digital technology in classrooms, checking available wiring and ports, and 1-1 devices accessible to students. One single classroom was observed as a baseline. Furthermore, the teacher was asked about the use of digital technology within their classroom instruction as well as digital integration in general.

### 4.2 Data Collection

Our data collection involved observing the school campus to identify tools and processes that could be leveraged to develop a SMART classroom learning enterprise, along with their benefits, challenges and opportunities can. Moreover, the culture of the workforce on campus was also observed in order to prepare for the need to address possible change resistance. During our data collection, observations of the current state of classrooms at Saint Patrick's were conducted. Their activities and processes were studied, along with challenges faced by teachers. After the activities and processes of the current state of classrooms were studied, a single classroom within the campus was examined and audited to determine the current state of technology and devices that are being utilized during instructional hours. The teacher for this classroom provided us with a list of technologies that are currently present in the classroom.

Table 4.2.1: Table of available equipment, software, hardware and resources.

| **Current – 5th Grade Equipment & Software** | | |
|---|---|---|
| *Item* | *Description* | *Personal or Provided* |
| Chromebook | Currently using 4 (5 students bring their own devices). | Provided by School |
| Projector | Placed on projector cart. | Provided by School |
| Laptop | Sometimes used by students. | Provided by School |
| AV Cart | Used as a standing desk to control laptop connected to projector. | Provided by School |
| Pulldown Projector Screen | Content from laptop is projected onto this pulldown screen. | Provided by School |
| Projector Cart | Cart is used to secure projector in place. | Personal Item |

| | | |
|---|---|---|
| Wireless Keyboard | To control laptop connected to projector from across the room. | Personal Item |
| Bluetooth Speaker | Used to project audio from instructional videos and other content. | Personal Item |
| MacBook | Teacher resource to aid in providing classroom instruction. | Personal Item |
| Printer | Used in classroom to provide instructional content. | Personal Item |
| IXL | Online learning program for mathematics. | School Subscription |
| BrainPOP | Online learning program. | Personal Subscription |
| GimKit | Live digital game-quiz/review platform. | Personal Subscription |
| PearDock | Online classroom response system. | Personal Subscription |
| Reading A-Z | Online resource for leveled and differentiated reading instruction. | Personal Subscription |
| CommonLit | Online comprehensive literacy program. | Personal Subscription |
| Classroom Screen | Digital classroom management widgets. | Personal Subscription |
| Google Classroom Suite | Tools and resources designed to help educators manage classrooms and enrich learning experiences. | School Account |

Table 4.2.2: Table of desired software, hardware, and resources.

| **Would Like to Have – 5th Grade Equipment & Software** | |
|---|---|
| *Item* | *Notes* |
| Charging Cart/Station | Used for 1-1 devices such as Chromebooks, laptops, and tablets. |
| SMART whiteboard | Used for interactive educational instruction. |
| Additional Chromebooks | 1-1 Devices. |
| Headsets | For each student to complete exercises independently. |
| Collaborative Furniture | Stand-alone desks, tables, and chairs that interlock or move easily for group work. |
| Mobile Power Towers | Placed in the middle of interlocking desks to provide USB ports/power outlets. |
| Digital Podium | Accommodates laptop, document camera, large surface area for multiple devices, etc. |
| Standing Student Desk | To offer adjustable stationing for students. |
| Movement Seating | Wobble stools, floor cushions, ottomans for flexible seating options. |

| | |
|---|---|
| High-Definition Document Camera | To display live examples, work through problems and examples with students. |
| Sound System | To allow students to listen to lessons, and educational videos. |
| In Class Printer | To print homework, examples, reading material, etc. |

In addition to the list created for current use of equipment and software, a separate list was created by the instructor naming the equipment and software that the classroom would like to use in the foreseeable future. Upon conducting our site observation and running a speed test on the current signal strength, it was determined that the current network did not provide sufficient bandwidth to supply current devices. PNG was at 143 ms, Download was at 3.60 Mbps, and Upload speeds were at 0.63 Mbps.


Illustration 4.2: Network Performance Measurement

If the goal is for SMART classrooms to be leveraged on this campus, we will certainly be needing a more reliable and robust network to support these new devices. A large part of leveraging these technologies, equipment, and software is the ability to provide internet with the signal strength and speed to support multiple devices. The speed test these values as shown in the figure above are insufficient to leverage SMART classroom capabilities. Thus, we very quickly realized that our starting point would be to establish a reliable and robust internet connection for classrooms. More data was collected after installing a Cambium network router and running a second speed test. The photo below displays one of the newly installed Cambium routers on campus. Other data collected from cnMaestro includes that collected from cnMaestro network which contains speeds, users, etc. Moreover, the heatmap prepared from Ekahu tools was also utilized for data analysis. The following photos capture the current state of the classrooms.

Illustration 4.3: Previous Access Point Before SMART Classroom Leveraging

Illustration 4.4: Access Point Location

Illustration 4.5: Expected Access Point Coverage

The above three photos capture the wireless network that had been in place at Saint Patrick’s school campus. The wireless network was comprable to that of a home network, and was stuggling to support the many devices and users throughout the school campus. Another challenge that this wireless network presented was the poor and inadequate placement of access points. As shown in illustrations 4.4 and 4.5, the wireless access point was placed on one end of the hallway and expected to project network coverage all the way to the opposite end and throughout the classrooms within the hallway. As mentioned earlier, the structural architecture and thickness of the walls does not allow ample signal to be projected throughout the classrooms. This combined with weak signal strength and poor placement of routers presents a challenging predicament to teachers and students attempting to utilize the internet and other network resoureces.

Illustration 4.6: Newly Installed Cambium Network Access Point

Illustration 4.7: Interactive SMART Board

The above two photos, illustrations 4.6 and 4.7, display a Cambium network access point and a Boxlight mimio interactive display. At the beginning of this study, there were only two of these screens available on campus, but after installing the Cambium wireless network router, more network reinforcement was made available to support more bandwidth for devices within this school campus for instructional use. As part of this project, Saint Patrick’s has acquired more of these interactive screens to engage their students, and take the next steps towards leveraging SMART classrooms.

### 4.3 DATA ANALYSIS

The recurring theme and valuable contribution of this case study is approaching the problem with a systems thinking socio-technical perspective that perceives the system as a group of subsystems that work together. For the technical aspect of our data analysis, we carefully considered our observations of the campus architecture and infrastructure, such as lack of ports, wiring, and poor network speeds along with the table that listed current state technologies and capabilities, and desired future state of technologies and capabilities. As for the social aspects of this study, we recognized a bit of a change resistance from teachers, as some expressed that they do not use the technology available in their classrooms and do not understand the need to adopt technology.

### 4.4 DISCUSSION OF DATA ANALYSIS

From the data collected and analyzed, a table was created to describe these socio-technical components and their significance is defined to better understand how to leverage SMART Classroom capabilities. Understanding the data collected from these socio-technical factors allowed us to develop a functional flow block model to understand these entities and how they influence each other, as summarized in the figure below. Data collected from socio-technical factors allowed us to develop a functional flow block model to understand these entities and how they influence each other, as summarized in the figure and table below.

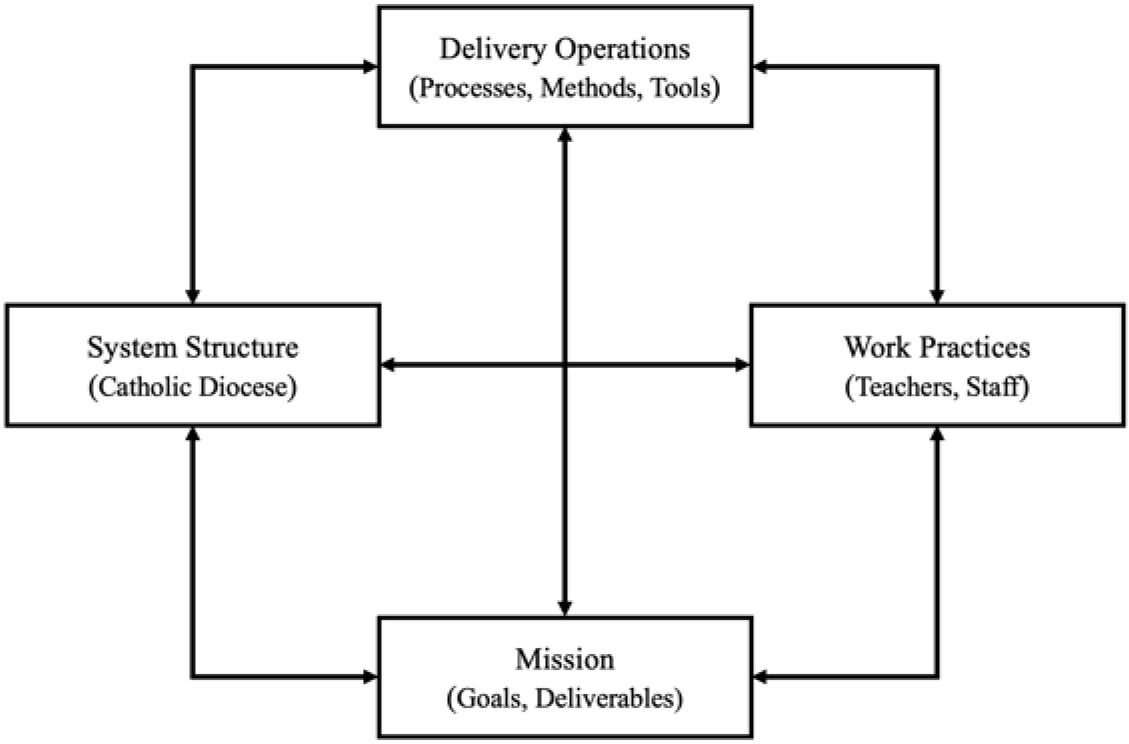


Figure 4.4.1: Functional Flow Block Diagram in Equilibrium

Table 4.4.1: Features of Structure, Mission, Technology, and Actors

| *Socio-technical component* | *Significance* | *Main Properties* | *Gaps* | *Literature* |
|---|---|---|---|---|
| Structure | The structure covers systems of communication, authority, leadership and workflow. It includes values, norms, and general roles. | Levels of formality, centralization Means of organization. | Existing or defined structures do not support actors in their tasks. The structure is not adequate, well specified, or appropriate for the task. | Leavitt (1964) Lucas (1982), Beath (1987), Lyytinen(1987a), Curtis et al. (1988), Nidumolu (1994), Sabherwal & Elam (1996). |

| | | | | |
|---|---|---|---|---|
| Mission | Mission describes the enterprise goals and purpose and the way in which work is completed within the organization. Tasks are defined through project deliverables and aspired process features in that a development task dictates what developers should accomplish and how in relation to a socio-technical change. | Mission size and complexity<br>Mission uncertainty<br>Mission specificity<br>Mission stability<br>Time and performance. | The actors do not understand or accept the mission or cannot carry out the mission.<br>The structure is not aligned with the mission or inadequate structure is defined for a given mission.<br>The technology is not adequate to support the mission, or it is unreliable or inadequate in its support. | Leavitt (1964), Perrow (1979) Ginzberg (1981), Keen (1981), Curtis et al. (1988), Groveret al. (1988), Boehm &Ross (1989), Hirschheim &Newman (1991), Henderson & Lee (1992), Markus & Keil (1994), Willcocks & Margetts (1994), Keil (1995). |
| Technology | Technology denotes tools – problem-solving, work measurement, computers, and devices. This includes software and hardware and software technology, design methods, tools. | Functional dimension (production, coordination, control, adaptability)<br>Level of specialization<br>Functional scope and integration<br>Systemic properties (Performance, ease of use, compatibility, and interoperability.) | usage andperformance.The structure is not aligned with the technology and does not support technology operations and use.<br>Structure does not take advantage of the capabilities of technology. | Leavitt (1964), Ouchi (1979), Perrow (1979), Damanpour(1991), Beath (1987), Lyytinen (1987a), Curtiset al. (1988), Davis et al., 1992), Markus & Keil (1994), Nidumolu (1994). |
| Actors | Actors include an enterprise members and stakeholders who carry out or influence the work.<br>Individuals or groups of stakeholders who can benefit from system development. Actors include teachers, staff, administrators, students, parents, maintainers, developers, and users. This also includes any individual or group that has as take or can set up a requirement towards the organization. | Personal properties<br>Commitment and skill<br>Differences among stakeholders<br>Unrealistic expectations<br>False beliefs<br>Non-existent or unwilling actors<br>Unethical professional conduct<br>Personnel volatility<br>Opportunism and personal agenda | Actors are expected to carry out tasks which they are not fit or trained to perform.<br>Actors do not understand the vision, cannot operate, or do not accept the technology.<br>Actors do not know the processes and procedures, do not accept the structure, or are not aligned adequately with the mission. | General: Leavitt (1964), Perrow (1979), Lyytinen(1987a), Sabherwal & Elam (1996) ; Willcocks & Margetts (1994). |

v.

## Chapter 5: Conclusion

In this work, we have performed a systematic literature review and data analysis to support the leveraging of SMART classrooms. In this study we found that a stable data connection is essential for a SMART classroom to properly execute the adoption of the digital transformation within the K-12 learning enterprise. A reliable internet connection which is very economical today is the basic requirement needed for using this technology (Halili, 2019). Optical fibers and networks are highways for data, and in a fully connected, intelligent digital world, we need to connect everything, including students, to the world they are learning from (Sharrrab, Y., 2023). Here, we use a network system called Cambium and a cloud management system called cnMaestro to monitor different devices on the school campus, such as smart boards, tablets, cameras, etc.

In terms of the social factors affecting this case study, we developed systems engineering tools such as a systemigram, functional flow block diagrams, and an enterprise architecture model to guide stakeholders through the social aspects to consider such as training, clearly communicating goals, and the value in adopting novel technologies. These tools and graphics act as a formulated approach for enterprises seeking to leverage digital transformation. Furthermore, the research provides guidance to the educators and institutional leaders to take the steps necessary to leverage the concept of a SMART classroom. One of the most important steps to take is change and transformation in work activities. This is thus built on the social practice of people, with much training to understand value, and fully grasp capabilities. To intentionally change work practices, teachers need to learn new ways of thinking and working. In this way, we can attribute change in work practices by inviting educators to understand the value of technology integration in school curriculum.

# Chapter 6: Limitations and Future Work

As with any study, this research is not without limitations. First, to get more insightful conclusions, it would be valuable to replicate this research and framework in a different domain or industry. Second, essential factors (e.g., demographic, and societal factors) could be explored to see if they affect SMART classroom adoption. Examining such factors and adding them to the present model would be a helpful extension of the present study. To further empirically validate factors influencing the acceptance and adoption of technology in education which have not been so widely explored, for example perceived ease of use which has been associated with a high level of perceived usefulness (Lin & Yeh, 2019) should be further examined as well. Moreover, continuous development of new technologies and devices requiring interoperability standards, along with a growing number and diversity of users in educational context, opens new directions of research that could raise understanding of the technology acceptance, and use.

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## Vita

Jazmyne Del Hierro is a Systems Engineering graduate student at The University of Texas at El Paso. She completed her undergraduate degree at The University of Texas at El Paso during the fall of 2019 and expects to earn a Master of Science in Systems Engineering degree this upcoming May of 2023. Jazmyne's experience includes data analysis techniques, system architecture and design, system requirements management, as well as implementation of SysML-based MBSE methods, tools, and frameworks. Her interest in Systems Engineering and Industry 4.0 helped her correlate research in systems thinking for leveraging the concept of SMART classrooms for preK-8 Education. This research project involves applying systems thinking to identify areas of the preK-8 learning enterprise that may benefit from systems engineering methods, techniques, and technologies to leverage the Digital Transformation brought upon us by Industry 4.0. Jazmyne, Dr. Luna, and the UTEP Industrial, Manufacturing, and Systems Engineering department are grateful for St. Patrick Cathedral School, who has generously allowed us to observe and use our Systems Engineering knowledge to elicit areas of opportunity.

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