

Positive Influences and Educational Practices in the STEM Learning Ecosystem: An
Asset-Based, Multi-Case Exploration of Non-Formal Youth Education in Senegal

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Abstract

STEM (Science, Technology, Engineering and Mathematics) education for youth can lead to the development of skills to design technologies, innovate tools, optimize work processes, and solve problems to improve society. The public high schools in Senegal are reported to have a low enrollment of students in STEM-related subjects. Youth are taught to memorize theories, with limited opportunities for hands-on STEM activities. However, there are other opportunities for Senegalese youth to engage in STEM education outside the formal school system. This research used case studies to explore the experiences of Senegalese youth learners and educators engaged in hands-on STEM education within non-formal learning settings in Dakar, Senegal. The first case involved six youth and six educators from wood carpentry and metal joinery apprenticeships. The second case involved seven youth and five educators from Go4STEAM, an all-girls out-of-school STEM program. The Ecological Systems Theory was used as a theoretical framework to situate the youth and educators in their learning context and consider ways in which their self and environment influences their STEM learning and teaching experience. An asset-based analytical approach was used in both cases to identify and describe positive influences and educational practices related to learning STEM. Results of the study indicated that educators in the apprenticeship setting display elements of cultural-based education as they not only teach the youth learners engineering through guided instructions, but also help raise them into adulthood. The youth learners in this setting

have dropped out of school, thus recommendations for this learning setting include leveraging apps, mobile training, and competitions to promote engineering education as well as ensuring a strong foundation in reading, writing, and math. The Go4STEAM learning setting was found to offer activities that were interesting and responsive for their youth learners, and their learning environment emphasized peer collaboration.

Recommendations for this learning setting include encouraging youth to take leadership of their learning whilst positioning the educators as co-learners, and offering the youth opportunities to engage in STEM with various partners and settings around the community. By recognizing and valuing the strengths of non-formal learning settings, this study identifies opportunities to strengthen the Senegalese STEM Learning Ecosystem. The additional support can lead to opportunities for Senegalese youth to become innovators and problem solvers that use their skills for educational and career advancement, upward economic mobility, and improved community development.

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General Audience Abstract

STEM (Science, Technology, Engineering and Mathematics) Education can be beneficial for the youth because it gives them useful skills for their jobs and their community. There are many factors that influence how youth learn STEM, and youth are able to learn in school and out of school. In Senegal, there are a low number of students enrolled in STEM-related subjects in high school, and the schools do not offer hands-on STEM activities. This research uses case studies to investigate STEM education for youth in non-formal, out-of-school settings, in Dakar, Senegal. Six youth and six educators from the wood carpentry and metal joinery apprenticeships, and seven youth and five educators from the Go4STEAM all-girls program, participated in this study. For each case, the Ecological Systems Theory was used to help consider the various influences that may directly or indirectly impact the youth's STEM education. An asset-based approach was used to identify positive influences and educational practices from the two cases. The study determined that the educators in apprenticeships use cultural norms and values to teach the youth learners engineering and raise them to become adults. The learners do not go to school so they can potentially benefit from apps, mobile training, and competitions that facilitate learning engineering, and the basics of reading, writing and math. At Go4STEM, the study determined that the learning environment was fun for the youth and encourages teamwork. The learners at Go4STEAM may benefit from deciding what STEM topics they want explore and the educators support as co-learners. Also, the

educators can help facilitate STEM activities that engage community resources. This study identifies the strengths of non-formal, out-of-school-learning, and identifies opportunities to improve the Senegalese STEM Learning Ecosystem. With the additional support, Senegalese youth can become innovators and problem solvers that use their skills to benefit themselves, their families, and their communities.

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Introduction

STEM (Science, Technology, Engineering & Mathematics) is a term coined in 2001 by Dr. Ramaley of the United States National Science Foundation, to weave together the elements of science and math which are critical to a basic understanding of the universe, with engineering and technology, the means by which people interact with the universe (Christenson, 2011). The definition and use of STEM varies (Brown et al., 2011; Bybee, 2010; Scherer et al., 2019) and depends on the stakeholders during implementation. STEM has been used as a generic label for any event, policy, program, or practice that involves one or several of the STEM disciplines (Bybee, 2010), and can also be referred to as a discipline, instruction, field or career (Hasanah, 2020). The pursuit of STEM outcomes can occur through either separate and distinct efforts or through a coordinated relationship between subjects; literature on the use of STEM shows instances of integrated and non-integrated approaches to STEM education (Scherer et. al, 2019). In this study, STEM education is used to refer to science, technology, engineering, and mathematics related skills being taught to youth, both integrated and non-integrated.

Despite the STEM terminology being rooted in the West, it is important to note that all societies share the common ancestry of using STEM to adapt to their environment. African indigenous sciences are a culturally specific knowledge system that relates to the knowledge of the original peoples of Africa, their oral culture and traditional ecological knowledge, as affected by their worldview; the knowledge that incorporates their social and natural wellbeing, their cosmos and their spiritual world (Shizha, 2010). While interacting with their environment and transforming raw materials, Africans arrived at various hypotheses about nature, the natural world and society. The fabrication of metallic tools and implements, textile production, traditional medicine and food processing, involved the application of various techniques,

principles, and propositions arrived at through observation of the environment and experimentation at various levels (Emeagwali, 2006). With that, we should avoid claims suggesting that sciences and engineering were imported to Africa from the West.

When discussing STEM history in Africa, we may use examples such as traditional use of tools for the construction of huts and the making of hunting tools (Mosweunyane, 2013). Some may argue that these are simplistic and uninspiring views of African history and would rather discuss more sophisticated examples of science and engineering like the scholarship and infrastructure known in Timbuktu and Egyptian civilization. However, it is beneficial to honor the more simplistic and everyday forms of science and engineering because it is a reminder that STEM is accessible and used by all. It does not belong to one group of people, and there is not a particular level of sophistication that must be achieved for a practice to be considered science and engineering. In fact, we should be critical regarding what we deem impressive and desirable. For example, there are Western innovations that are useful but also oppressive and damaging to the environment such as large vehicles used for transporting goods that also cause pollution, or interstate highways strategically designed and placed to facilitate transportation but also to destroy Black neighborhoods and to keep Black and White neighborhoods apart (Kruse, 2019).

The subjects in STEM are timeless and can be used in numerous domains to problem solve and innovate, including by youth. In Senegal, West Africa, half of the population are under the age of 18 years (United Nations Population Fund, 2014). Also, approximately 75% of families suffer from chronic poverty (World Food Programme, 2021), and about 55% of working age people are inactive or unemployed (World Bank, 2018a). With such a high percentage of youth, and issues of poverty and unemployment, there is a dire need to direct more attention to support the youth. STEM education is an avenue for youth to develop their creativity and

analytical skills, which can lead to careers and contributions to meet major challenges that confront society (Next Generation Science Standards, 2013).

Education is not limited to the formal school system, rather it includes non-formal and informal means of learning. Formal education is characterized as usually taking place at school, and is structured, prearranged, sequential and teacher-led; non-formal education usually takes place out of school, is structured, prearranged, typically non-sequential, and may be guided or teacher-led; informal education occurs everywhere, is unstructured, spontaneous, non-sequential and usually learner-led (Eshach, 2007). This study references the non-formal learning settings as educational spaces that have their own objectives, structures and methods, taking place outside of the national school system. The educational needs and rights of large groups of disadvantaged and vulnerable youth may benefit from non-formal initiatives that are an alternative or a supplement to the formal education system (Hoppers, 2006). This research study seeks to leverage non-formal learning settings to support STEM education for youth in Senegal.

Limitations of Education in Formal Schools

Education is a method to transmit from one generation to the next, the accumulated wisdom and knowledge of the society, and to prepare the young people for their future participation in the maintenance and development of the society (Kunjufu, 1984). This description of education communicates a general purpose for education but can be specified further depending on the subject matter. Historically, African societies offered training to their members characterized by the provision of survival skills to individuals who were supposed to selflessly serve their societies, but with the advent of colonial rule, a formal system of education was introduced to prepare children to serve the colonial administration (Mosweunyane, 2013). Even though children were still receiving knowledge in schools, the subject contents changed,

and students were being taught to maintain and develop a colonized society rather than their native. For the case of Senegal, the country and its citizens were colonized by the French.

In the early 20th century, European officials established secular schools in their colonies (Decker, 2016). Schools have a tremendous amount of power in maintaining the ideology of the ruling class and in the production of hegemony (Althusser, 1971), because of their access to the minds of children to deposit dominant ideals, values, and systems of knowledge (Givens, 2016). Education was seen as a vehicle through which western cultures could be fostered in the African continent by its colonizers, to promote a capitalistic system that included individualistic instinct (Mosweunyane, 2013). The French colonialist had an assimilation approach to education in Africa, with the objective that the social, political, and economic environments should not differ between schools in France and those in its colonies (Clignet, 1968).

Under colonization, Senegalese students were taught to meet the needs and values of the French. For example, as the student's level of education increased, so did their desire to live in urban residences because the importance was emphasized in the curricula (Clignet, 1968). This is reminiscent of Carter Godwin Woodson quote from *The Mis-Education of the Negro* (Woodson, 2006, p.41) referring to attempts to enslave the minds of African-Americans in the United States. He said,

If you can control a man's thinking you do not have to worry about his action. When you determine what a man shall think you do not have to concern yourself about what he will do. If you make a man feel that he is inferior, you do not have to compel him to accept an inferior status, for he will seek it himself. If you make a man think that he is justly an outcast, you do not have to order him to the back door. He will go without being told; and if there is no back door, his very nature will demand one.

This powerful quote provides a glimpse into the psychology of controlled minds, which is what French colonizers pursued in Senegal.

By the 1960s, with the rise of educated African elites, there was also an increasing demand of independence from colonial powers (Decker, 2016) and the pursuit of decolonization. In 1961, Frantz Fanon defined decolonization as a restorative process that, through the actions and mobilization of the colonized, erases the realities and legacies of the colonial situation and the epistemic and systematic violence, exploitation, and racism embedded within them. Ngugi wa Thiong'o, the world renown writer from Kenyan, published a book in 1986 entitled *Decolonising the Mind: The Politics of Language in African Literature*. Thiong'o argues that though countries may have gained formal independence, they are now neocolonized. He refers to neocolonialism as situations in countries where local culture tends to be subordinate to their former colonized culture. He explains that there is a tendency from those societies to look for validation from the West, indicating that their mind is affected by colonization more than just economic materiality (IFRA Nairobi, 2019).

Thiong'o argues that the colonization of politics and economy is easier to detect than that of the mind – and that it is hard to eradicate colonization of the mind. He emphasizes the power of language, explaining that in many African countries, it is the European language that defines knowledge, administration, economic exchange, legal practices - and the local African languages are subordinates. If students were heard speaking a language other than the colonial language, they would be beaten and oftentimes made to wear or carry a 'symbol' that marked them as linguistic transgressors (Speciale, 2020). The symbol could be a button, a bone, or a sign that read 'I am stupid' or 'I am a donkey' (Thiong'o, 1994). This practice continued in Francophone Africa even during the postcolonial era. It was prohibited by the Ministries of Education in the

early nineteen eighties but due to lack of enforcement of the policy, it is still possible to catch some frustrated teachers using such coercive measures against pupils who have difficulties expressing themselves in French (Alidou et al., 2006). It has been posited that self-esteem comes from an individual's culture and frame of reference (Kunjufu, 1984). Senegalese students report that school does not help them know more about themselves (Gueye, 2006). There have been some government initiatives to reintroduce local languages in schools, along with textbooks being written in African languages, and translating great literature to African languages (IFRA Nairobi, 2019). However, in Senegal, the official language is French and that is the primary language of instruction used in the school systems (Dexis Consulting Group, 2020).

There are divided opinions about using local languages in schools. Some believe it would increase student understanding of the material while others believe that Senegal is a poor country that cannot afford to promote its language, and that French and English are already international languages that cannot be disregarded (Gueye, 2006). Some Senegalese parents believe that learning Wolof in school, the most common local language, would not open any opportunities to their children in the future. According to them, learning French is the only way for their children to be successful in school, since French is the official, and only language valued by the government and the administration (Gueye, 2006).

Though schools in Senegal offer opportunities for youth learners to build their educational foundation, the engagement of STEM related subjects is relatively low. In Senegal, students that want to pursue formal STEM education must be groomed early to be on the STEM track for high school and university. To qualify for the STEM track, students are required to pass an exam to receive their Brevet de Fin d'Études Moyennes (BFEM), a diploma marking the successful completion of middle school. The success rate for passing the exam is relatively low,

with 28.9% of girls and 34.3% of boys passing the exam (Islamic Development Bank, 2019) and in 2016 24.3% of girls and 30.7% of boys that passed enrolled in the science and math related series in high school (World Bank, 2018b). Additionally, some Senegalese youth do not go to school at all, or they attend and then drop out. In Senegal, 41% of boys and 45% of girls middle school aged youth are out of school (Education Policy and Data Center, 2018).

However, there are other methods for youth to learn outside of formal school settings. This research study investigates the two non-formal learning spaces of apprenticeships and an out-of-school program that educates youth using STEM related education. Both learning settings offer youth a chance at hands-on, practical engagement with STEM tools and methods for designing, constructing, and problem solving. The STEM education that the youth receive in their non-formal learning settings do not come with advanced degrees or professional licensing like in formal schooling, however, the skills they gain can be used for their careers, entrepreneurship, and projects that benefit their communities.

Background of Cases on Non-Formal Learning Settings

Throughout sub-Saharan Africa, apprenticeships between a master craftsman and an apprentice are a historic yet still common and principal medium for skills development (Sonnenberg, 2012). In Senegal, more than 33% of young men and 12% of young women spend time as apprentices (World Bank, 2018a). Due to the non-formal nature of apprenticeships, there are no formal tracking systems like student registrations, no exams that can track progress, and no formal degrees such as ones offered at universities. Knowledge from the trade's master craftsmen (such as electricians, welders, mechanics, tailors, hairstylists) are often passed down to youth through oral lessons and hands-on, on-sight training. This was also the case pre-colonization, where knowledge, skills and attitudes were passed from generation to generation

mostly through word of mouth in the African societies (Mosweunyane, 2013). Apprenticeships in Senegal remain a popular form of education and cover various domains and services such as repairing, and remodeling also involve building and problem solving. Thus, there is opportunity in these spaces to learn about their use of engineering methods to offer services to their community.

Over recent years, there has also been an increase of youth STEM programming in out-of-school settings in Senegal. STEM (Science, Technology, Engineering & Mathematics) is a term coined in 2001 by Dr. Ramaley of the United States National Science Foundation to weave the elements of science and math which are critical to a basic understanding of the universe, with engineering and technology which are means in which people to interact with the universe (Christenson, 2011). These STEM initiatives in Senegal include Feed the Future 4-H Positive Youth Development; Pan-African Robotics Clubs; Mathsolo learning centers; Espaces Topatoo which specializes in 21st century techno-fun skills; ImagiNation Afrika innovation hubs; and Go4STEAM which combines STEM with arts to educate young girls and women. Though these STEM programs exist and are operating, they are new and under researched. Thus, there is opportunity to learn about their approach to STEM education for Senegalese youth.

The youth age range being considered for this research study is ages 12-19. Literature on child development in West Africa was reviewed to determine a suitable range. A research study was conducted with the Bamiléké cultural group in Cameroon on activities that are age-related based on cultural beliefs and principles that foster the child's cognitive development. There, adolescence stretches from 12-19 years (Tchombe, 2007) and in this stage adolescents are expected to demonstrate a sense of responsibility, growing maturity and creativity; social competency and growing intelligence; and encouraged to ask questions to demonstrate their

understanding, awareness and the sharing of acquired knowledge (Tchombe, 2011). These competencies are used as the justification for the selected age range for this study because they are aligned with the expectation for youth participants to be able to assess and describe their perspective and experience of the STEM Learning Ecosystem. The two learning settings of apprenticeships and STEM programs do not represent the entire STEM Learning Ecosystem but strengthening the STEM education opportunities in these two non-formal learning settings has the potential to impact many Senegalese youth learners.

Theoretical Framework

Urie Bronfenbrenner is an American researcher and psychologist who published the Ecological Systems Theory in 1977. Bronfenbrenner defines development as a person's evolving conception of the ecological environment, his relation to it, as well as the person's growing capacity to discover, sustain, or alter its properties (Bronfenbrenner, 1979). There is reciprocity in the relationship that humans have with the environment, both influencing each other. At the time, traditional psychologists discussed the links of perception, motivation, thinking and learning as part of development, but with his theory Bronfenbrenner emphasizes that a child's development is influenced by their environment including factors such as their parents' employment, significant life events, societal culture, and interrelations among influencers. Bronfenbrenner organizes and describes these factors into microsystem, mesosystem, exosystem, and macrosystem (Bronfenbrenner, 1979).

Microsystem refers to the immediate interactions that the child interfaces with, and the direct influence they have on the child. Examples of actors in the microsystem are the child's family, school, and neighborhood. Mesosystem is the interactions and interconnections between actors in the microsystem and how they interact with each other and with the child. Examples of

these interactions are the relationship between the child's church and neighborhood, or between their parents and teachers. Exosystem is the interactions that occur in the child's environment without their direct involvement. These events still influence the child, such as a parent losing their job and the child now experiencing financial and emotional distress from family members at home, or decisions made by the school board that now impact the child at school.

Macrosystem is the overarching patterns of ideologies and cultures that the child experiences through-out life. The context may change depending on identity, resources, age, location, etc. and each has an influence on the child's development. In 1986, Bronfenbrenner further developed his theory to include the impact of the individual characteristics of the child, and the influence of time: Ontogenic-level system refers to the variables within the child themselves that impact their development (Cicchetti & Lynch, 1993); Chronosystem refers to the ever-changing nature of the child and of society and how various experiences and events impact the child (Bronfenbrenner, 1986).

This systems approach emphasizes that numerous factors such as geographic location, societal values, and significant events all impact a child's development. These considerations may be considered in Senegal because there are numerous diversities within the country. For example, the agriculture landscape is unique in Senegal because the northern region is a part of the Sahel region which is desert-like; the middle region has a steppe climate with Rain-fed agriculture; and towards the bottom of the country is a tropical, grassland & forestry environment. The youth in each region are experiencing different environmental settings. Senegal is also home to a diverse group of ethnicities. The Wolof people account for approximately 40 percent of the population, however other ethnicities living in the country include the Pular, Serer, Mandinka, Diola, and Soninke (Central Intelligence Agency, 2020).

There are many considerations in terms of history, geography, ethnicity, and resources that may influence the youth's STEM education.

In 2015 the United States National Research Council (U.S. NRC) adapted Bronfenbrenner's Ecological System into a context for Science, Technology, Engineering, and Mathematics (STEM) learning. They define the STEM Learning Ecosystem as the dynamic interaction among individual learners, diverse settings where learning occurs, and the community and culture in which they are embedded (National Research Council, 2015). This STEM Learning Ecosystem model describes the direct and indirect influencers that play a role in youth learning STEM, modeled after the layers of the Ecological System Theory. This study uses Ecological Systems Theory as a theoretical framework to explore the Senegalese STEM Learning Ecosystem using an asset-based approach to community development (Kretzmann & McKnight, 1993).

Asset-Based Community Development (ABCD), a term coined by Kretzmann & McKnight (1993), was designed to counteract the problem-based approach to community development. This approach encourages community development that leverages local culture and assets. The problem-based approach tends to unintentionally suppress community involvement by emphasizing deficiencies, needs and problems, which then results in communities becoming dependent on services rendered by organizations (Nel, 2018). The deficit approach is sometimes perceived as disempowering for communities and can discount valuable wisdom, information, skills and other assets that communities possess (Baum, 2008). ABCD guides communities towards discovering and using hidden, untapped or under-tapped talents and gifts in the creation of wealth for themselves and their communities (Nel, 2017). An asset-based

approach is used in this study to highlight strengths related to learning and teaching STEM within the non-formal settings in Senegal.

Overview of Case Studies

The purpose of this multi-case qualitative research study is to use the Ecological Systems Theory (Bronfenbrenner, 1979) as a framework to explore the Senegalese STEM Learning Ecosystems, particularly the wood carpentry and metal joinery apprenticeships, and the Go4STEAM youth program. Individual interviews and focus groups are used to engage youth learners and educators to gain insight about their motivations, educator pedagogy, cultural and historic influences, and accessibility to content knowledge and materials. Based on responses, an asset-based approach is used to identify factors that influence youth to learn in their non-formal learning setting, and educational practices that facilitate their STEM learning. Knowledge gained from this study enlightens understanding of STEM education for youth in Senegal, and highlights ways to leverage local influences and practices to strengthen STEM education in non-formal settings.

In 2007, Agence Française du Développement (AFD) published research findings of apprenticeships in Senegal. The findings from the study categorized wood carpentry and metal joinery as part of the construction and civil engineering sector (Walther, 2008). There are an estimated 11,921 woodwork and 7,620 metalwork workshops in Senegal (World Bank, 2018a). Since the apprenticeships are already considered to be in the engineering sector, this study focuses on their engineering education within the STEM Learning Ecosystem. Six youth learners and six educators participated in this research. This case study on the wood carpentry and metal joinery apprenticeships aims to answer the following questions:

1. What influences facilitate youth to learn in the wood carpentry and metal joinery apprenticeships?
2. What educational practices facilitate youth to learn engineering in the wood carpentry and metal joinery apprenticeships?

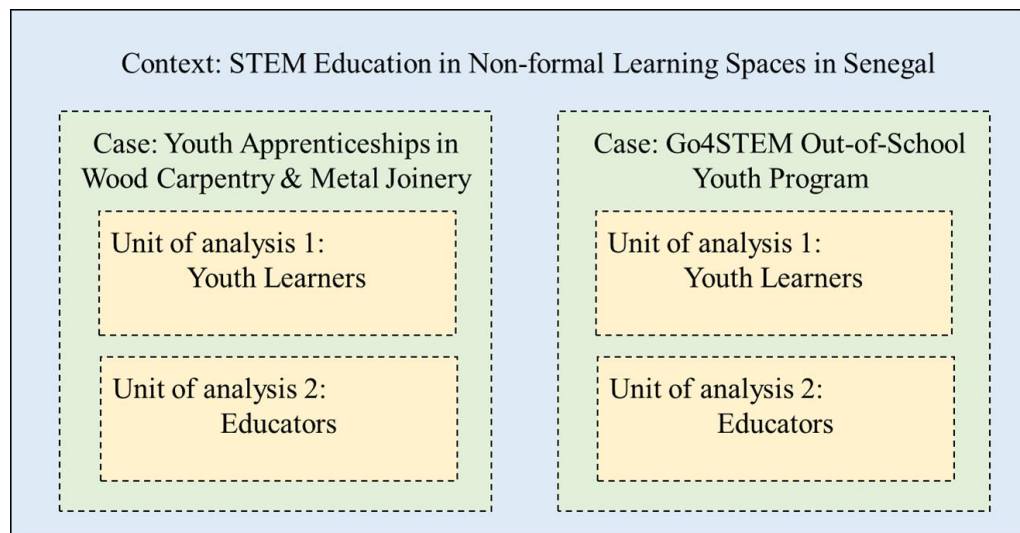
Go4STEAM was founded in 2019 as a non-profit association that works to promote and popularize STEAM (Science, Technology, Engineering, Arts, and Mathematics) among young girls. Their STEM MOUSSO 2020 initiative is a free month-long program aimed to develop STEM interest through awareness of STEM professions, mentorship with women role models, and participation in projects related to robotics, mechanics, electronics, and web programming (Go4STEAM, 2022). Seven youth learners and five educators participated in this research. This case study on the Go4STEAM program aims to answer the following questions:

1. What influences facilitate youth to learn at the Go4STEAM program?
2. What educational practices facilitate youth to learn STEM at the Go4STEAM program?

This research study uses the descriptive case study methodology to gather and interpret information about Senegalese youth and educators' STEM education experiences in their respective non-formal learning setting. Case studies are used to describe a phenomenon and the real-life context in which it occurred (Yin, 2014), within a bounded system (Merriam, 1998). Yin's Embedded Multiple Units of Analysis Case Study Design (2009) is used as a conceptual model for these studies (Figure 1). STEM education in non-formal learning spaces in Senegal is the context of the study, and the wood carpentry and metal joinery apprenticeships make up one case and the Go4STEAM program is the other case being studied. Each study has two units of analysis, the youth learners and educators, that provide insight into their learning setting.

Figure 1

Design study of the context, case, and unit of analyses, with dashed lines representing blurred boundaries between the three categories.



The first procedure in both studies was to complete a pre-interview screening questionnaire (Appendix B) to gather basic information about the participants and ensure that they met the study criteria for participation. Participants could select to answer the questions orally or through an online form. The second procedure was the individual interviews (protocol in Appendix C) which were up to one-and-a-half-hours audio-recorded sessions for educators and one-hour sessions for youth. The interviews consisted of standardized open-ended questions to begin, but there was flexibility so that follow-up questions were based on the participants' response. The interviews for the apprenticeship case were conducted in person at their workshop, and the Go4STEAM interviews were conducted online using video conferencing. The Go4STEAM program had a third procedure, which was online focus groups (protocol in Appendix D) consisting of the same individuals from the second procedure interviews. The focus group for educators was scheduled to last up to one-and-a-half hours as a member-checking opportunity for participants to validate the findings from the interviews (Saldaña, 2015), give feedback, and offer any additional insight. For all procedures, participants could select to give

their responses in Wolof, French, or English; a translator that spoke all 3 languages was present at each session to assist in the communication between the researcher and participants as necessary. Audio from interviews were transcribed and translated by a translator, into English text. Everyone that assisted with the translating and transcribing signed a letter of confidentiality, agreeing not to share any of the data from the study.

Sharan Merriam's approach to data analysis was used to interpret and consolidate what participants said and what the researcher has seen and read (Merriam, 1998). The data gathered from the interviews was combined for source triangulation and corroboration, to create a rich description of the influences and educational practices that facilitate STEM education in their learning setting. A codebook was developed with predefined categories as headers to group evidence. The codebook for each case was based on the categories of the Ecological Systems Theory (Bronfenbrenner, 1979). The apprenticeship case had additional categories based on scholarly literature of common engineering education features, and the Go4STEAM had additional categories based on the National Research Council criteria for identifying productive STEM out-of-school programs (National Research Council, 2015).

To analyze the data, each transcript was reviewed and then open coded, assigning meaning to the data by labeling it with a code that reflected the data (Saldaña, 2015). The emergent codes that were strengths and assets were matched to the predefined codebook categories. The codes within each category were then analyzed to identify patterns and commonalities from the participants. Finally, the analyzed data was summarized into themes, with a definition written to describe each theme. The discussions used the theoretical framework to draw conclusions and recommendations that describe and strengthen STEM education within the non-formal learning settings of the Senegalese STEM Learning Ecosystem.

Researchers' Perspective

In this section, I describe my position as a researcher in the form of a reflexivity statement. This statement explains how my personal experiences have influenced my approach to this research study. I then describe my ontological and epistemological views which explain how I understand reality and knowledge. These views influence how I interpret interactions within Senegalese societies and influence the case study method I have chosen to collect and analyze study participants' experiences.

Reflexivity

I consider myself to be Senegalese-American, because though I was born and raised in the United States, both of my parents are from Senegal, West Africa. In America, I am constantly labeled as a minority because I am Black. I also have other characteristics that distinguish me from the majority including that I am a Muslim who wears a hijab (headscarf) in public, and that I am a woman who has worked in the male-dominated field of engineering. I am a child of immigrant parents and have gone through complexities of not feeling African enough in African spaces and not feeling American enough in American spaces. However, I value and appreciate the various aspects of my identity. I tend to seek or create spaces where I feel comfortable, so I do not spend a lot of my time feeling like an outcast. As a result of my experiences, I am sensitive to the importance of feeling culturally rooted in my personal and professional life.

Having gone through public schools and universities in America, I characterize myself as having a formal, western educational background. As a result, I am familiar with American history, leaders and ideologies. Growing up in Black communities, I learned and felt the impact of atrocities that happen during and post slavery in the United States. Learning the history and witnessing present day racism and maltreatment has engraved in me the importance of

discernment and critical thinking. People have the ability to lie, steal and manipulate, but there are also people who inspire, strategize and work towards positivity and justice. Growing up in America, I benefit from the historic and present-day sacrifices of others. It is a sad and guilt-invoking reality, but it humbles and inspires me to give back and try to be of helpful servitude to others.

Before becoming a researcher, I was an engineer in the manufacturing field, and I worked on community service projects related to education and economic development. I have my bachelor's degree in Industrial and Systems Engineering (ISE). I was attracted to this field because it encourages a holistic approach of reviewing processes, and then finding improvement opportunities which may be reducing waste, saving costs, or any other objective depending on the situation. As an ISE, I have the reflex to take time to understand a situation, and then assist accordingly. Aside from working as an engineer, I was, and still am, heavily involved in community programs. In particular, I enjoy organizing events and activities for youth, around the topics of Science, Technology, Engineering and Math (STEM), life skills, and mentorship. Now stepping into the role of a researcher, I bring my interests and expertise as an ISE and community organizer into this research study which includes systems building and capacity building.

Though I consider myself Senegalese, and I even speak Wolof (one of the local languages), there are many realities in Senegal that I have not experienced or am not privy to. Growing up I did not spend much time in Senegal, but once I graduated college, I began visiting the country more frequently. I currently work on Senegalese-based educational projects and engage with local educators and students. I am mindful that the transfer of knowledge works two-ways, so I am teaching *and* learning in these educational spaces. With my research study, I want to avoid the perception that I am coming to Senegal and mandating changes to the

educational systems. Instead, I hope to share my skills and expertise, keeping in mind that my individual values and experiences may not be the same as others. I will have my own ideas that I want to share but engaging with people locally will be crucial in creating content that they find helpful.

Senegal was colonized by the French and gained independence in 1960. However, Senegal is considered by some to neocolonized because though technically independent, the country is still influenced politically, economically, and culturally by France. A large part of me wishes to use this research study to tell the story of Senegal without mentioning the French and colonization. Senegal has a rich history, and it would be great to spend time centering Senegalese people and highlighting positive education stories. However, I decided to face the reality that the impact of colonization influences the Senegalese educational system to this day. When considering the Senegalese STEM Learning Ecosystem, there are considerations such as time, culture, and history that signify how past events are a part of the evolution that influences the current state of education.

I decided to use qualitative methods for this research study because I am drawn to the idea of capturing the stories of individuals. I like the idea of sharing space for people, especially the traditionally marginalized, to express their experiences and opinions in-depth. With that, I settled on a case study design where I can interview participants to learn about their positive educational experiences related to STEM education in Senegal. It is my hope that with an asset based, culturally ground, and systems thinking approach, I will be able to gain deeper insight and identify opportunities to strengthen STEM education for youth in Senegal.

Ontological & Epistemological Views

I consider myself to have an interpretive-constructivist paradigm which argues that researchers assert their beliefs when they choose what to research, how to research and how to interpret their data (Edge & Richards, 1998). I am of the belief that what knowledge is, and the ways of discovering it, are subjective (Scotland, 2012), so as a researcher, my particular paradigm influences how I collect and interpret data in this study. I want my research to be useful to people, so I have worked towards designing a relevant and coherent research study. However, I also believe that any conclusions or recommendations that I offer will not be fully representative or a viable solution for everyone. So instead of striving to create content that will perfect everyone's lives, I am more modestly seeking to listen, learn, and curate content that is meaningful for my participants, and stakeholders that want to support STEM education for youth.

This research study uses an interpretive-constructivist paradigm in attempts to understand why things are the way they are in the social world and why people act the way they do (Tuli, 2010). In alignment with this paradigm, I use the ontological positioning that there is no single reality or truth because reality is subjective and differs from person to person (Guba & Lincoln, 1994). We each experience and interpret situations differently. The same scenario, or phenomena, may occur to multiple people but they may not feel it, react to it, or even describe it the same. However, general consensus can still be recognized and understood. For example, no one experiences the death of a parent in exactly the same way as anyone else, with the same mix of memories, regrets, affirmations, and pain. Yet, at the same time, bereavement as a process of recognizing and accepting loss contains a number of patterns and rhythms that could be described as generic (Brookfield, 1998).

I use the epistemological positioning of relativism in this study, arguing that to understand a phenomenon from an individual's perspective, we must investigate the interactions among individuals, as well as their historical and cultural contexts (Creswell, 2009). The potential pitfall of investigating the Senegalese STEM Learning Ecosystem is the overwhelming number of potential interactions that directly and indirectly influence STEM learning. However, source triangulation and member checking are used to converge ideas and build consensus (Angen, 2000) on participants' collective experience. Scholarly literature is used to help interpret and discuss the study findings and create case reports that describe STEM education for Senegalese youth.

Significance of Study

This research study seeks to document the experience of educators and youth in apprenticeships and STEM out-of-school programs as part of the Senegalese STEM Learning Ecosystem. In deliberately taking an ecological systems and asset-based approach to this research study, there is opportunity to understand positive aspects of STEM education in Senegal within its cultural context. Strengthening engineering education within the hands-on learning approach in the wood carpentry and metal joinery apprenticeships may increase youth skills and allow for opportunities in which they can use their skills to innovate and increase efficiency at their workplace, increase their qualification for other job opportunities, and work on initiatives that improve their community. In Senegal, girls are less likely to go to school, and are less likely to qualify and enroll in the high school scientific track. Supporting out-of-school STEM programs such as Go4STEAM, can provide young girls access to a variety of hands-on activities that build knowledge and skills that they can use to pursue STEM in school, in their careers, and in projects that benefit their community. The study is designed to identify and describe

influences and educational practices that study participants experience within their non-formal learning settings. With this knowledge, recommendations are given on ways to leverage local resources and educational assets to further support STEM education for Senegalese youth. The results of the study may generate new information on the Senegalese STEM Learning Ecosystem and topics for additional research studies in the educational field.

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Article One: The Case of Engineering Education in Wood Carpentry & Metal Joinery

Apprenticeships

Abstract

Engineering skills are used in numerous ways including to design technologies, innovate tools, optimize work processes, and solve problems to improve society. There are various influences within the Engineering Learning Ecosystem that directly and indirectly impact youth learning engineering. Literature suggests various features important to engineering education such as investigating, problem solving, innovating, testing, collaborating and critical thinking, to name a few. This case study explores the experience of youth and educators engaging in engineering education within the non-formal learning settings of wood carpentry and metal joinery apprenticeships in Senegal, West Africa. A qualitative approach was used to interview six youth learners, ages 12 to 19, and six educators. The participants were prompted to describe their learning ecosystem including influences and educational practices related to engineering education. The theoretical framework used to inform data collection and analysis is the Ecological Systems Theory. The theory was used to situate youth and educators in the learning context, and an asset-based, analytical approach was used to identify influences and educational practices that facilitated engineering education. Results of the study indicate that parents often play an important role in establishing and maintaining the relationship between youth learners and educators. Also, the educators not only teach the trade, but they also have a role in raising the youth learners as if they were kin. Elements of engineering education were found in the educator's guided instructions and feedback to the youth learner, as well as when the learner is working on their own projects, when they are creating tools for the trade, and when they are optimizing their work processes. Recommendations to strengthen engineering education in the

wood and metal apprenticeships include offering youth learners' resources contextualized for the trade and building their foundations in reading, writing, and math. Engineering education can be offered using informal methods such as online apps, mobile training, or activities such as competitions. Educators can also be supported and trained on their engineering skills and pedagogy so that they are better able to support youth learners in their engineering education.

Introduction

The discourse of engineering in the context of Africa incorporates transformative and renowned accomplishments, such as the scholarship and infrastructure known in Timbuktu (Shuriye & Ibrahim, 2013) and Egyptian civilization (Hassan, 2017). Through-out time, Africans while interacting with their environment and transforming various raw materials, arrived at various hypotheses about nature, the natural world and society. The fabrication of metallic tools, implements, textile production, traditional medicine and food processing, involved the application of various techniques, principles, and propositions arrived through observation of the environment and experimentation at various levels (Emeagwali, 2006). Innovation and invention continue to be influential forces in economies (Roberts, 2012).

In present day Senegal, West Africa, the enrollment of engineering related subjects in schools is relatively low. In 2016, 24.3% of girls and 30.7% of boys were reported to be enrolled in the science and math series in high school (World Bank, 2018b). Students that do not go the high school route may pursue technical, short technical or vocational paths (Djité & Diakhate, 2019; Freeman, n.d.). However, in 2017, only 7.7% of students were enrolled in vocational and technical training (World Bank, 2018a). At the higher education level, between 2008 - 2017, only 26.5% of women and 31.9% of men in Senegal enrolled in science, technology, engineering, and mathematics related majors (Islamic Development Bank, 2019).

However, schools are not the only means of acquiring engineering education. The level of school dropouts in Senegal is relatively high throughout middle school aged groups. Of ages 12 to 18, 41% of boys and 45% of girls are out of school (Education Policy and Data Center, 2018). Some youths do not consider school to be a place, or an opportunity, that could positively change their lives or the situations of their family (Gueye, 2006). The educational needs and rights of large groups of disadvantaged and vulnerable youth may benefit from non-formal initiatives that are an alternative or a supplement to the formal education system (Hoppers, 2006). Fortunately, there are numerous avenues to learn engineering related practices and processes, including non-formal learning spaces such as homes, Quran schools, museums, events, mentoring, out-of-school programs and apprenticeships. In Senegal, more than 33% of young men and 12% of young women, spend time as apprentices (World Bank, 2018a).

Increasing and strengthening engineering education could be beneficial for Senegalese youth because engineering is commonly characterized as an avenue to develop creative and analytical skills, which can lead to careers and contributions to meet major challenges that confront society (Next Generation Science Standards, 2013). Reported by the World Food Programme (2021), more 33% of the population in Senegal lives below the poverty line, and 75% of families suffer from chronic poverty. In 2015, about 55% of working age people were inactive or unemployed (World Bank, 2018a). Furthermore, half of the population in Senegal are under the age of 18 years (United Nations Population Fund, 2014). With such a high percentage of youth, and issues of poverty and unemployment, there is a need to direct more attention to support the youth.

This qualitative research study uses the Ecological Systems Theory (Bronfenbrenner, 1979), as a framework to explore the Senegalese Engineering Learning Ecosystem. In this study,

the Engineering Learning Ecosystem refers to the dynamic interaction among individual learners, diverse settings where learning occurs, and the community and culture in which they are embedded (National Research Council, 2015). The systems approach encourages an in-depth consideration of learners and the direct and indirect influences that their environment has on their education. The case being investigated in this study is the non-formal learning settings of wood carpentry and metal joinery apprenticeships, trades considered to be within the construction and civil engineering sector (Walther, 2008). The intention of increasing and strengthening engineering within the apprenticeship is not to change the carpenters and joinery's job description and objectives, rather to promote engineering skills that can be used to create innovative tools for the trade, and improve their work processes to reduce waste, save time, and optimize resources. The engineering skills may also be transferable to other worksites and be used in community projects that benefit society.

This study uses an asset-based approach to capture the experiences of teaching and learning engineering within the apprenticeship setting. Individual interviews are used to engage the youth learners and educators to gain insight about their motivations, approaches, societal influences, and accessibility to content knowledge and materials. Results of the study lead to a better understanding of the engineering education strengths taking place inside the Senegalese Engineering Learning Ecosystem within the wood carpentry and metal joinery apprenticeships. The findings that emerge highlight opportunities to duplicate and leverage influences and practices that increase engineering skills among youth in non-formal learning settings. With increased engineering skills, youth are in a better position to use creative and critical thinking to develop their livelihood and communities.

Statement of Purpose

The purpose of this case study is to use a systems approach to gain an understanding of how engineering education is offered in Senegal, in non-formal settings, through the lived experience of youth and educators in wood carpentry and metal joinery apprenticeships. This is a qualitative research study that uses individual interviews to collect participants' experiences, and an asset-based analysis is used to identify the strengths of the learning setting. Results of the study identifies current influences that facilitate youth to learn in apprenticeships, and educational practices that facilitate learning engineering. Knowledge gained from this study enlightens understanding of engineering education for youth in Senegal, and highlights ways to leverage local resources and educational practices to strengthen engineering education in non-formal settings.

Research Questions

This research study aims to answer the following questions:

1. What influences facilitate youth to learn in the wood carpentry and metal joinery apprenticeships?
2. What educational practices facilitate youth to learn engineering in the wood carpentry and metal joinery apprenticeships?

Literature Review

The following section is a review of literature that describes key elements and approaches used to form this research study. Common engineering education features are identified to be used when investigating current engineering educational practices within the wood carpentry and metal joinery apprenticeships. The Senegalese education system is reviewed, comparing schools with colonial influences that disrupted culturally grounded education, to apprenticeships that have maintained cultural relevance in Senegal. Literature on the asset-based approach

communicates the positive impact of leveraging communal knowledge and resources, and capitals commonly seen in societies that could be used to strengthen engineering education for youth learners in Senegal. Lastly, a review of the theoretical framework that undergirds this research study is discussed and critiqued, with justification provided on why it has been deemed appropriate for the Senegalese context.

Common Features of Engineering Education

Based on literature, various features of engineering education have been identified that cover the purposes of engineering pursuits; practices, knowledge and principles used in engineering; and commonly used methods to design and implement engineering projects. Learning settings do not have to practice all features to be considered engineering learning spaces, however they are considerations put forth by scholars on common engineering education features. The following inventory of features is used in this research study to determine how engineering education is practiced for Senegalese youth in wood carpentry & metal joinery apprenticeships.

Engineering education should encourage intentionality in identifying the purpose of the engineering pursuit. Learners should be encouraged to understand the goal that is to be achieved, investigate the nature of the problem along with any possible constraints (Adams, 2004; de Vries, 2009; Next Generation Science Standards, 2013; Pawley, 2009). Learners should build skills to use systematic approaches to iterate, increase thoroughness and traceability (Koen, 2003; Next Generation Science Standards, 2013). Systems thinking should also be encouraged to consider interactions and impact of engineered solutions (Adams 2004; Dym et al., 2005; Feng & Feenberg, 2008). Engineering education should also encourage learners that engineering may

lead to well-paying careers, entrepreneurship, and skills to improve lifestyles (Chou & Chen, 2017; Jonassen, Strobel, & Lee, 2006; Pawley, 2009).

To use engineering principles and methods, learners should be encouraged to use math, science and technology knowledge for optimizing and designing technologies, processes, and systems to innovate or solve problems (Dym et al., 2005; Fralick et al., 2009; Koen 2003). Modeling and prototyping should also be taught to communicate, test and improve upon the engineered solutions (Cross, 2000; Dym & Brown, 2012; Kroes, 2012). Learners should be encouraged to collaborate with others to consider intentions, perspectives and expertise to negotiate and strengthen engineered solutions (Idhe, 2008; Niever et al., 2020). Engineering education should also promote creativity, critical and analytical skills to identify problems and innovate (Adams 2004; Dym et al. 2005; Koen 2003; Next Generation Science Standards, 2013; Niever et al., 2020; Pawley, 2009).

There are different methods that can be used to implement engineering projects. Engineering education should encourage learning, improving and creating tools, techniques and methods that can be used for engineering (Adams, 2004; Next Generation Science Standards, 2013; Reeve, 2015). In the process, learners can understand that there are diverse ways to engage with engineering, and in numerous domains (Houkes, 2009; Reeve, 2015; Van de Poel, 2013). Thus, the skills they are learning may be transferable to other engineering projects. Engineering education should also encourage real-world and hands-on activities so that learners are building skills, getting a chance to practice and communicate their work (Braun et al., 2013; Jonassen, Strobel & Lee, 2006; Next Generation Science Standards, 2013).

Culturally Grounded Education in Senegal

Historically, African societies offered training to their members characterized by the provision of survival skills to individuals who were supposed to selflessly serve their societies; with the advent of colonial rule, a formal system of education was introduced to prepare children to serve the colonial administration (Mosweunyane, 2013). For the case of Senegal, the country and its citizens were colonized by the French. The French colonialists had an assimilation approach to education in Africa, with the objective that the linkages of school systems with their social, political, and economic environments should not differ between institutions in France and those in its colonies (Clignet, 1968). To this day, the official language in Senegal is French, and it is the primary language of instruction used in the national school systems (Dexis Consulting Group, 2020). Research indicates that learning in a language which is not one's own exerts undue pressure for children because of the challenges in learning a new language, plus new knowledge and skills (Nieto, 2010; Singh & Espinoza-Herold, 2014). Some students value going abroad more than going to school because they do not consider school to be a place, or an opportunity, that could positively change their lives or the situations of their family (Gueye, 2006).

Cultural-based education is the grounding of instruction and student learning in the ways of being, knowing, and doing - including the values, norms, knowledge, beliefs, practices, experiences, and languages - that are the foundation of a(n indigenous) culture (Kana'iaupuni, 2007). Indigenous knowledge is not static but evolves and changes as it develops, and influences and is influenced, by both internal and external interactions with other knowledge systems (Onwu & Mosimege, 2004). However, because indigenous knowledge is often undocumented, it is subsequently forgotten or replaced by "modern" education and technology that is associated with Western thought (Semali & Stambach, 1997). When internal and communal knowledge are

ignored and replaced with external ways of being and knowing, it can generate feelings of inferiority and self-doubt that lead learners to discount their home, community learning experiences, capacities and gifts (Battiste, 2002).

It has been complained that western-formatted schools transfer authority from elders to teachers, leading to view the elder's knowledge and approach as outdated relics, which is socially damaging in communities like Senegal that traditionally value age and hierarchy (Semali & Stambach, 1997). Throughout sub-Saharan Africa, informal apprenticeships between a master craftsman and an apprentice are a historic yet still common medium for skills development (Sonnenberg, 2012). Informal educational settings, like apprenticeships, with high degrees of hands-on activities do not necessarily distinguish between "theoretical" and "practical" lessons; they learn through experience and practice, rather than through the technical processes which are emphasized by education specialists (Semali & Stambach, 1997). However, the downside to gradually learning the basics of the trade mainly through practice is that learners lack the know-how backed up by theory, which would allow them to achieve better results and afford them a better chance of joining the labor force (Walther, 2008).

There have been approaches within the educational setting that are used to be culturally relevant and productive for the youth learners. For example, in 2014, the Senegalese Ministry of Professional Training, Apprenticeship, and Artisanry developed the *Déploiement Massif de l'Apprentissage Rénové* [Massive Deployment of Renovated Apprenticeship]. This initiative uses a competency-based and dual system approach of learning in the trade workshop, and at a technical training institute, so that participants are offered skills that respond to labor market demands (World Bank, 2018a). The director of learning explained that the program targets a wide range of youth including school dropouts, young people who have a good level of

qualification, and street children (Towards the recruitment, 2014). This initiative is intentional in understanding and responding to the needs of youth learners.

The United States National Research Council (2015) uses cultural-based education to promote STEM (Science, Technology, Engineering and Mathematics) learning in out-of-school programs. They propose that productive STEM out-of-school programs should engage young people intellectually, socially, and emotionally; respond to young people's interests, experiences, and cultural practices; and connect STEM learning in out-of-school, school, home, and other settings (National Research Council, 2015). This Engage - Respond - Connect framework promotes engineering in non-formal learning settings while valuing youth's individuality and connecting their learning experience to their larger system of community. It is advantageous to curate a learning environment that interests and motivates the youth. Individuals that are interested and motivated to attain a goal are more likely to believe in their capabilities to attain that goal (Bandura, 1997), and their motivation manifest itself in various forms such as effort, persistence and choice of activities (Mulder, 2017; Oyserman, Terry, & Bybee, 2002) that can strengthen their engineering skills. The youth age range considered for this study is 12-19. Based on a study in Cameroon, West Africa, adolescents in this age range are expected to demonstrate a sense of responsibility, growing maturity and creativity; social competency and growing intelligence (Tchombe, 2011), positioning them to be able to assess and describe their educational experiences.

Asset-based approach to Senegalese Education Systems

Apprenticeship gives young people the chance to gain professional skills and opportunities for economic and social progress, however, apprenticeships in Senegal are also reported to be underequipped, lacking in structured content and standardized pedagogical

approach (Walther, 2008), dangerous, labor intensive and lengthy to complete (World Bank, 2018a). The traditional problem-solving approach is to identify problems that are occurring and then find solutions for the issues. However, the problem-based approach to development tends to unintentionally suppress community involvement by emphasizing deficiencies, needs and problems, which then results in communities becoming dependent on services rendered by organizations (Nel, 2018). This deficit approach is sometimes perceived as disempowering for communities and can discount valuable wisdom, information, skills and other assets that communities possess (Baum, 2008). Asset-Based Community Development (ABCD), a term coined by Kretzmann & McKnight (1993), was designed to counteract the problem-based approach to development. The ABCD approach, contextualized in the Senegalese education setting, leverages local culture, knowledge and other individual and communal assets to improve the learning environment.

All communities have assets, resources and capital in their local area that are for the benefit of the community (Hawtin & Percy-Smith, 2007). Asset mapping is a process of identifying information about a community's assets such as condition, behavior or knowledge, that a person, group, or entity possesses, which serves as a resource to one's self and others in the community (Burns, Paul, & Paz, 2011). Capacity building can occur when citizens and providers work collaboratively to identify and strengthen community assets and resources (Nel, 2018). Education settings and policies can learn from community involvement wherein the extended family and the rest of the community participate actively in the education of the child (Keller & Whiston, 2008; Nsamenang & Tchombé, 2012; Otto, 1991). By involving individuals, families, communities, and indigenous educators to integrate their history, knowledge, and

experiences, resulting curricula may be culturally grounded and sensitive to traditional customs and social norms (Semali & Stambach, 1997).

Flora & Flora (2008) developed the Community Capitals Framework as a planning and measurement approach for various considerations of community capitals. Using this framework, community members can do their own research and assessments by surveying and mapping their local resources. The available resources can then be leveraged for opportunities to increase and strengthen engineering education for Senegalese youth. The following are the Community Capitals Framework categories and example resources: Human capital: knowledge, expertise, well-being; Social capital: communication, relationship, participation; Cultural capital: values, heritage, perceptions, local content; Political capital: accountability, power, civic engagement; Built capital: local infrastructure, telecommunications, housing; Financial capital: monetary resources, local business capacity, local workforce; Natural capital: location, environment geography, amenities (Flora & Flora 2008). Recognizing community capitals within Senegal, and having a mindset of abundance in assets, can lead to the sharing of information and resources that are beneficial for wood carpentry and metal joinery apprenticeships.

In ABCD-sensitized communities, local people drive their own development, gain skills and confidence, and work together towards common goals (Nel, 2018). When community members begin working with each other, they multiply their power and effectiveness (Kretzmann & McKnight, 1993). YouthMap, a program of the International Youth Foundation (IYF), used an asset-based approach to seek out the voice of youth in Senegal to assess their current circumstances and chart their future directions. IYF intentionally considered the youth as “problem-solvers” rather than as “problems to be solved” (International Youth Foundation, 2011). Key findings from the YouthMap are that poverty is the driving factor behind youth

crime, drug and alcohol abuse, and other destructive behaviors in Senegal, and that out-of-school youth want to learn the skills needed to earn a living, sustain their families, and contribute to their communities (International Youth Foundation, 2011). It has been argued that if education planners could listen to the African worldview and consider African livelihoods, they would learn to focus on a holistic and integrated way of looking at the family and the universe to visualize and design Africa's education in new ways (Callaghan, 1998). The ABCD approach is used in this study to highlight values and strengths within individuals and communities in Senegal, to strengthen engineering education in non-formal settings.

Theoretical Framework

Systems are a set of connected parts that together form a complex whole (Hartzler & Blair, 2019). Urie Bronfenbrenner is an American researcher and psychologist who published the Ecological Systems Theory. Bronfenbrenner defines development as a person's evolving conception of the ecological environment, his relation to it, as well as the person's growing capacity to discover, sustain, or alter its properties (Bronfenbrenner, 1979). He argues that there is reciprocity in the relationship that humans have with the environment, both influencing each other. At the time, traditional psychologists discussed the links of perception, motivation, thinking and learning as part of development, but with the Ecological Systems Theory, Bronfenbrenner emphasizes that a child's development is influenced by their environment including factors such as close connections, interrelations among influencers, indirect influences, societal culture, and significant life events. Bronfenbrenner organizes and describes these factors into microsystem, mesosystem, exosystem, and macrosystem (Bronfenbrenner, 1979).

Bronfenbrenner's Ecological Systems Theory is the theoretical framework used to inform this study. The theory is used in this study to situate youth and educators in the learning and

teaching context, and describe how they, and their environment, influence the youth's engineering education in wood carpentry and metal joinery apprenticeships. Bronfenbrenner describes the influences on a child's development into interrelated and concentric systems: *Microsystem* refers to the immediate interactions that the child interfaces with, and the direct influence they have on the child; *Mesosystem* is the interactions and interconnections between actors in the microsystem and how their interactions impacts the child; *Exosystem* is the interactions that occur in the child's environment that impact the child, without their direct involvement; *Macrosystem* is the overarching patterns of ideologies and cultures that the child experiences through-out life (Bronfenbrenner, 1979). Bronfenbrenner further developed his theory to include the impact of the individual characteristics of the child, and the influence of time: *Ontogenic-level system* refers to the variables within the child themselves, that impacts their own development (Cicchetti & Lynch, 1993); and *Chronosystem* refers to the ever-changing nature of the child, and of society, and how various experiences and events impact the child (Bronfenbrenner, 1986). The Ecological Systems Theory facilitates a systems view and consideration of various attributes, people, interactions, practices and events, that directly and indirectly influence engineering education in non-formal learning settings.

The Ecological Systems Theory used in a Senegalese setting prompts the need to critically reflect on the cultural appropriateness of concepts, programs, practices, and policies exported from the global North (Archibald et al., 2021). A common description of the Ecological Systems Theory is concentric circles with arrows linking context within each system, and a passive, and isolated, child at the center (Darling, 2007). The cultures of North America and northern and western Europe have been identified as generally individualistic - egocentric, separate, autonomous, self-contained and independent; whereas African cultures are collective -

described as an ensembled and interdependent conception of self (Ma & Schoeneman, 1997). Though the traditional depiction of the Ecological Systems Theory centers a child, the overall message of the theory still speaks of interconnectivity with society. Also, this study considers the influence that the individuals' characteristics have on their own development. Thus, the Ecological Systems Theory is presumed to be an appropriate framework for this study, to help identify direct and indirect factors influencing engineering education in Senegal.

Methodology

Case studies are used to describe a phenomenon and the real-life context in which it occurred (Yin, 2014), within a bounded system (Merriam, 1998). This research study uses the descriptive case study methodology to gather and interpret information about Senegalese youth and educators' engineering education experiences in wood carpentry and metal joinery. A thick description of the learning setting is crafted, beneficial for audiences to identify and transfer appropriate findings to other learning settings (Merriam, 1998). In person, individual interviews were conducted to collect data, giving participants the chance to express their insights. Audio was recorded during each interview so that that data could be replayed, on demand, as necessary. The researcher brings a construction of reality to the study design and data analysis, which interacts with the participant's constructions of the phenomenon being studied. The final product is an interpretation of people's views filtered through the researcher's own views (Merriam, 1998).

To increase repeatability and reliability, a protocol was developed (Yin, 2014), documenting and organizing methods and data through-out the case study. This protocol also serves as an audit trail to verify that the results of the study are consistent with the data collected (Guba & Lincoln, 1981). With the data collected from youth and educators, triangulation of

sources is used to increase the internal validity, helping to ensure that the reality of the situation is being perceived and conveyed as truthfully as possible (Merriam, 1995). In a comparison of two or more individual interviews, there is opportunity to triangulate perspectives (Vogl, Schmidt & Zartler, 2019) and a convergence occurs where the sources are similar, and the findings of one substantiate the findings of the other (Sands & Roer-Strier, 2006), or they may complement one another in that the different parts together create a more complete picture (Erzberger & Prein, 1997). In this research study, having 12 participants was helpful to triangulate data and create a combined description that represents the experience of the youth learners and educators in the apprenticeships.

Case Study Boundaries

This research study focuses on the traditionally popular education system of apprenticeships in Dakar, Senegal. Dakar is located in the most western part of Africa, surrounded by the Atlantic Ocean. Though the region of Dakar is the smallest of 14 regions in Senegal, covering only 0.3 % of the national territory, it is also the most populated, with nearly a quarter (23%) of the population living in Dakar (United Nations Population Fund, 2014). Due to the non-formal nature of apprenticeships, there are no formal tracking systems like learner registrations or formal exams that track youth progress. Most youth learners have no way to convey their skills to employers or clients, beyond the word of their educator. While no reliable statistics exist, it seems that in 2017, only about 1,300 apprentices applied to obtain a certification, and there are an estimated 11,921 woodwork and 7,620 metalwork workshops in Senegal (World Bank, 2018a). Each workshop is a learning space that dictates their own rules and standards. There are no national curricula that must be followed, so educators have flexibility in the approaches they use to educate their youth learners.

Knowledge from trade skill jobs (such as electricians, welders, mechanics, tailors, hairstylists) are often passed down to youth through oral lessons and hands-on, on-sight training at worksites or the educators' workshop. This was also the case pre-colonial, where knowledge, skills and attitudes were passed from generation to generation mostly through word of mouth in the African societies (Mosweunyane, 2013). The youth learner and educator relationship is quick to establish, and it is free for learners, which is advantageous for increasing youth accessibility to these learning spaces. Apprenticeships in Senegal cover various domains and services such as repairing and remodeling, which involves creating and problem solving. Thus, there is opportunity in these spaces to promote the use of engineering practices in their education and work environment.

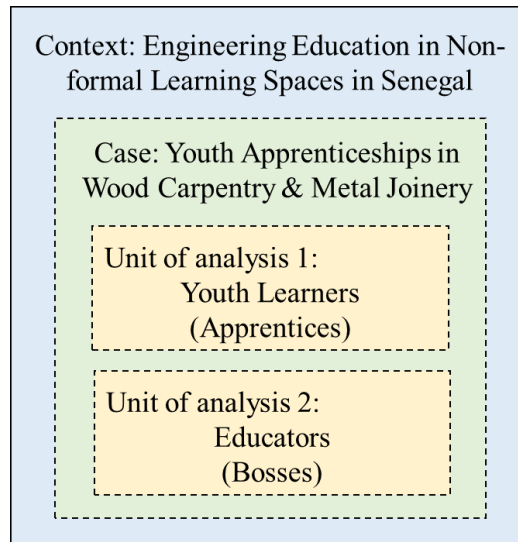
In 2007, Agence Française du Développement (AFD) published research findings of apprenticeships in Senegal. The findings from the study constitute the target sector for this research study. According to the AFD report, the construction and civil engineering sector includes trades such as masonry, plumbing, electricity, tiling, painting, wood carpentry and metal joinery (Walther, 2008). In an oral agreement, parents bring their children to the workshop and delegate part of their parental authority to the educator as part of the apprenticeship education experience. There are no prescribed curricula for youth learners in this sector, however the typical phases of learning is the youth learner watching the action of their educator; undertaking simple tasks; undertaking more responsibilities; and acknowledgement from the educator that training is complete. The training ranges from two to 10 years depending on the trade, age, background knowledge and engagement of the youth learner. The youth learners receive minimum pay for their participation in production within the workshop. Continuity of the

learning content varies in this sector depending on if the youth learner remains in the same trade, same building site, or even with the same educator. (Walther, 2008).

Yin's Embedded Multiple Units of Analysis Case Study Design (2009) is used as a conceptual model for this study (Figure 2.1). Engineering education in non-formal learning spaces in Senegal is the context of the study, and the wood carpentry and metal joinery apprenticeships make up the case to be studied. This study has two units of analysis, the youth learners, which are the apprentices, and their educators, referred to as "patron", French for boss. Interviews were conducted to learn about the participants' individual and collective behavior, attitudes, and perception of the apprenticeship setting. A potential pitfall of the embedded design is when the case study focuses only on the subunit level and fails to return to the larger unit of analysis (Yin, 2009). Thus, this study is mindful that the subunits of youth learners and educators are sources to learn more about their apprenticeship learning context. To scope the research study, an a priori table (Appendix E) was developed aligning propositions with supporting literature, research questions, interview and focus group questions.

Figure 2.1

Design study of the context, case, and unit of analyses, with dashed lines representing blurred boundaries between the three categories.



Participant Screening and Selection

A screening flyer (Appendix A) of the youth learner and educator criteria was shared through informal channels to recruit participants. This included word of mouth marketing using social relationships and driving in search of apprenticeship workshops to recruit participants in person. To screen for Educator participant eligibility, the following criteria were developed: Educator must teach at a wood carpentry or metal joinery apprenticeship; Educator must be teaching a minimum of one youth ages 12-19; Educator must speak Wolof, French or English. To screen for Youth Learner participant eligibility, the following criteria has been developed: Youth must be learning in the wood carpentry and metal joinery apprenticeship; Youth must be between the ages of 12-19 by the time they complete the pre-interview questionnaire; Youth must speak Wolof, French or English. Youth under the age of 18 must provide their assent and parent or guardian permission to participate in the study. This may be obtained in the form of a signed permission form (Appendix B) or the researcher speaking to the parent or guardian to confirm permission to participate.

Purposive sampling was used to select 12 participants, six youth learners (Table 2.1) and six educators (Table 2.2), to give firsthand experience and perspective of their apprenticeship

learning setting. Recruitment was based on the youth and educators volunteering to be a part of the study. All participants of this study were male, which in Senegal is typical for the wood carpentry and metal joinery sector (World Bank, 2018a). Among a group of relatively homogeneous individuals, 12 interviews suffice to achieve data saturation where new information produces little or no change to the codebook (Guest, Bunce & Johnson, 2006).

Table 2.1

The pseudonyms of the youth learners that participated in this study, along with their age, apprenticeship sector, and level of schooling.

Pseudonym	Age	Apprenticeship Sector	Schooling level
Abdou	18	Wood Carpentry	No school
Souleymane	15	Metal Joinery	No school
Mbaye	15	Wood Carpentry	3rd Grade
Bira	19	Wood Carpentry	8th Grade
Mansour	15	Metal Joinery	Some 6th Grade
Modou	18	Metal Joinery	5th Grade

Table 2.2

The pseudonyms of the educators that participated in this study, along with their sector of work.

Pseudonym	Work Sector
Amadou	Metal Joinery
Oumar	Wood Carpentry

Lamine	Wood Carpentry
Samba	Wood Carpentry
Malick	Metal Joinery
Issa	Metal Joinery

Data Collection

The first procedure of this study was to complete a pre-interview screening questionnaire (Appendix B), both an online and paper copy were available in English and French. There was also an option to complete the questionnaire orally with a member of the research team in Wolof, French or English. All participants chose to complete the questionnaire orally. The questionnaire was used to gather basic information about potential participants including name, contact information, role as youth learner or educator, experience level, and an indication on whether they were a part of the wood carpentry or metal joinery trade sector. This information ensured that selected youth and educators met the participant criteria requirements. Everyone who completed the screening questionnaire was made aware that if selected, their responses would be used as data in the study. If they were not selected to participate, then their responses would not be used and would be discarded.

The second procedure was the individual interviews (protocol in Appendix C), which were up to one-and-a-half-hours audio-recorded sessions for educators and up to one-hour sessions for youth. The interviews consisted of standardized, open-ended questions to begin, but there was flexibility so that follow-up questions were asked based on the participants' response. The interviews were conducted in Wolof, French or English, depending on the participant's preference. The researcher speaks fluent English and intermediate Wolof, thus a translator was

present at each interview to assist in the communication between the researcher and participants as necessary. The interviews took place at the participant's workshop.

Audio from interviews were transcribed and translated by a translator, into English text. Everyone that assisted with the translating and transcribing signed a letter of confidentiality, agreeing not to share any of the data from the study. Participants were assigned pseudonyms, with the key under a password protected file. Only the research team has access to the key and no identifying data will be released outside of the research team. The key will be stored on the cloud-based platform Google Drive under a Google Group and destroyed three years after publication.

Data Analysis

Sharan Merriam's approach to data analysis is used to interpret and consolidate what participants said and what the researcher has seen and read (Merriam, 1998). The data gathered from the interviews was combined for source triangulation and corroboration, to create a rich description of the influences and educational practices that facilitate engineering education in Senegalese wood carpentry and metal joinery apprenticeships. A codebook was developed with predefined categories as headers to group evidence (Appendix F). Each category was defined based on literature and included a description of qualifiers that was used to recognize the categories within the data (Pearse, 2009). Using predefined categories helped to focus the coding on factors that are known to be important in existing literature (Miles, Huberman, and Saldaña, 2013). The ontogenic-level system, microsystem, mesosystem, exosystem, chronosystem from the Ecological Systems Theory were used as categories to identify influences that facilitate engineering education. The 11 engineering education features based on the literature review,

were used as categories to identify engineering education activities and opportunities within the apprenticeships.

To analyze the data, each transcript was reviewed and then open coded, assigning meaning to the data by labeling it with a code that reflected the data (Saldaña, 2015). The emergent codes that were strengths and assets were matched to the predefined codebook categories. The codes within each category were then analyzed to identify patterns and commonalities from the participants. Finally, the analyzed data was summarized into themes, with a definition written to describe each theme. Based on the findings, the researcher discussed the perspectives of the youth learners and educators in the apprenticeships. The discussions used the theoretical framework to draw conclusions and recommendations that describe and strengthen the Senegalese Engineering Learning Ecosystem through wood carpentry and metal joinery apprenticeships.

Findings

In this section, the influences and educational practices as reported by the participants are described in response to the research study questions. Eight themes are reported as influencing youth to learn engineering through the apprenticeships. Five themes are reported as engineering educational practices that occur within the apprenticeships.

Findings on Influences: Research Question 1

The following findings are influences in response to Research Question 1: What influences facilitate youth to learn in the wood carpentry and metal joinery apprenticeships?

Ontogenic-level System

Variables within an individual that influence their own development are part of the ontogenic-level system (Cicchetti & Lynch, 1993). These variables may include individual

characteristics such as demography, psychology, personality and behavior. The following themes *Youth learners are self-driven to succeed in the trade* and *Youth that are open to learning and have a basic educational foundation are at an advantage to learn the trade* are described and categorized under the *ontogenic-level system*.

Youth learners are self-driven to succeed in the trade. The educators emphasized that the youth learners that are self-motivated, are the ones that progress and succeed in the trade. Lamine, an educator, said, “If you want to be successful, you have to work hard, sweat, have good thoughts, be very humble, and not be lazy.” Malick, another educator, describes the drive that self-motivated students have. He said,

If the motivation is there, if their heart is in it, and they start to cut something crooked, they’ll be the first person that will want to straighten it. They are the ones who see welding and want to do it. Automatically they will be asking ‘let me try’, or you tell them to go weld, and they go. Everything is step by step, but it is they who will teach themselves, it is not you who is going to force them.... They are on the path, and you are there just to help. If they make a mistake, you help guide them. But saying, ‘come here and master the trade by force’ doesn’t exist anywhere.

Souleymane, a youth learner, explained that his most interesting project thus far has been a metal door because he completed the project on his own. Abdou, another youth learner, described his drive and desire to do a great job with his work. He said,

God has made it so that I have mastered the finishing and detailing of items. My patron [the educator] doesn’t ask anyone to do it except me. It is something I really like and it’s just in me to do it well. I don’t want to do a bad job and have people criticize me. When I

am doing something, my aim is when I am done people will be for people to be in awe of the great job I've done.

The youth learners' drive is also seen in the way they take ownership of their learning and working on their own ideas. Issa, an educator, recounted, "Sometimes I come and see that they are on YouTube checking out new things, or they may be trying to create something, but I don't say anything. I just let them continue." The youth learners described using YouTube, Google, Pinterest and their surroundings to draw inspiration. Modou, a youth learner said,

I can be walking and see a beautiful door so I take out my tools and begin measuring it and writing down notes. Just recently I was washing my pants and saw a paper inside with measurements and I don't even remember what the measurements are for. But that's what I do, I constantly take notes and keep it in my pockets.

The youth learners indicated two major motivations for their desire to succeed in the trade: for the knowledge to do the job well, and for financial security to be able to take care of their family.

Abdou said,

I want to master pretty much everything, because things keep on improving, that is why we have to learn more. Within a few years you will see new designs and new styles, and that is why I really need to be skilled and qualified at it. I don't need money, because once you have your knowledge, money will come after, may Allah [God] help us.... I want to become very successful so that I can help my mother, my future children and my grandchildren too.

In this theme, the educators describe the importance of youth learners having drive in order to succeed in the trade. The learners show their drive by seeking knowledge and working on their own ideas. The youth learners taking ownership of their learning, and engaging in tasks

that interest them, is an indicator of productive learning (National Research Council, 2015). Through their personal projects, they work on real-world and hands-on activities that allow them to practice and build their skills (Braun et al., 2013; Jonassen, Strobel & Lee, 2006; Next Generation Science Standards, 2013). With the reduced supervision, the learners have the autonomy to identify their own objectives and constraints and use their own creativity and critical thinking skills to complete their work, which are important features of engineering education (Adams 2004; Dym et al. 2005; Koen 2003; Next Generation Science Standards, 2013; Niever et al., 2020; Pawley, 2009). The youth learners described being motivated by the desire to master their trade and the financial ability to help their family members. Their motivation increases their belief that they are capable of attaining their goals (Bandura, 1997), and increases their effort, persistence and choice of activities to achieve their goals (Mulder, 2017; Oyserman, Terry, & Bybee, 2002).

Youth that are open to learning and have a basic educational foundation are at an advantage to learn the trade. The educators and youth learners described that having a few years of schooling is advantageous to learning the trade. Lamine, an educator, said, “Some of the kids have little education. Some did go to school for a little bit, and they have a good reputation for their work because they are able to calculate.” Bira, a youth learner with 7 years of schooling said,

The fact that I went to school does help me a lot in the work. The guys here even tell me that I am smart. I was thinking I was smarter than them, but it is more so due to the fact that I have been to school.

The youth learners that had some formal schooling, specified that it is their language, reading, writing, and math foundations from school that benefits them in the trade. Modou, a youth learner with 5 years of schooling said,

Well, school is very helpful [in this line of work]. You might have a customer who only speaks French, or you might have to use calculations to correctly measure wood dimensions. If you don't know how to read and write, it won't be easy for you.

Djite, an educator, explained that schooling isn't a requirement to excel in the trade, as long as the learner is smart, strong, and has a good attitude. He said, "The easiest thing is having someone who is super smart, very hard working, strong, and isn't easily upset." Abdou, a youth learner who has never been to school said,

You have to be smart to achieve what we are doing here because you need to think before making any decision.... I haven't spent a year yet in the workshop, but Allah [God] has helped me and I am a fast learner. I can pretty much do all those things they are doing.

In this theme, the findings indicate that the ability to communicate, read, write, and do basic math are all helpful skills to learn the trade. Similarly, in engineering education, math, science and technology are often leveraged to optimize designs, processes and systems used to innovate and solve problems (Dym et al., 2005; Fralick et al., 2009; Koen 2003). Though schools offer the opportunity for the youth learners to build their educational foundation, some do not go to school at all, or they drop out. In Senegal, 41% of boys and 45% of girls middle school-aged youth are out of school (Education Policy and Data Center, 2018). The participants suggest that prior school experience is not the only method to be successful in the trade. It is beneficial for the youth to learn fast, and work hard, because the trade requires critical thinking and physical labor. Efforts to increase engineering education within the trade should include learning tools,

techniques and methods that can be used for engineering (Adams, 2004; Next Generation Science Standards, 2013; Reeve, 2015). With a willing attitude, the learners can work with their educator to build upon their knowledge and learn new skills.

Microsystem

People and contexts that the youth interact with directly are part of the microsystem (Bronfenbrenner, 1979). These situations and interactions include direct engagement with youth and engineering related activities. The following themes, *Youth learners are encouraged to learn the trade by the people close to them* and *The educator's role is a combination of teaching and raising the youth learner* have been described and categorized under *microsystem*.

Youth learners are encouraged to learn the trade by the people close to them. The people close to the youth learners push them to learn and progress in the trade. Modou, a youth learner explained, “If I were to stay at home doing nothing, everyone would tell me to go find work, have some pride. So their words motivate me.” Mansour, another a youth learner, also shared that his family’s words are motivating. He said, “Their encouragement and motivating words like ‘work hard’ and ‘be patient’, really support me.” One of the educators, Malick, recalled when he was an apprentice, it was difficult to see his peers go to school.

When you are going back to work around 3pm, seeing your friends who were working on their baccalaureate [high school diploma] was very hard. But if you have a strong mother whose desire for you is to have a good future, then it’s easier. My mother told me if you love your kids, force them to do what is good for their future, don't just let them do whatever they want.

Along with family members, the youth learners’ educators also push them to succeed. Amadou, an educator, shared,

Their [the youth learners] future is my success. If they have a good future, I have succeeded. The success is wherever I go, they point at me saying, 'He is the one who taught me, he is the one who did this for me'- that is success.

Malick, an educator, explained that pushing the youth learners to learn is delicate and can affect the youth learners positively or negatively. He stated, "It depends on the method you use to teach because some people can see beneficial things by the way you teach them. For others, you are disturbing them and they will not be thankful." Samba, an educator, elaborated on being mindful of interacting with the youth learners to evaluate their learning. He said,

When they [the youth learners] show up and start working, whatever they do is going to be marked. But you don't tell him in front of his peers, because if someone did not perform well or is not as good as his peers, he can be embarrassed or frustrated and can be mad at you. You just let him work, until they go home and you call him and evaluate him.

Abdou, a youth learner, explains that his educator supports his learning progress. He shared,

The fact that I have never been to school can make things a little bit harder, but my patron [the educator] is here to help with the dimensioning. In addition, if I want to measure something, I use the measuring tool and count up to there, then I mark it. God has given me that ability.

In this theme, the findings indicate that family members and educators push the youth to learn the trade. Both family and educators are in the youth learner's microsystem (Bronfenbrenner, 1979), and are frequently interacting with and motivating the youth. Family members use their words to encourage the youth learner to not be idle. Strengthening the family's involvement would provide a holistic and integrated approach (Callaghan, 1998) that

leverages family influences to encourage youth to learn the trade. Findings in this theme also express that the educators are careful in teaching and providing feedback to the youth learner in a way that avoids resentment from the learner. As the educator transmits their knowledge to the younger generation through oral lessons, and hands-on, on-sight training, (Kunjufu, 1984; Mosweunyane, 2013), they are mindful to encourage the child while caring for their feelings. Considering the learner's whole self and well-being (Kana'iaupuni, 2007) is an example of a cultural-based educational approach occurring within the trade.

The educator's role is a combination of teaching and raising the youth learner. Most of the youth learners described their educators as parent figures. Bira, a youth learner, said, "I can say he [the educator] is the one who raised me, because I've been here since I was 14 years old." Abdou, a youth learner, shared,

It is like I am working with my parents. They [the educator] are the one helping me along which is why I don't need anything. I am working regularly, they are very kind and open, they basically share whatever they know. Since I've started working here, they have been helping me. I have seen their efforts and I cannot repay them.

The educators describe their role as it relates to the youth learner is to not only teach them, but to raise them. Oumar said, "To teach them this trade you must first raise them like you raise your children." Raising the youth learner includes tending to their needs but also instilling good values in them. Malick detailed,

They [youth learners] have breakfast and lunch here, and every weekend we give them transportation fare or spending money.... Here, they are also going to have a well-rounded education because you will have to pray daily. They are also going to have good behavior because some workers have a bad reputation. Some people think they are idiots,

and they are not civilized. As for me, probably because of what I went through, if you've been trained here, you will be well-behaved and speak and act like a human.

Amadou described the responsibility associated with caring for the youth learners. He said,

In addition, we also have a great responsibility because in case of accidents we have a problem. If you don't have the means to bring your kids to school, the government will just watch, they won't get involved. But if our kids get into a work accident, and we don't have the means to pay, it is a problem. So it is a great risk, so that's why we don't take random people. It is not easy at all, because our work is very risky. If I send a boy to buy materials and he has an accident, it is going to be my responsibility. We work with electricity, so if he gets electrocuted, it is my responsibility. If he falls, it is my responsibility. Even if they fight between them and someone gets hurt, it is my responsibility. There are a lot of risks.

The educators described two main approaches to teaching the youth learners: being strict and intimidating, or being open and approachable with the youth learners. Amadou, an educator, shared, "The kind of relationship I have with the youth is that I'm closed off, severe and firm. No laughing or joking with them. This is so that they don't have access to me. Because when they don't fear you, they will not work." Whereas Malick, another educator, describes an opposite teaching approach. He said,

Well, there's only one method to get the kids to learn. You cannot be scared of me, you have to be willing to approach me. I discuss with them, if you make a mistake, I will correct them in a proper way. When it is time for discussion, I talk to them and explain to them what I have been through. I am always telling them, you may have friends who don't want to see you learning, so it is you who has to know what you want and go for it.

Don't be on things that will not benefit you because in this trade, once you master it, it is for good until you become old.

In this theme, the findings indicate that the educator's role combines teaching the youth the trade while raising them as if they were family. Being responsible for the youth learner includes overseeing them through-out the day and taking care of any issues that may occur. The holistic approach to taking care of the entire learner is an aspect of cultural-based education because raising the youth includes engaging the learners beliefs, values, and societal norms (Kana'iaupuni, 2007). However, the educators seem to push the cultural-based education further by doubling as a parent and taking full responsibility for the safety and development of the learner while they are learning the trade. The educators described two techniques used to communicate with the youth learners; some are strict to intimidate the youth learners into learning, others are open and approachable, intentionally connecting with the youth learners. These findings indicate that the trade learning environment is conducive to engaging the youth intellectually and emotionally, which are important for productive and culturally responsive engineering education (National Research Council, 2015).

Mesosystem

Connections between people and contexts within the microsystem that affect the youth's experience, make up the mesosystem (Bronfenbrenner, 1979). These include situations where actors and factors within the microsystem interact directly with each other in regards to the youth's engineering experience. The following theme, *Parents of youth learners coordinate with the educators to facilitate learning the trade*, has been described and categorized under *mesosystem*.

Parents of youth learners coordinate with the educators to facilitate learning the trade. The educators shared that their youth learners are usually someone that they know through family or friends. Oumar explained, “Some of these apprentices are my nephews, some of them are from the neighborhood.” Amadou, an educator, explained that the free nature of apprenticeships motivates parents to bring their children to learn. He said,

They [the youth learners’ parents] don’t have money to pay tuition fees for their kids, so they bring them here and make them learn the trade. It can be myself, my brother or my sister or someone close; for those people I can teach their kids and they do not have to pay me.

However, Amadou also clarified that the educators must have a good reputation so that the parents can trust them with their children. He said, “People look at me to see if I am a drug addict or alcohol addict, if yes they will not give me their kids.” Another educator, Issa, explained that parents of clients also reach out to have their children learn the trade. He said, “Some of them [youth learners], I know their family. I was working for them and did a good job, so they brought their children to me.”

The educators also expressed that it is beneficial when the parents are actively engaged and encouraging the youth learners to remain serious and focused. Lamine, an educator, shared, Some [youth learners] can be here one year and you see them improving very fast, but some can be here for years without improvement. Once again, it all depends on how the kids want to learn, and the type of parents they have. Because some of the parents are always making sure that their kids are coming and checking to see if the boys are improving and what they are doing in the workshop. But some kids don’t even show up at the workshop; they will be hanging with their friends until the evening and once they

arrive at home, they lie to their parents by telling them they were at the workshop.

However, some parents do follow their kids to know what they are doing.

Modou, a youth learner, shared that his mom stays engaged with him as he learns the trade. He shared, “At the beginning when my mom asked my patron [the educator] how I am doing, he was like ‘He is not working at all’, but now he tells her I am working hard and moving forward.”

Oumar, an educator, shared that for troubling youth learners, speaking to their parents is the reasons why he continues to give the learners another chance. He shared,

There was one boy, I spoke to his mother in front of him. Negotiating with him is the reason why he is still here. Another boy, same thing, his father just left here. Sometimes they do something and letting them go would be more peaceful, but you have to tolerate them, forget and forgive.

Though parents and educators directly engage with the youth learner in their microsystem, the parents and educators also interact amongst each other within the mesosystem to influence the youth learner (Bronfenbrenner, 1979). In this theme, the findings indicate that parents often utilize their network to get their children to become apprentices. This finding is an example of social capital in use (Flora & Flora, 2008) because parents are able to use their relationships to secure the free educational experience for their child with someone that they trust. The participants also indicate that when parents stay engaged with the educators, they are able to encourage the youth learners to ensure they are focused on learning the trade. The parents sometimes serve as mediators between the youth learner and educator, convincing both parties to continue working with each other. Though parents are not directly involved in transferring the knowledge of the trade to the youth learner, they tend to play an important role in establishing and maintaining the youth learner and educator relationship.

Exosystem

Situations not directly involving the youth, but indirectly influencing their experience, is part of the exosystem (Bronfenbrenner, 1979). These include indirect influence on youth's engineering education experience without their presence or input. The following theme, *Educators seek to pass down knowledge acquired from their own experiences*, has been described and categorized under *exosystem*.

Educators seek to pass down knowledge acquired from their own experiences. The educators explained that they wanted to teach the youth to pass down knowledge of the trade. Lamine, an educator, explained, "Mainly we advise them [the youth learners] because we are trying to teach them, since we know something about it [the trade]. So just helping them to know what we know." Samba, an educator, said that he was working for a different company when he decided to open his workshop and recruit apprentices. He recalled, "I thought, 'Won't it be better if I open my workshop and start teaching youngsters?' That was what influenced me to start teaching them." Amadou, an educator, expressed that he enjoys teaching the trade to the youth. He said, "I love the work, it is like a sport for me and helps me exercise my muscles, get rid of my stress. Seeing them [the youth learners] work makes me feel happy."

The educators learned their trade in various ways. Issa explained that he gained skills working for a Japanese company in Senegal; Samba said he gained his from a White person in Senegal; and Oumar gained skills while working at a company assembling imported furniture from countries like China, France and Italy. Amadou shared that he gained skills within the country and while traveling abroad. He said,

The fact that I have traveled a lot, I have become more experienced, because I discovered new work and new skills. As a young boy I learned some skills in Mauritania for

instance. Also from Mali and Niger, I have learned many different skills. Regarding the Westerners, what I mostly learned from them is how to work safely and organize the work.

The educators' pedagogy was formed in part by their own experiences. Malick shared,

This trade requires intelligence and strength. When you become fatigued, you may get hurt or break something so it's better to stop and do something else. I remember in the company I was working for, the manager was doing the same. For example, if he saw you working hard under the sun and he knew that you were tired, he would just come and open up a conversation, 'Wow, have you seen what is happening in Senegal... this president will put us in trouble.' He created conversation to give us a break, even though he is the leader and we shouldn't be stopping. That is where I learned that from. We would pause and talk until the conversation got good, and then he'd say 'Okay, stop the talking and get back to work.' I asked him 'Why are you doing this? You're slowing down my work.' And he explained, 'I could tell you were very focused and tired, that is why I came just to distract you a bit.' I learned those tips from him.

In this theme, the findings indicate that the educators were interested in teaching to pass down knowledge of the trade and interact with the youth. The educators formed their skills and pedagogy from various learning and working experiences including working at companies and traveling to different countries. The educator's knowledge evolves with influences from external and internal knowledge systems (Onwu & Mosimege, 2004). The educator's knowledge and expertise are forms of human capital (Flora & Flora, 2008) that the youth learner gets to benefit from. By sharing the educator's experience, the youth learn about diverse domains in which their

trade could be used which is an important aspect of engineering education (Houkes, 2009; Reeve, 2015; Van de Poel, 2013).

Macrosystem

The social aspects and cultural makeup of society that influence youth's experience, is part of the macrosystem (Bronfenbrenner, 1979). The influences include any societal ideologies, traditions, expectations and behaviors. The following theme, *Learning the trade is an alternative to school and trouble*, is described and categorized under *macrosystem*.

Learning the trade is an alternative to school and trouble. Some of the youth learners had never been to school, while others attended a few years and then dropped out. Learning the trade became an alternative to attending school. Abdou, a youth learner shared,

I wanted to do this. I didn't like school because the punishments were very hard, and you are not allowed to go out. Me, I like the work, I just enjoy it. At an early age I used to pick up small iron scraps and play with them.

Modou, another youth learner that dropped out of school, explained he didn't want to waste time and resources, and preferred to do something more aligned with his interests. He said,

I was at a point in my life, where I thought if you are doing something that doesn't interest you, you should stop and do what you really like. Also, you are the one who can help your parents, it's a sacrifice for them to work and pay tuition fees, so you had better let them know early on that you don't want to go to school, so that you can do something else.

The educators expressed that learning the trade is a safer outlet than being idle and being tempted to engage in criminal activity. Amadou said, "If these youths aren't learning the trade, they will

wander the streets.” He continued on to explain his desire to save the youth from street life. He said,

What motivates me to teach is that we are in a destitute country and many people don't want their kids to be hanging in the streets. So they prefer to give them to a friend, a brother or other family, and say, 'look after my child,' to save them. So, they gave me their children to look after so that they can be saved.... All throughout the world, young children are forbidden to work. But here we don't have an alternative so we broke through the barrier, so that our kids don't become delinquents. We don't wait for the state; we broke through the barrier to preserve our children and hold on to them.

Lamine, another educator, explained engaging in the trade orientates the youth to not commit crimes and instead builds their capacity to lead and take care of their families. He said,

What is interesting about teaching is that in a lot of ways we are just giving them knowledge. But additionally, we are trying to make sure that they will not become criminals. We are making sure they have an occupation and in the future, can take care of their own responsibilities, and survive without depending on anyone.... We want them to have bright futures because if you don't make it in the future, you will suffer a lot. Either you are going to become a criminal or you will totally depend on your family.

In this theme, the findings indicate that learning the trade as an apprentice is an alternative to attending school, being idle, and participating in criminal activity. Within the trade, the youth can engage in real-world, hands-on activities to build their engineering skills (Braun et al., 2013; Jonassen, Strobel & Lee, 2006; Next Generation Science Standards, 2013). Increasing engineering education within the trade can also produce transferable engineering skills that may lead to jobs, entrepreneurship and skills to improve lifestyles (Chou & Chen, 2017; Jonassen,

Strobel, & Lee, 2006; Pawley, 2009). Communicating the various opportunities that youth can strive for can help them realize their options to stay engaged and be productive members of society.

Chronosystem

The constant changes that occur throughout the child's life and surrounding context, are part of the chronosystem (Bronfenbrenner, 1986). This includes personal transitions and societal events that over time impact the youth's development within the trade. The following theme, *Advancement in skill level transitions the youth learner to more responsibilities*, is described and categorized under *chronosystem*.

Advancement in skill level transitions the youth learner to more responsibilities. The youth learners shared that through observation and repeating of tasks, they were able to build their skills over time. Bira said,

I won't say it is easy but for me everything is doable. As I said, things were very hard at the beginning, maybe that is why it has become easy now. As people are working, I watch what they do, and when I start doing it, it becomes easy, and I start to advance.

Mbaye explained that he makes doors, beds and chairs very well, and he is especially good at the finishings because he is always repeating those tasks. Similarly, Souleymane said that painting has become the easiest task because he spent a lot of time doing it.

Samba, an educator, explained that over time, he gets to know his apprentice and can gauge their abilities. He said,

After about 3 years of learning they [the youth learner] can start practicing what they have learned. From there I can tell how skilled you are. If you cut corners, I can tell if

you did it on purpose or not, because I now know you very well, and you also know me. I can know how good you are and how fast you are with the work.

The educators shared that the youth learners show signs of mastering their work once they start taking on more responsibilities. Issa, an educator, explained, “When the apprentice starts taking responsibilities without waiting on me for anything, I can tell that he has mastered the work.” Souleymane, a youth learner said, “I know I am improving through my achievement and how useful I am in the workshop, because in the beginning, I wasn’t given a lot of tasks compared to now.”

Quick and accurate work were also indicators of an apprentice mastering the trade. Souleymane, the youth learner, went on to state, “When I am fast at what I am working on, I know that I am starting to master the work.” Mansour, another youth learner, shared,

When I start welding and see that it is good work, I know my welding is improving. And when I am working and someone is watching and then they leave and don’t come back, then I know that I am doing a good job.

Once the educators are confident in the learner’s skills, the apprentice is encouraged to find employment or begin their own workshop. Lamine, an educator, stated,

Once he [the apprentice] has spent three to four years here, I start giving him the tasks that I do, just to test him. If he succeeds in getting it done well, from there you know now that the boy is good. After his fourth or fifth year, as his educator I can call his parents and tell them that their boy is now skilled enough to work by himself. Then he can either be employed or create his own workshop.

Oumar, an educator, shared that he has an apprentice who has recently completed their training. He said, “He can open his workshop because he has the skills and the experience to do so.”

Oumar encourages his learners to work towards managing their own workshops. He said,

For their future, I want every one of them to know this trade and open up their own workshop, even if they are working in big industries. I hope they have their own workshop, because once you have mastered your work, owning your workshop is better.

In this theme, the findings indicate that the youth learners build their skills by engaging in the trade over time. During their time within the trade, there is opportunity for the learner’s engagement to include real-world and hands-on activities to improve their engineering skills (Braun et al., 2013; Jonassen, Strobel & Lee, 2006; Next Generation Science Standards, 2013). As the learner’s skills strengthen, they are given more responsibilities with less oversight. The youth learner’s ability to work on their own projects indicate that they are building skills to conduct their own investigations and analyses to identify problems, constraints and objectives of their task, which are important in engineering education (Adams, 2004; de Vries, 2009; Next Generation Science Standards, 2013; Pawley, 2009). Once the educator is confident about the learner’s skill level, the learner’s role transitions, and they are encouraged to be employed or establish their own workshop. An advantage to learning the trade is that the learner’s develop skills that could be useful at other worksites, which is helpful for the youth to find employment. By incorporating engineering education, the youth can also learn about the diverse ways they can engage with engineering in varying domains (Houkes, 2009; Reeve, 2015; Van de Poel, 2013). Learning the trade is also conducive to entrepreneurship, which aligns with a feature of engineering education, the awareness that it may lead to well-paying careers, entrepreneurship

and skills to improve lifestyles (Chou & Chen, 2017; Jonassen, Strobel, & Lee, 2006; Pawley, 2009).

Findings on Educational Practices: Research Question 2

The following findings are educational practices in response to Research Question 2: What educational practices facilitate youth to learn engineering in the wood carpentry and metal joinery apprenticeships?

The educators give the youth learners guided instructions

The educators explain that when teaching the apprentices, they have the learners observe the work and then try the work themselves. Issa, an educator, said,

When we have work to do, I call him [the youth learner], and he stands near me and I do the work while he observes. Sometimes when I am welding something I give him the welder and hold his hands to show him how to weld or cut a metal. Sometimes I show him how to hold the tools, how to take measurements, and also teach him how to communicate and work with clients.

Malick, an educator, explained that templates are used as a guide to help the youth replicate items. He said,

I am the one who thinks through the work on what I will create. I do the designing at home, come to the workshop and begin measuring and cutting one by one while the kids look. When one is done, I give it to them to replicate. They use the finished one as a reference.

In addition to the observations and hands-on trials, the educators provide information like dimensions of an item to the youth learners, to supplement their learning. Oumar, an educator, said,

If I want to make a dresser, I will show them how to start and trace the length of the dresser.... I will tell them the dimensions. I give them the dimensions until they know it themselves. As they learn the dimensions, that is the beginning of this trade.

Bira, a youth learner, explained that when he is working on his own projects, he uses his own system of working. However, when he is working for his educator, he follows the educator's instructions. Similarly, Mbaye and Souleymane, both youth learners, shared that they follow instructions from their educator. Mbaye said, "Any new information I get is from my educator, and I do what he asks me to do. I put things together under help and supervision." Souleymane said, "I may come in the morning like today, and they will give me a door to work on, or give me something to repair.... I just do what my educator asks me to do."

The educators also described their approach of distributing tasks to the youth learners. Malick, an educator, said,

I am the one who is coordinating all of the work. I am the one doing the bills of materials, taking measurements, doing the design, buying all the materials and determining the dimensions. I write everything that needs to be done and assign every one of them things they should do. When they start the work, I verify it is good. If there is a mistake, we rectify it.

In this theme, the findings indicate that to teach the youth learners, the educators first have the learners observe how to do the task. The educators then provide guided instructions which may include verbally telling the learners what to do, or physically providing guidance by moving the learner's hands to show them how to do a task. At times the educators provide the learners with a template or model that can be used to reference and reproduce items to specification. The emphasis placed on observing and following standard instructions is similar to

taking a systematic approach to iterate and increase thoroughness and traceability, which are important in engineering education (Koen, 2003; Next Generation Science Standards, 2013). The educators provide detailed instructions to the youth learners, which promotes the learner to understand the goal that is to be achieved. Investigating and understanding goals and constraints are important aspects of engineering education (Adams, 2004; de Vries, 2009; Next Generation Science Standards, 2013; Pawley, 2009). However, with the educators providing instructions, it decreases the learners' opportunity to conduct their own investigation about their assignment. With the guided instructions, the educator tells the learner the appropriate dimensions and techniques used to get the job done. To increase engineering education, the educators could allow the youth learners to calculate, experiment, and build their math, science, and technology skills to innovate and problem solve (Dym et al., 2005; Fralick et al., 2009; Koen 2003). In this theme, the educator and youth learner work closely together. Their working dynamic is collaborative which is a major feature of engineering education (Idhe, 2008; Niever et al., 2020). The educators assign tasks to the learner, so that the learner knows what they are supposed to do throughout the day. However, to strengthen the collaboration and increase the engineering education, the youth learner can still continue to follow guided instructions, but also have more opportunity to contribute ideas to get the job done.

Tools are acquired and used to educate the youth learners

The educators have the youth learners purchase material needed for an item so that they can better understand what items are needed for a particular task, and to promote autonomy. As Issa, an educator, explained, “In case you [the educator] are not there, they [the apprentices] are able to get it themselves.” The educators use various approaches when they are missing tools needed for a task, such as purchasing tools, or borrowing them. Oumar, an educator, said,

I don't have many tools. If I have to design something and I don't have the right tool, I will bring it to another workshop and work from there. The place doesn't have a name, it's just another workshop. Everything we cut there we have to pay for.

At times, the educators may even create their own tools. Malick, an educator, said, "Well, you can't be working or having a workshop without tools. At times, we have created tools. If I know that I cannot afford it, then we create it, like the tools that we use to forge."

The youth learners use templates and models to replicate and save time on work. Malick, the educator, explained, "They may see something and want to make it. They make one and it takes time, so they decide to make a template to save time. The template can be used to make other pieces more quickly." Tools are also used to draw designs, measure, and assemble items. Oumar, an educator, explained,

We have a worksite in a mosque at Mboro, where we are making doors. Those doors have designs on it, so we are obligated to draw because the doors are kind of circular. For that you have to take measurements and take a look at all the details and draw it out. We may also see someone who wants an antique-style bed. To make that kind of bed you are going to draw.

The youth learners and educators also shared that the tools and machinery used in the trade makes the job easier. Mbaye, a youth learner, explained that making beds, chairs, and desks are easy with the machines. Oumar, an educator, explained that with the advancement of technology, working in the trade has become easier over the years. He said,

The trade now has changed a lot. Because if you look at the type of wood we were using, it is not the same, it has become easier to use. The issues that you used to have you don't have now because everything is already prepared for them [the apprentices]. There is a

lot of difference because nowadays, they have a push-push [wheelbarrow] that you can buy to carry the wood. Also nowadays, there are many places that sell wood so it's easy to acquire. In my days, if the wood wasn't too much you would have to carry it on your head to bring to the workshop.

In this theme, the findings indicate that the youth learners are taught to familiarize themselves with the materials and tools used within the trade. An important aspect of engineering education is learning, improving and creating tools, techniques and methods that can be used for engineering (Adams, 2004; Next Generation Science Standards, 2013; Reeve, 2015). As the youth learn more about the tools of the trade, their knowledge of the tool can be linked to engineering principles. The participants also shared that when tools are missing, they borrow, purchase, or create their own tools. There are other, more equipped, workshops available to be used for a fee. Those infrastructures are a resource within the trade setting in the form of built capital (Flora & Flora, 2008). As the educators and learners create tools, they can use engineering to optimize their process and innovate to improve the tool. The educators use tools to show the learner how to draw, measure, and assemble. The tools can be used to model, prototype and test items, which are principles of engineering education (Cross, 2000; Dym & Brown, 2012; Kroes, 2012). The participants indicate that advancement in technology has made using tools easier within the trade.

The youth learners receive feedback on their work

The youth learners shared that they try to do the job well to avoid negative feedback about their work. Souleymane, a youth learner, said that he considers how everything works together and rectifies any issues that he notices. Abdou, a youth learner as well, explained that he works during lunch time so that he can concentrate while others are on break. He said,

I first go to the store and buy all the things I need, then when we have a break, I get started working on the thing slowly, going step by step because I don't want to rush it and have people tell me that it is ugly. So I wait until they are on break, and I use the machine to cut things piece by piece, taking my time to get everything done.

Testing is a method that is used for youth learners to get feedback on their work.

Mansour, a youth learner, shared, "When I finish an item, I always test it, take a look at it, and verify it before completing and delivering." Lamine, an educator, explained that testing is also beneficial for planning and ensuring accuracy. He said,

We are always testing the quality of the wood if it is the good one or not before doing the work. Also, you have to draw the design you want to do on paper, before doing it on the wood. You cannot directly put designs on the wood because there may be a mistake.

The educators also provide direct feedback to the youth learners. The youth learners shared that they are better able to gauge their improvement based on their educator's comments. Mansour shared, "Whenever I cut or weld a metal, I will show it to my patron [the educator] or my father, and if they tell me it's good, then I say okay." Sometimes however, the feedback may be disheartening and requires the youth learner to disassemble their work and start again. Malick, an educator, stated,

Suppose some boy does not know how to cut. You ask him to do the frame, he frames it, and it is not perfectly straight so you remove the frame and have him do it again while you oversee his work. You tell him to chain the frame, and once he does it, you ask him to take the diagonals and measure them.... Once he is done you come with the correct measurements and verify, telling him 'You made a mistake here, there is a mistake here too.' When you finish telling him all his mistakes, you disassemble it. You already know

it is very frustrating to work on something and then have to disassemble it. It's part of the things that hurt the heart.

In this theme, the youth learners indicate that they receive feedback in regards to their work. An advantage of working in this trade is the opportunity to build skills through real-world, meaningful activities, a relevant element of engineering education (Braun et al., 2013; Jonassen, Strobel & Lee, 2006; Next Generation Science Standards, 2013). The learner having positive or negative reactions as a result of their work prompts systems thinking and consideration of interactions and impact of their work, which is also relevant to engineering education (Adams 2004; Dym et al., 2005; Feng & Feenberg, 2008). The learners test their work to ensure it is of quality. Testing to improve upon creations is an additional facet of engineering education (Cross, 2000; Dym & Brown, 2012; Kroes, 2012). Feedback from the educators also provides the learners with insight on how to improve their work. Incorporating feedback increases accuracy to do the job well, which is important in engineering education because it increases mindfulness in using systematic approaches to iterate, increase thoroughness, and traceability (Koen, 2003; Next Generation Science Standards, 2013).

The youth learners collaborate with peers and skilled workers

The youth learner shared that their peers, who are also apprentices, help them in the trade. Mansour, a youth learner, shared they often borrow tools among each other. He said, "We help each other by borrowing from each other. If you don't have something, someone will let you borrow it. When the time comes you pay them back." Abdou, a youth learner, shared, "Depending on what we are doing we either work individually or in teams. Here it's all about working in teams and helping each other. I prefer teamwork because you get to learn a lot from each other." Bira, a youth learner, shared,

I came up with many solutions in the workshop. Sometimes we can be in the middle of a job and he [the educator] asks me ‘What do you think?’ I tell him what I think and tell him ‘But since it is your work, it is up to you to choose what to do...’ Because usually giving your thoughts doesn't hurt anything.

When the youth learners’ educators are not near, the learners rely on more skilled workers to help them. Amadou, an educator, shared, “It is mostly the oldest, the most skilled and experienced among them, that is the one who helps.” Mansour, a youth learner, said, "Here you have many skilled people. We have four or five of them who can help me out.”

The educators and youth learners expressed that teamwork is an opportunity to spread resources so that everyone is working, yet no one is overextended. Bira, a youth learner, said “Usually we work together. For example, if someone doesn’t have work to do you can say ‘Help me assemble this bed or dresser’, this way no one is idle”. Malick, an educator, said,

Say if one [youth learner] is making a chair, and another one is making a table. If I can tell someone is stuck on their work, I swap them. It’s not even that they can’t do it but they are just tired. Especially when it is hot, and they aren't moving forward. That is how I was taught. If they see you working on something for a while and not advancing, they will say stop working on the chair and go work on the car. You know why? Because they see for two days you haven’t been advancing much, so they’ll say stop working on that and swap work with someone else. You’ll see that they will start moving forward. The next day you put them back to their original work; they will see that the place they were stuck at, someone else did it for them, so they can just continue to finish the job. And it is not that they cannot do it, but they were just exhausted.

In this theme, the findings indicate that the youth learners in the trade often have the chance to collaborate with not only their educator, but also their peers and other more experienced skilled workers. The trade workshops often work in teams to complete a task. The youth learner interacting with others is a chance for them to learn from others, but also gives the youth learner a chance to share their knowledge and skills. The collaborative nature of the learning environment can be useful to promote engineering education because the learners are able to consider intentions, perspectives and expertise to negotiate and strengthen engineered solutions (Idhe, 2008; Niever et al., 2020).

Knowledge from the trade can be used in various ways and acquired from numerous sources

The educators expressed that knowledge from the trade can be used through-out a lifetime. Malick, an educator, said,

This trade is something else. Even compared to office work, apprenticeship is more secure because once you retire from your work you cannot do anything else. But with a trade there is no retirement, even if you cannot work your knowledge is here and is going to be needed.

The educators explained that the skills being taught can be used to work on numerous items.

Lamine, an educator in wood carpentry said, “There are a lot of different sections in carpentry. Some are doing decorations, some are building and working on frames, and some are covering the chairs. We also do repairs.” Amadou, a metal joinery educator, listed,

We are doing all kinds of work regarding metal welding, and metal work is the largest in the world because you have trucks, you have manufacturing companies, you have metal in boats or ships, you have metal furniture, you also have buildings, aids for the handicapped to walk, cars, trucks, motorcycles.

Knowledge of the trade can come from various sources. One of the youth learners, Bira, recalled,

The way we are working here is not the same when you go to another workshop; everyone has their own style. That's why in this trade the learning never ends.... One time my patron's [the educator's] friend came and saw we were working on a door and said we were wasting wood. My patron said he was just used to doing it this way. So the friend suggested a different method and when we tried it, it worked. So my patron said that we would use this method from now on.

The educators also shared that the youth learners acquire new information from the internet.

Lamine, an educator, discussed that his youth learners find new models and systems of work using the internet. He said,

Sometimes they are obliged to come up with new models and new systems, because you cannot depend on only one style, you always have to be creative. That is why we use the internet to find new designs that are beautiful and copy them here.

In this theme, the findings indicate that the knowledge the apprentices learn from this trade is timeless and transferable, so it can serve the youth learner through-out their life, and in numerous domains. Awareness of how engineering within the trade can benefit the learner's future is an important factor when increasing engineering education within the trade (Chou & Chen, 2017; Jonassen, Strobel, & Lee, 2006; Pawley, 2009). Promoting creativity, critical and analytical skills to identify problems and innovate (Adams 2004; Dym et al. 2005; Koen 2003; Next Generation Science Standards, 2013; Niever et al., 2020; Pawley, 2009) are vital in engineering education, as well as learning about the diverse ways to engage with engineering in numerous domains (Houkes, 2009; Reeve, 2015; Van de Poel, 2013). Results from this theme also indicate that the youth learner can acquire information from numerous sources including

others in their trade, their environment, and the internet. The collaboration promotes sharing perspective and expertise which are important in engineering education (Idhe, 2008; Niever et al., 2020). The real-world setting of the trade is beneficial in building engineering skills for the youth learner (Braun et al., 2013; Jonassen, Strobel & Lee, 2006; Next Generation Science Standards, 2013), and engineering inspirations can emerge from daily scenarios like walking down the street and noticing interesting structures.

Discussion

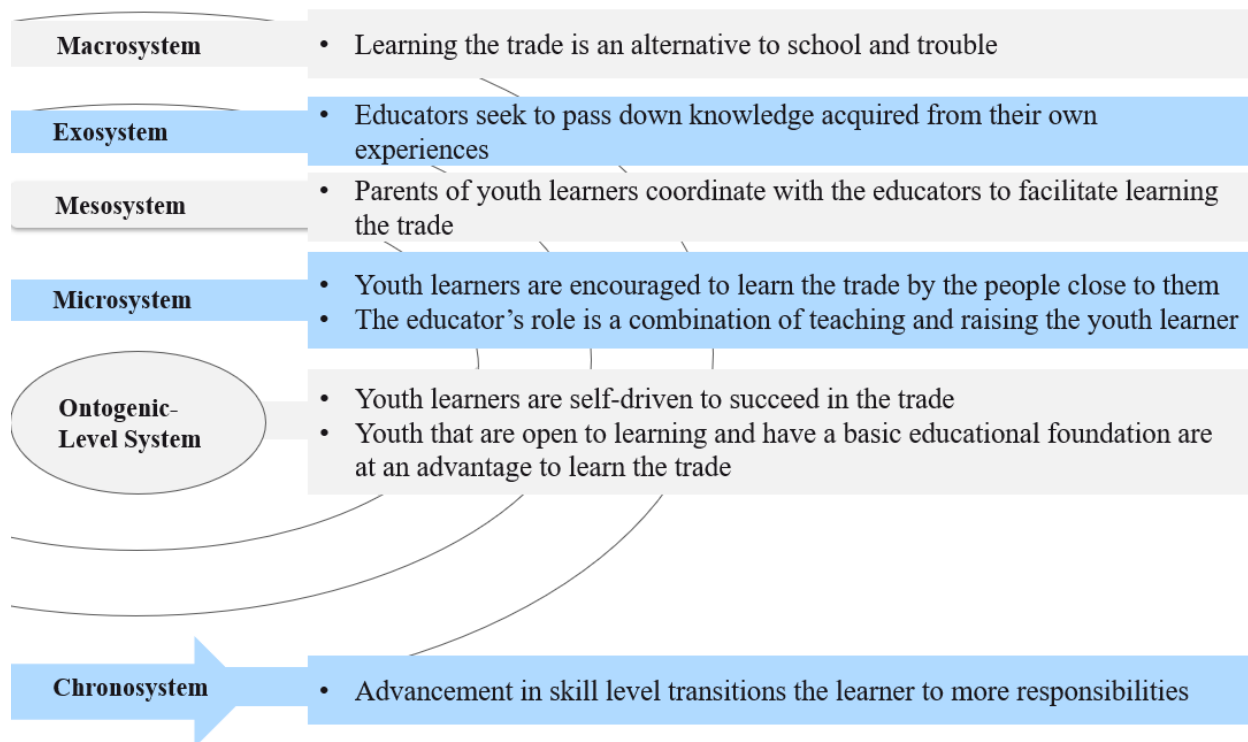
In this section, the major findings are discussed to understand the apprentices learning environment including how youth are influenced to learn in apprenticeships, and what educational practices facilitate learning engineering. Recommendations are described on ways to consider the study findings to strengthen engineering education in the wood carpentry and metal joinery apprenticeships settings, and other non-formal learning settings. Opportunities for further investigations are offered as suggestions for future studies.

Discussion on Influences: Research Question 1

The following is a discussion on the findings (Figure 2.2) for Research Question 1: What influences facilitate youth to learn in the wood carpentry and metal joinery apprenticeships?

Figure 2.2

The following themes are the eight influences that facilitate youth to learners in the wood carpentry and metal joinery apprenticeships.



One of the findings that emerged from this study is that the youth's family members, typically parents, use their social capital to vet and find an educator that they can entrust with their child. These findings confirm that family and community members may influence the education of youth learners (Keller & Whiston, 2008; Nsamenang & Tchombé, 2012; Otto, 1991). The foundation of interpersonal relationships is a distinctive characteristic of the apprenticeship learning setting. In this setting, parents trust in the child's apprenticeship as an education system, but also know and trust the individual educator themselves. The study findings also indicate that it is beneficial to the youth learner for their parents to stay engaged with their apprenticeship experience. Parents should check in periodically to ensure that their child is focused on learning the trade. Parents may also serve as mediators between the youth learner and educator if issues arise that disturb the apprenticeship process. Other learning settings could learn from leveraging communal relations to establish learning environments for the youth that also combine their parent's trust and engagement.

The study findings also indicate that the youth's relationship with their educator influences their engagement in the apprenticeship. The youth learners describe their educators as parent figures, and the educators describe feeling as though they are raising the learners as if they were kin. The educators are responsible for teaching the trade to the youth, but also feeding them, instilling good values in them, and taking care of any injuries that may occur. Future studies could engage youth learners and educators to capture their feedback to proposals of increased formality with government oversight and support into apprenticeships. For example, educators that register an apprentice with the government could receive stipends and health insurance to help care for the youth learners. Literature indicates that apprenticeship workshops in Senegal are typically underequipped (Walther, 2008), dangerous and labor intensive (World Bank, 2018a). Thus, a formal relationship between the apprenticeship settings and the government could provide opportunities to support in terms of access to equipment, work opportunities, and regulations that enforce child safety and worker rights. Input from youth learners and educators on various proposals could lead to more effectively supporting their learning setting.

The findings from this study also suggest that youth learners are respectful and appreciative of their educator, and the educator nurturing, protecting, and having a desire to see the learner succeed in the trade. This approach to teaching that caters to the learner's whole self is reminiscent of cultural-based education in that it considers the learner's way of being, their values and norms (Kana'iaupuni, 2007), however it goes beyond teaching to also incorporate child-rearing. It would be interesting to further investigate the teaching and rearing relationship between the educator and learner. In the apprenticeship learning setting, the educators are highly invested in the success of their learners, and they spend a lot of direct contact with the youth

learners. Individualized learning may be highly advantageous for youth learning the trade. Future studies can also explore the nuance between education and development by contrasting the educators' role in increasing the youth's knowledge of the trade, to also holistically aiding in their development into adulthood. Other youth learning settings could be inspired by elements of the learner and educator dynamics displayed in apprenticeships.

Another major finding that emerged from this study is that apprenticeships prevent the youth from being idle in society. The study finds a reason that youth become an apprentice is because it is an alternative to attending school. In Senegal, 41% of middle school aged boys are out of school (Education Policy and Data Center, 2018), and more than a third of the population of young boys spend time as apprentices (World Bank, 2018a). The study findings also suggest that engaging in an apprenticeship is also an alternative to engaging in criminal activity. Instead, apprenticeships provide an opportunity for youth to gain skills, and earn income, to help take care of themselves and their families. Thus, the apprenticeship learning setting has a socioeconomic impact, and helps to address the chronic poverty (World Food Programme, 2021) and high inactive and unemployment (World Bank, 2018a) that is troubling Senegal. Future studies can investigate the retention rate of apprenticeship in wood carpentry and metal joinery, and help retain youth that want to leave the trade by identifying ways in which interest in the trade can be fostered and grown. Results of this study highlight that in order to succeed in the trade, youth learners must be interested in the subject and willing to work hard, learn, and do physical labor. For the youth that want to quit the apprenticeship, identifying ways to interest and engage them within the trade can help them from being idle and unproductive.

Results of this study indicated that basic foundations in reading, writing, math and communicating are advantageous, and facilitate the learning of the trade. The formal school






option is not successfully attracting apprentices. Until that changes, other supplementary out-of-school learning opportunities could be developed for apprentices. The content can promote literacy contextualized for the trade such as learning to read and draw schematics, interpreting devices used to simplify tasks and using software to model a concept before building. The literacy learnings can also be for other relevant knowledge useful for the trade such as money management, communications skills, and customer service. In promoting literacy, different methods could be used to accommodate the apprenticeship learning environment, such as a mobile program that is able to go to workshops, part-time or off-hours to better accommodate the apprentice's workday, a mentor that specializes in literacy, or even online and self-paced content so that the learner customizes the learning to their schedule. A distinct characteristic of apprenticeship is that they learn but also generate small income, thus for consistency, any supplementary education opportunities should also consider a financial incentive for the youth learners.

Discussion on Educational Practices: Research Question 2

The following is a discussion on the findings (Figure 2.3) for Research Question 2: What educational practices facilitate youth to learn engineering in the wood carpentry and metal joinery apprenticeships?

Figure 2.3

The following themes are the five educational practices that facilitate youth to learn engineering in the wood carpentry and metal joinery apprenticeships.

- 
 - The educators give the youth learners guided instructions
- 
 - Tools are acquired and used to educate the youth learners
- 
 - The youth learners receive feedback on their work
- 
 - The educators collaborate with peers and skilled workers
- 
 - Knowledge from the trade can be used in various ways and acquired from numerous sources

One of the major findings that emerged from the study is that the educators have a process of transferring knowledge to the youth learner. Before working on a task, the educators first have the learners observe the task being done. Then verbally, the educator tells the learner how to do the task. At times, the educator shows the learner how to do the task physically, such as by moving the learner's hand to correct positions and showing them specific motions. As the learner begins to work with less supervision, they are still provided guidance through the use of templates and models so that the learner has an item to reference when making duplicate work, which saves time and increases accuracy. This learning process observed in the apprenticeship could be further studied to explore how hands-on and scaffolding activities occur within the trade. Further findings may be beneficial for other learning settings that are interested in experiential, hands-on, learning.

The guided instructions that the educator provides the youth, including observation, verbal and physical guidance, templates and models as reference, each show elements of engineering education that promotes the understanding goals and constraints (Adams, 2004; de Vries, 2009; Next Generation Science Standards, 2013; Pawley, 2009); use of math, science, and technology (Dym et al., 2005; Fralick et al., 2009; Koen 2003); iteration and thoroughness for

accuracy (Koen, 2003; Next Generation Science Standards, 2013). However, there were no indications that the educators correlated and specified to the learners that the methods used are considered to be engineering principles. To strengthen engineering education in the apprenticeships, it would be beneficial for the learners to be able to identify and label some of their systems of work as engineering skills. The guided instructions can also be adjusted to increase engineering education by allowing the learner to bring their own ideas and feedback to the task at hand. By encouraging the learner's input, they are in a better position to be creative, analytical and innovative (Next Generation Science Standards, 2013; Niever et al., 2020; Pawley, 2009), and sets a more collaborative environment to share insight and perspectives (Idhe, 2008; Niever et al., 2020).

Another major finding from this study is that learners are given various opportunities to receive feedback so that they can evaluate and improve their work. During this process, numerous instances of engineering education occur. The feedback allows the learners to iterate, and increase thoroughness (Koen, 2003; Next Generation Science Standards, 2013); the learners consider components and interactions of their task at hand to rectify issues (Adams 2004; Dym et al., 2005; Feng & Feenberg, 2008); the learners test and verify their work to ensure it meets the work requirements (Cross, 2000; Dym & Brown, 2012; Kroes, 2012). Though the apprenticeship learning setting does not utilize formal grading and exams, the learners still receive real-time feedback on their progress. The meaningful, real-world, and hands-on work opportunities that the learners receive are beneficial to help build their engineering skills (Braun et al., 2013; Jonassen, Strobel & Lee, 2006; Next Generation Science Standards, 2013) because they have specifications to meet, and clientele to satisfy. As their skills advance, they are given more trust, responsibility, and pay, until they reach the point in which they transition out of being an

apprentice.

Aside from completing job orders, the study findings indicate that there are other opportunities for the learners to build their engineering skills, such as when working on their own projects, when creating tools for their trade, and when optimizing their work processes. Future studies can further investigate each option to identify specific engineering principles and methods that could be of direct benefit to the wood and metal apprenticeship. In the study, the youth gave examples of designing and constructing beds and welding doors as part of their learning experience. Thus supportive engineering education may include learning tools and techniques related to structural design and testing, material science and fabrication, joining technology, and more. These principles and methods could be packaged and shared with educators so that they can better support the youth learners. Knowledge sharing among the educators through the internet, formal training, or non-formal gatherings could strengthen their engineering skills and engineering education pedagogy, to more effectively pass on engineering principles to their apprentices.

The findings from this study indicated that youth learners acquire information from numerous sources including their educators, peers in their trade, their environment, and the internet. To strengthen engineering education within the trade, these various sources can be leveraged to communicate new ideas and opportunities for the youth learner. All communities have assets, resources and capital in their local area (Hawtin & Percy-Smith, 2007). Asset mapping could be used to identify local opportunities (Burns, Paul, & Paz, 2011) that youth can acquire information and inspiration to enhance their engineering skills. Programs or institutes that service the youth should consider offering engineering education resources, training, or even activities like competitions, to engage, challenge, and support the youth that are learning in the

metal and wood trades. Online content, and even specialized apps, could be developed to offer relevant design and processes that use engineering to improve methods of work within the trade. The learners and educators could be encouraged to view the content but also upload and contribute their own ideas and methods for others to see.

Limitations of Study

An asset-based approach was used in this study to identify strengths of the wood carpentry and metal joinery apprenticeships. The difficulties that the participants experience within their trade is not shared in this study. Omitting issues and obstacles prevents a holistic view of the trades; however, the asset-based approach highlights strengths that can be leveraged to address issues, inequalities, and concerns related to learning and teaching engineering within the trade. Also, this study uses two units of analysis to collect data, the youth learners and educators. Other direct and indirect influences and educational practices from the Engineering Learning Ecosystem may emerge if data collection were to be expanded to include people such as Senegalese historians, school officials, policy makers, and other sources.

The process of validating findings with the participants in a focus group did not occur in this research study. The individual interviews were conducted at the participants' workshop to save them time and resources. Due to the workshops not being within a reasonable walking distance of each other, it would have required additional resources to gather all participants in one setting for a focus group. Additional resources would also be needed to equip all participants with the technology and Wi-Fi to meet virtually. Also, the participants' work schedule keeps them occupied, so it would have been more appropriate to compensate them for their time. Due to limitations of resources, and to be considerate of the participants, the researcher decided not to organize a focus group to conduct member checking.

Conclusion

This research study contributes to the knowledge of non-formal, culturally grounded engineering education in Dakar, Senegal, by documenting the experience of educators and youth in wood carpentry and metal joinery apprenticeships. In Senegal, apprenticeships are a historic system of learning that has maintained cultural relevance despite colonial influence that promote formal schooling to educate youth. The Ecological Systems Theory is used to explore the Senegalese Engineering Learning Ecosystem, and an asset-based approach is used to understand the influences that lead to youth learning in an apprenticeship. These influences include the youth's self-drive to progress in the trade, support from their family in attaining and maintaining the apprenticeship, and the educators whose role is a combination of teaching and childrearing. The apprenticeships provide a space for learners to engage in learning outside of school settings and avoid delinquency. As youth increase their skills, their education and responsibilities within the trade also increase. Efforts should be made to support youth to build a strong foundation in reading, writing and mathematics which are useful skills to excel in the trade.

The findings from this study illustrate that engineering educational practices occur within the wood carpentry and metal joinery trade, and recommend ways to increase and strengthen engineering education using local knowledge, resources, and educational norms in non-formal learning spaces. In the apprenticeship settings, the educator provides guided instructions that incorporate scaffolding techniques that build upon the learner's skills. The youth learners are also given feedback and tools to expedite their work while meeting required specifications. To strengthen their engineering education, youth learners should be encouraged to share their ideas, and use engineering principles to improve their work processes and innovate useful tools for their trade. The findings indicate that youth learners acquire information from numerous sources

including their educators, peers in their trade, their environment, and the internet. Asset mapping to identify resources available to learners, and activities that support engineering inspiration and knowledge sharing are recommended. This case study is an opportunity to learn from the strengths showcased in engineering education within the non-formal learning settings of wood carpentry and metal joinery apprenticeships in Senegal. Recommendations provided also position stakeholders to support engineering education so that youth have engineering skills to design, improve and innovate inside and outside of their trade.

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Article Two: The Case of STEM Education at Go4STEAM

Abstract

There are various influences and resources within a learning ecosystem that impact youth learning STEM (Science, Technology, Engineering and Mathematics) including direct and indirect interactions with youth, and assets within their environment. Literature suggests that productive STEM education in non-formal learning settings should be engaging and responsive to the youth learners, and should connect their learning to other settings. This case study explores the experience of youth learners and educators engaging in STEM education within the non-formal learning settings of Go4STEAM, an all-girls out-of-school program in Senegal, West Africa. A qualitative approach, that includes interviews and focus groups, was used to engage seven youth ages 12 to 19, and five educators from Go4STEAM. Participants were prompted to describe their learning ecosystem, including influences and educational practices related to STEM. The theoretical framework used to inform data collection and analysis is the Ecological Systems Theory. This theory was used to situate youth and educators in the learning context and consider ways in which their environment influences their STEM learning and teaching experience. An asset-based analytical approach was used to identify strengths and resources described by participants about their participation at Go4STEAM. Results indicated that the youth participants are interested and motivated to succeed in STEM, the educators are intentional in providing hands-on and responsive STEM activities, and the learning environment is supportive in that it encourages peer collaboration and informal, yet respectful, interactions between educators and youth. Recommendations to leverage influences and increase STEM education for Senegalese youth include coordinating with parents and community resources to support youth early enough so that they may qualify for the scientific track in high school and

university. Also, increasing productive STEM educational practices by having the youth take leadership of their learning, whilst positioning the educators as co-learners, and offering the youth opportunities to engage in STEM with various partners and settings around the community.

Introduction

Over recent years, there has been an increase of youth STEM programming in out-of-school settings in Senegal, West Africa. STEM (Science, Technology, Engineering & Mathematics) is a term coined in 2001 by Dr. Ramaley of the United States National Science Foundation, to weave together the elements of science and math which are critical to a basic understanding of the universe, with engineering and technology, the means by which people interact with the universe (Christenson, 2011). This study is on STEM education for youth within the Senegalese STEM Learning Ecosystem. In this study, the STEM Learning Ecosystem refers to the dynamic interaction among individual learners, diverse settings where learning occurs, and the community and culture in which they are embedded. This learning ecosystem includes designed settings such as schools and youth programs; naturalistic settings such as waterways and deserts; people and networks of people such as STEM professionals; and everyday encounters with STEM including on the television or conversations with family members (National Research Council, 2015).

In Senegal, students that want to pursue formal STEM education must be groomed early to be on the STEM track for high school and university. To qualify for the STEM track, students are required to pass an exam to receive their Brevet de Fin d'Études Moyennes (BFEM), a diploma marking the successful completion of middle school. The success rate for passing the BFEM is relatively low, with 28.9% of girls and 34.3% of boys passing the exam (Islamic

Development Bank, 2019). Upon passing BFEM, students have the option to pursue their baccalaureate (BAC), similar to high school. Based on their grades, the students are assigned to a track, be it languages and social sciences (L1, L2), sciences and technology (S1, S2, S3, T1, T2), or management and economics (G). Those not pursuing a BAC may do technical, short technical or vocational or a teaching path (Djité & Diakhate, 2019; Freeman, n.d.). Only 24.3% of high school girls and 30.7% of high school boys enrolled in the science and math related series in 2016 (World Bank, 2018). At the higher education level, between 2008 - 2017, only 26.5% of women and 31.9% of men in Senegal enrolled in STEM related majors (Islamic Development Bank, 2019).

Senegal has a high percentage of youth, about half of the population are under the age of 18 years (United Nations Population Fund, 2014). There is a need to direct more attention to support the youth, including their educational endeavors. STEM education may lead to the development of creative and analytical skills, which can lead to careers and contributions to meet major challenges that confront society (Next Generation Science Standards, 2013). However, the school system maintains a low enrollment of students, especially girls, in STEM fields. Results of a 2003 survey of a national sample in Senegal found that poverty prevents families from providing their children with an environment favorable to learning, and children with educated fathers are more likely to enroll in school (Dumas & Lambert, 2011). Literature also suggests that very young adolescent girls that grow up in developing countries such as Senegal are vulnerable to child marriage, and adolescent pregnancy which affects their education (Kohli et al., 2021). Many parents choose to send their sons to school over their daughters. In a study conducted in the rural town of Vélingara, Senegal, it was found that decision-making related to girls' education and marriage is collective, with adults and elders usually playing leading roles;

and little space is given to girls' own opinions (Kohli et al., 2021). The educational needs and rights of large groups of disadvantaged and vulnerable youth can benefit from non-formal initiatives that are an alternative or a supplement to the formal education system (Hoppers, 2006).

There are studies which indicate that addressing issues with a problem-based approach may lead to emphasizing deficiencies, needs and problems (Nel, 2018) and may discount valuable wisdom, information, skills and other assets that communities possess (Baum, 2008). All communities have assets, resources and capital in their local area that are for the benefit of the community (Hawtin & Percy-Smith, 2007). For example, the knowledge, expertise and well-being of individuals are referred to as human capital, and the communication, relationship and participation amongst community members are a form of social capital (Flora & Flora, 2008). Recognizing assets leads to community members gaining skills and confidence, working together by sharing information and resources (Nel, 2018) and multiplying their power and effectiveness (Kretzmann & McKnight, 1993). In using an asset-based approach, this study offers the chance to see what resources are used, or can be used, to increase and strengthen STEM education for young Senegalese girls.

STEM education is understudied in Senegal, and with emerging STEM programs within the country, more effort should be taken to understand the experience of youth learners and educators as they teach and learn STEM in their non-formal settings. Go4STEAM is an example of an organization that teaches STEM to young girls in Senegal. In this study, the Go4STEAM program is analyzed within the Senegalese STEM Learning Ecosystem, which encourages the consideration of interactions, culture and transformations that influence youth learning STEM. Stakeholders can use this lens to reflect on how they can more strategically collaborate and

contribute to STEM education in Senegal. Listening to the African worldview and considering African livelihoods, would encourage education planners to focus on a holistic and integrated way of looking at the family and the universe to visualize and design Africa's education in new ways (Callaghan, 1998). Policymakers can also learn from communities in which extended family members and community members participate actively in the education of the child (Keller & Whiston, 2008; Nsamenang & Tchombé, 2012; Otto, 1991). This research case study allows us to learn the strengths of the Go4STEAM learning setting so that it may be improved, and the knowledge acquired can be used to benefit other STEM programs through-out Senegal, and the world.

Statement of Purpose

This research study investigates the case of Go4STEAM (Science, Technology, Engineering, Art, Math), an out-of-school program in Dakar, Senegal, that educates middle school girls using STEM related education. This study uses Ecological Systems Theory (Bronfenbrenner, 1979) as a framework to identify factors that influence youth to learn within the STEM Learning Ecosystem, and an asset-based approach to capture the experiences of teaching and learning STEM at Go4STEAM. The qualitative approach of interviews and focus groups to engage youth learners and program educators at Go4STEAM to gain insight about their motivations, educator pedagogy, cultural and historic influences, and accessibility to content knowledge and materials. Results of the study lead to a better understanding of STEM education being taught in out-of-school programs in the Senegalese STEM Learning Ecosystem. Highlights of the strengths of the learning space can be leveraged or duplicated to increase support of STEM education in non-formal settings.

Research Questions

This research study aims to answer the following questions:

1. What influences facilitate youth to learn at the Go4STEAM program?
2. What educational practices facilitate youth to learn STEM at the Go4STEAM program?

Literature Review

The following section is a review of literature on education in Senegalese schools and out-of-school programs, along with a literature review on the theoretical framework that undergirds this study. Literature suggests that a cultural-based education sparks interest and engagement among students, which influences motivation and success. However, the Senegalese formal school system, heavily influenced by the French, upholds French culture while minimizing Senegalese culture. Literature also reveals that STEM subjects have been integrated into formal schools since the 1900s but current statistics indicate low mastery for young students learning math and science. However, schools are not the only methods in which students can engage in STEM. This section reviews out-of-school STEM programs in Senegal along with their approach to engaging youth in STEM. The Ecological Systems Theory is reviewed and presented as the theoretical framework for this study. This framework facilitates the use of a systems approach to assess direct and indirect influences in Senegalese out-of-school STEM programs, and reviews criteria that can be used to ensure STEM programs are engaging youth in STEM, responding to their interests and cultural values, and connecting their learning experience across settings.

Cultural-based Education in Senegal

Cultural based education is the grounding of instruction and student learning in the ways of being, knowing, and doing - including the values, norms, knowledge, beliefs, practices, experiences, and languages - that are the foundation of a(n indigenous) culture (Kana'iaupuni,

2007). In a study on cultural-based education, results indicated that students who solved problems personalized to reflect their interest (e.g., in sports or food) performed better than students who solved matched standard problems (Walkington, 2013). Literature suggests that individuals motivated to attain a goal are more likely to believe in their capabilities to attain that goal (Bandura, 1997). Motivation can have a pivotal impact on academic outcomes (Zimmerman, 2008; Duckworth et al., 2007), and it can manifest itself in various forms such as effort, persistence and choice of activities (Mulder, 2017; Oyserman, Terry, & Bybee, 2002). Research has shown that when students are interested in a task or activities, they exhibit useful STEM education learning practices such as engaging longer and with more effort and productive learning behaviors including generative questioning, self-regulation, deep strategy use, and problem-solving (Lipstein & Renninger, 2006). Effort must be made to explore the Senegalese youth's interests, motivation, and topics that are useful to their life and goals. The youth age range considered for this study is 12-19. Based on a study in Cameroon, West Africa, adolescents in this age range are expected to demonstrate a sense of responsibility, growing maturity and creativity; social competency and growing intelligence (Tchombe, 2011), positioning them to be able to assess and describe their educational experiences.

Formal education in Senegal has been a continuous attempt to adapt a foreign system conceived by a foreign culture in a foreign language to local circumstances (Vandewiele, 1983). In the early 20th century, European officials established secular schools in their colonies (Decker, 2016). Schools have a tremendous amount of power in maintaining the ideology of the ruling class (Althusser, 1971) because of their access to the minds of children to deposit dominant ideals, values, and systems of knowledge (Givens, 2016). The cultures of North America and northern and western Europe have been identified as generally individualistic -

egocentric, separate, autonomous, self-contained and independent; whereas African cultures are collective - described as an ensembled and interdependent conception of self (Ma & Schoeneman, 1997). Education was seen as a vehicle through which western cultures can be fostered or promoted in the African continent by its colonizers, to promote a capitalistic system that included individualistic instinct, and schools connected children, education and economy to produce laborers (Mosweunyane, 2013). For the case of Senegal, the country and its citizens were colonized by the French. The French colonialists had an assimilation approach to education in Africa, with the objective that the linkages of school systems with their social, political, and economic environments should not differ between institutions in France and those in its colonies (Clignet, 1968).

To this day, the official language in Senegal is French, and it is the primary language of instruction used in the national school systems (Dexis Consulting Group, 2020). On intellectual and emotional levels, the discontinuity between the knowledge of the mother tongue and French can hinder integration of thought and expression (Vandewiele, 1983). Research indicates that learning in a language which is not one's own exerts undue pressure for children because of the challenges in learning a new language, plus new knowledge and skills (Nieto, 2010; Singh & Espinoza-Herold, 2014). However, there have been early attempts to introduce cultural-based education in the Senegalese school system. In 1913, a teachers' training college introduced the study of the milieu, teaching within the social environment, as a new pedagogical approach, including adapted textbooks and replacing French teachers with Senegalese ones; but the attempts at adapt teaching to the sociocultural environment were also seen by some as cheapening the schools (Vandewiele, 1983).

Culturally relevant teaching is a method that uses students' cultural knowledge experiences, prior knowledge, and individual learning preferences as a conduit to facilitate curriculum and instruction (Siwatu, 2007). Indigenous knowledge, which includes science and engineering, is not static but evolves and changes as it develops; influences and is influenced by both internal and external circumstances and interaction with other knowledge systems (Onwu & Mosimege, 2004). Literature suggests that the approach for creating curriculum should require teachers to understand students' fundamental indigenous knowledge to teach a kind of science and engineering that coincide with their intellectual interest and socio-economic and cultural setting of such students (Dziva et al., 2012). However, educational stakeholders in Senegal describe that student's weak performance in school may be due to teachers' lack of adequate training and poor use of available resources (DeStefano, Lynd & Thornton, 2009).

STEM Education in Senegalese Schools and Out-of-School Programs

In Senegal there have been early records of STEM related courses in schools. In 1909, there were 21 village schools run by local headmasters with French as a major subject and arithmetic and agriculture as secondary ones; 17 regional schools headed by French teachers, whose syllabus was the same as that of village schools with the addition of the history of France, natural and physical sciences, geometry, drawing, and Arabic; and 6 urban schools entirely run by a European staff with the same syllabus as Parisian schools (Vandewiele, 1983). Thus, there has been an early presence of science and math within the Senegalese formal schooling. Currently in Senegal, in the first three grades, the majority of instructional time focuses on French language development, but by grade 6, almost 25% of the time at school is spent on science and math classes (Dexis Consulting Group, 2020). However, the level of dropouts is relatively high throughout middle school and secondary education. Of ages 12 to 18, 41% of

boys and 45% of girls are out of school (Education Policy and Data Center, 2018). Stakeholders agree that quality of education must improve within schools and priority interventions include improving the curricula, providing more and better teaching materials and textbooks, and providing training for teachers (DeStefano, Lynd & Thornton, 2009).

Senegalese schooling intends to prepare children to have certain types of knowledge that will allow them to pursue higher studies, secure a white-collar job and improve their life conditions (Sylla, 1985). The public school system in Senegal has a national curriculum and standards that must be followed, and the education is often lecture-driven or rote learning (United Nations Educational, Scientific and Cultural Organization, 2005) and the curricula is largely regarded as too theoretical rather than practical (International Youth Foundation, 2015). However, non-formal learning settings such as out-of-school programs, may dictate their own teaching style and objectives to include the hands-on practical engagement of STEM education. Researchers indicate that a variety of cognitive skills and higher-order thinking skills can be nurtured through their application to a practical context (Niiranen, 2021). Education philosopher, John Dewey, argued the benefits of learning-by-doing. Dewey proposes that learning through experience must focus on problem solving and critical thinking, rather than memorization and rote learning (Dewey, 1938). The advantage of out-of-school programs is the flexibility in methods of reaching youth learners and deciding what and how to teach them. Examples of out-of-school programs in Senegal with their own purpose and approaches include the Science Education Exchange for Sustainable Development, the Pan-African Robotics Competition, and 4-H Senegal.

The Science Education Exchange for Sustainable Development (SeeSD) was founded in 2016 with a mission of fostering Science, Technology, Engineering, Art, and Mathematics

(STEAM) education, encouraging critical thinking, and scientific literacy from K-12 and beyond in Senegal. Their projects include designing curricula to develop critical thinking and scientific exploration and training volunteers to provide hands-on STEAM education at local elementary schools and libraries; organizing the Ubbil Science Festival that brings local schools and universities, STEAM professionals, educators and inventors from across Senegal together to address challenges in agriculture, energy, climate change, environment, health and gender balance in STEAM; and offering Afreecademy Online Platform, a partnership with universities and STEAM organizations to create open STEAM educational resources that are adapted to local challenges, and translated into a local language (Science Education Exchange for Sustainable Development, n.d.).

The SeeSD mission and approach seem to value an important aspect of STEM education which is creativity, critical and analytical skills to identify problems and innovate (Adams 2004; Dym et al. 2005; Koen 2003; Next Generation Science Standards, 2013; Niever et al., 2020; Pawley, 2009). They also engage with real-world and hands-on activities which encourages skill building, practice, and communication (Braun et al., 2013; Jonassen, Strobel & Lee, 2006; Next Generation Science Standards, 2013). Their collaborative environment may allow others to consider intentions, perspectives and expertise to negotiate and strengthen STEM solutions (Idhe, 2008; Niever et al., 2020), and allow the participants to learn about the diverse ways to engage with STEM in numerous domains (Houkes, 2009; Reeve, 2015; Van de Poel, 2013). The

The Pan-African Robotics Competition (PARC) was founded in 2015 as an annual competition for robotics teams in Africa and its diaspora. The competition began in Dakar, Senegal and now consists of middle school, high school, and university participants from 36 countries both in person and virtually. The goal of the competition is to inspire the youth while

promoting STEM education using challenges based on real-world topics relevant to science, and the sustainable development of Africa. The winners in the various competitions are awarded prizes and scholarships. PARC also organizes a Community STEM Day where organizations and universities from around the globe offer community members free hands-on STEM activities; a Youth Forum for student-panel discussions, presentations from youth innovators, and for the youth to share their talents and cultures with each other; and a Virtual Learning Platform for students to learn to code, design and build their own robots, with offline capabilities to account for potential internet stability issues (Pan-African Robotics Competition, n.d.).

PARC challenges encourage participants to use STEM knowledge to be leveraged for optimizing and designing technologies, processes, and systems to innovate or solve problems (Dym et al., 2005; Fralick et al., 2009; Koen, 2003). In the process the youth build, model and prototyping their projects which may give opportunity to communicate, test and improve upon the engineered solutions (Cross, 2000; Dym & Brown, 2012; Kroes, 2012). They also work on real-world problems relevant for the sustainable development of Africa which encourages systems thinking to consider interactions and impact of engineered solutions (Adams 2004; Dym et al., 2005; Feng & Feenberg, 2008).

4-H Senegal is a Positive Youth Development program established in Senegal since 2015, housed within the Ministry of Higher Education, Research, and Innovation, led by the Feed the Future Senegal Youth in Agriculture (Jeunesse en Agriculture) project. The 4-H Senegal club leaders and youth participants decide on the club's topical focus, such as gardening, crafts, raising animals, food processing, entrepreneurship, environmental conservation, etc. Some clubs choose one focal topic while others move from topic to topic based on youth interests and available resources. At 4-H Senegal, there is a community of practice focused on the creation

and adaptation of evidence-informed curricula in the area of STEM (Archibald et al, 2021). The 4-H Senegal STEM curricula uses the Do- Reflect- Apply model for learning through experience, along with scientific inquiry and engineering design as methodologies for youth learners to discover and innovate on topics of their interest (Kebe & Scherer, 2022).

The scientific inquiry and engineering design approach used at 4-H Senegal seems to be a way to encourage the learning, improving and creating tools, techniques and methods (Adams, 2004; Next Generation Science Standards, 2013; Reeve, 2015) that can be used for the youth's STEM projects. The two methodologies also promote mindfulness and skill in using systematic approaches to iterate, increase thoroughness and traceability (Koen, 2003; Next Generation Science Standards, 2013). The youth's inquiry and innovation may encourage being intentional in investigating the nature of a problem and understanding the goal that is to be achieved and possible constraints, which are skills useful in STEM education (Adams, 2004; de Vries, 2009; Next Generation Science Standards, 2013; Pawley, 2009).

Theoretical Framework

Urie Bronfenbrenner is an American researcher and psychologist who published the Ecological Systems Theory in 1977. Bronfenbrenner defines development as a person's evolving conception of the ecological environment, his relation to it, as well as the person's growing capacity to discover, sustain, or alter its properties (Bronfenbrenner, 1979). There is reciprocity in the relationship that humans have with the environment, both influencing each other. At the time, traditional psychologists discussed the links of perception, motivation, thinking and learning as part of development, but with his theory, Bronfenbrenner emphasizes that a child's development is influenced by their environment including factors such as their parents' employment, significant life events, societal culture and interrelations among influencers.

Bronfenbrenner organizes and describes these factors into microsystem, mesosystem, exosystem, and macrosystem (Bronfenbrenner, 1979).

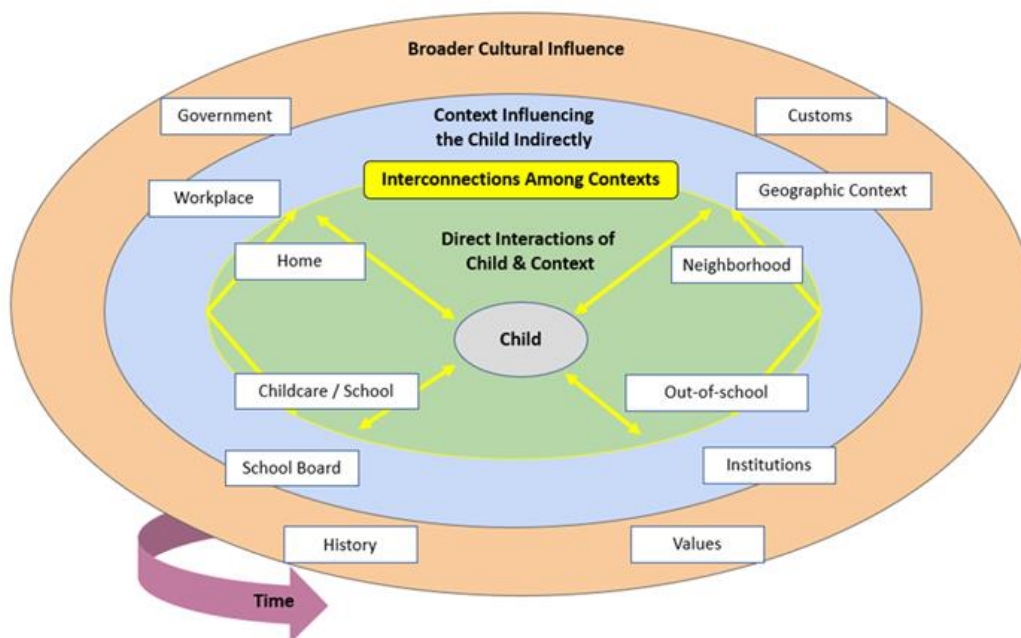
Bronfenbrenner's Ecological Systems Theory is the theoretical framework used to inform this study. The theory is used to situate youth and educators in their learning and teaching context and describe how they and their environment influences their STEM education experience. Systems are a set of connected parts that together form a complex whole (Hartzler & Blair, 2019). Bronfenbrenner categorizes the influences on a child's development into interrelated and concentric systems: *Microsystem* refers to the immediate interactions that the child interfaces with, and the direct influence they have on the child; *Mesosystem* is the interactions and interconnections between actors in the microsystem and how they interact with each other and the child; *Exosystem* are the interactions that occur in the child's environment that impact the child without their direct involvement; *Macrosystem* is the overarching patterns of ideologies and cultures that the child experiences through-out life (Bronfenbrenner, 1979). Bronfenbrenner further developed his theory to include the impact of the individual characteristics of the child, and the influence of time: *Ontogenic-level system* refers to the variables within the child themselves that impact their development (Cicchetti & Lynch, 1993); *Chronosystem* refers to the ever-changing nature of the child and of society and how various experiences and events impact the child (Bronfenbrenner, 1986).

The Ecological Systems Theory used in this study facilitates the consideration of various attributes, people, interactions, practices and events that directly and indirectly influence STEM education in non-formal learning settings. In 2015 the United States National Research Council adapted Bronfenbrenner's Ecological System into a context for STEM learning. They define the STEM Learning Ecosystem as the dynamic interaction among individual learners, diverse

settings where learning occurs, and the community and culture in which they are embedded (National Research Council, 2015). This STEM Learning Ecosystem model (Figure 3.1) describes the direct and indirect influencers that play a role in youth learning STEM, modeled after the layers of the Ecological System Theory.

Figure 3.1

Reproduced version of NRC STEM Learning Ecosystem Model (National Research Council, 2015).



Each of the factors that make up the youth’s settings can be further investigated to learn and leverage interactions to support youth learning: *Direct Interactions to Participants* is the microsystem, representing people and settings that the youth interact with frequently. *Interconnections Among Context* is the mesosystem, connections between people and contexts within the microsystem that affect the participant’s experience. *Contexts Influencing Participants* is the exosystem, representing people and settings that indirectly influence the participant’s ability to access education. *Broader Cultural Influences* is the macrosystem, representing the

social aspects and cultural make up of society. *Time* is the chronosystem, representing the constant changes that occur throughout the child's life as they learn, mature, and work through life's experiences.

In their report, the National Research Council uses the STEM Learning Ecosystem to highlight youth's individuality while connecting their learning experience to their larger system of community. Using this holistic approach, they have provided the following Criteria for Identifying Productive STEM Programs in Out-of-School Settings: 1) Productive programs engage young people intellectually, socially, and emotionally: They provide firsthand experiences with phenomena and materials; They engage young people in sustained STEM practices; They establish a supportive learning community. 2) Productive programs respond to young people's interests, experiences, and cultural practices: They position STEM as socially meaningful and culturally relevant; They support collaboration, leadership, and ownership of STEM learning; They position staff as co-investigators and learners alongside young people. 3) Productive programs connect STEM learning in out-of-school, school, home, and other settings: They connect learning experiences across settings; They leverage community resources and partnerships; They actively broker additional STEM learning opportunities (National Research Council, 2015).

The Ecological Systems Theory used in a Senegalese setting prompts the need to critically reflect on the cultural appropriateness of concepts, programs, practices, and policies exported from the global North (Archibald et al., 2021). In 2019, the 4-H administration team in Senegal vetted the U.S. National Research Council STEM Learning Ecosystem and the Engage-Respond-Connect framework. The team found the criteria to be appropriate for the Senegalese context and are using the criteria to add a STEM component to the 4-H Senegal clubs (Kebe &

Scherer, 2022). Though models fall short of representing the real world fully (Meadows, 2008), using a systems approach to model educational spaces in Senegal can help build understanding of collective and individual influences and impact (Stroh, 2015). The STEM Learning Ecosystem is used in this study to explore influences that impact STEM education for girls at the Go4STEAM out-of-school program. These Engage-Respond-Connect criteria are used in this study to identify productive STEM education activities and interactions occurring at Go4STEAM.

Methodology

Case studies are used to describe a phenomenon and the real-life context in which it occurred (Yin, 2014), within a bounded system (Merriam, 1998). This research study uses the descriptive case study methodology to gather and interpret information about Senegalese youth and educators' STEM education experiences at Go4STEAM. A thick description of the learning setting is crafted, beneficial for audiences to identify and transfer appropriate findings to other learning settings (Merriam, 1998). Individual interviews and focus groups were conducted using web conferencing to collect data, giving participants the chance to express their insights. Audio was recorded during each meeting so that that data could be replayed, on demand, as necessary. The researcher brings a construction of reality to the study design and data analysis, which interacts with the participant's constructions of the phenomenon being studied. The final product is an interpretation of people's views filtered through the researcher's own views (Merriam, 1998).

To increase repeatability and reliability, a protocol was developed (Yin, 2014), documenting and organizing methods and data throughout the case study. This protocol also serves as an audit trail to verify that the results of the study are consistent with the data collected

(Guba & Lincoln, 1981). With the data collected from youth and educators, triangulation of sources is used to increase the internal validity, helping to ensure that the reality of the situation is being perceived and conveyed as truthfully as possible (Merriam, 1995). In a comparison of two or more individual interviews, there is opportunity to triangulate perspectives (Vogl, Schmidt & Zartler, 2019) and a convergence occurs where the sources are similar, and the findings of one substantiate the findings of the other (Sands & Roer-Strier, 2006), or they may complement one another in that the different parts together create a more complete picture (Erzberger & Prein, 1997). In this research study, having 12 participants was helpful to triangulate data and create a combined description that represents the experience of the youth learners and educators at Go4STEAM.

Case Study Boundaries

Go4STEAM was founded in 2019 as a non-profit association that works to promote and popularize STEAM among young girls. This organization seeks to increase knowledge on the situation of girls' education in the field of STEM in Senegal and Africa; increase awareness of policies and practices that effectively support girls' and women's education in STEM; strengthen national and regional networks, partnerships, and cooperation in the education of girls and women in the field of STEM; train, coach and motivate the new generation in STEM disciplines; and participate in the large-scale popularization of STEM, especially among girls and women. Go4STEAM received a grant from the United States Embassy of Dakar to host a one-month long STEM program, which they refer to as STEM MOUSSO. Their STEM MOUSSO 2020 initiative is a free program aimed to develop STEM interest for young girls in Dakar and its suburbs, through awareness of STEM professions, mentorship with women role models, and challenging participants to engage in STEM projects (Go4STEAM, 2022).

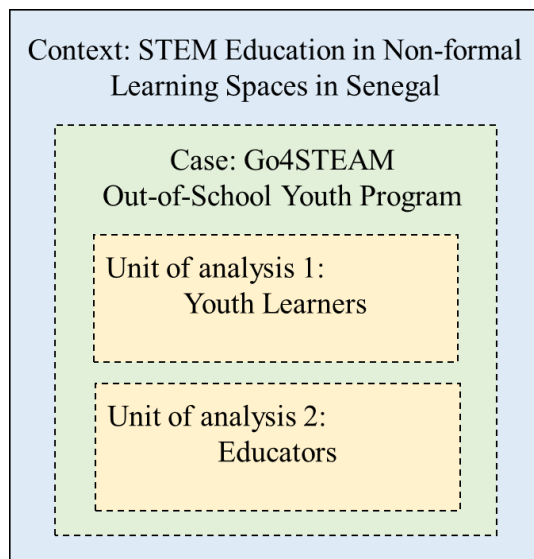
The partners of GO4STEAM include UNESCO, UNICEF, the Ministry of Education in Senegal, and Non- Governmental Organizations working with women. In 2020, the program targeted middle school girls in 4 zones of Dakar: Dakar, Pikine, Guediawaye and Rufisque, however their intention is to expand their program throughout the country. Of 350 applicants, 100 students were selected to participate in the 2020 program. Applications included an essay prompt asking the young girls if they were to create a machine, what would it be. The organizers read each essay and graded it for creativity and imagination. The applicants were also asked about their career goals to determine their current intention to pursue jobs in the STEM field. The two essays, along with the applicant's self-reported grades, were considered in selecting the final 100 program participants.

As part of the program initiative, the educators and volunteers were trained in techniques to engage the participants in an interactive way and make the sessions fun with attractive activities. The training included team building activities for volunteers to get to know each other, and presentations and discussions on volunteering and community engagement. Each topic and activity that would be offered at the program was reviewed with the volunteers, which was robotics, mechanics, electronics, and web programming. During the Go4STEAM STEM MOUSSO program, the youth learners were given activities to introduce them to STEM concepts, and then tasked to work on group projects. The three best projects were recognized and awarded. The program concluded with an award ceremony with about 300 people in attendance to celebrate the participants' projects and learnings. Parents, teachers, authorities and organizations that seek to address the gender gap in STEM were invited to attend the closing ceremony.

Yin’s Embedded Multiple Units of Analysis Case Study Design (2009) is used as a conceptual model for this study (Figure 3.2). STEM education in non-formal learning spaces in Senegal is the context of the study, and Go4STEAM makes up the case to be studied. This study has two units of analysis, youth learners and educators. Interviews and focus groups are conducted to learn about the participants’ individual and collective behavior, attitudes, and perception of Go4STEAM. A potential pitfall of the embedded design is when the case study focuses only on the subunit level and fails to return to the larger unit of analysis (Yin, 2009). Thus, this study is mindful that the subunits of youth learners and educators are sources to learn more about their STEM learning context. To scope the research study, an a priori table (Appendix E) was developed aligning propositions with supporting literature, research questions, interview and focus group questions.

Figure 3.2

Design study of the context, cases and unit of analysis, dashed lines representing blurred boundaries between the three categories.



Participant Screening and Selection

A screening flyer (Appendix A) of the youth learner and educator criteria was shared among the Go4STEAM program to recruit participants. To screen for Educator participant eligibility, the following criteria were developed: Educator must have taught at Go4STEAM; Educator’s role at Go4STEAM must include teaching a minimum of one youth ages 12 - 19; Educator must speak Wolof, French or English. To screen for Youth Learner participant eligibility, the following criteria were developed: Youth must have participated in learning at Go4STEAM; Youth must be between the ages of 12 – 19 by the time they complete the pre-interview questionnaire; Youth must speak Wolof, French or English. Youth under the age of 18 must provide their assent and parent or guardian permission to participate in the study. This may be obtained in the form of a signed permission form (Appendix B) or the researcher speaking to the parent or guardian to confirm permission to participate.

Purposive sampling was used to select 12 participants, seven youth learners (Table 3.1) and five educators (Table 3.2), to give firsthand experience and perspectives of Go4STEAM. Recruitment was based on the youth and educators volunteering to be a part of the study. Among a group of relatively homogeneous individuals, 12 interviews suffice to achieve data saturation where new information produces little or no change to the codebook (Guest, Bunce & Johnson, 2006).

Table 3.1

Pseudonym of the youth learners that participated in this study, including their age, and the STEM session they participated in.

Youth Pseudonym	Age	STEM Session
Khady	13	Electronics
Mariama	17	Web Programming
Aminata	17	Mechanics
Amy	15	Electronics

Coumba	16	Web Programming
Astou	14	Robotics
Aida	17	Mechanics

Table 3.2

Pseudonyms of the educators that participated in this study, along with the STEM session they led.

Educators Pseudonym	STEM Session
Khadija	Partial in All
Mohamed	Mechanics
Diallo	Electronics
Oumo	Electronics
Fatou	Web Programming

Data Collection

The first procedure of this study was to complete a pre-interview screening questionnaire (Appendix B), both an online and paper copy were available in English and French. There was also an option to complete the questionnaire orally with a member of the research team in Wolof, French or English. The questionnaire was used to gather basic information about potential participants including name, contact information, and an indication on whether they were a youth learner or educator at Go4STEAM. This information ensured that selected youth and educators met the participant criteria requirements. Everyone who completed the screening questionnaire was made aware that if selected, their responses would be used as data in the study. If they were not selected to participate, then their responses would not be used and would be discarded.

The second procedure was the individual interviews (protocol in Appendix C) which were up to one-and-a-half-hours audio-recorded sessions for educators and one-hour sessions for youth. The interviews consisted of standardized open-ended questions to begin, but there was flexibility so that follow-up questions were based on the participants' response. The interviews

were conducted in Wolof, French or English, depending on the participant's preference. The researcher speaks fluent English and intermediate Wolof; thus, a translator was present at each interview to assist in the communication between the researcher and participants as necessary. The interviews were conducted online through video conferencing.

The third procedure was a focus group (protocol in Appendix D) consisting of the same individuals from the first interview. The focus group for educators was scheduled to last up to one-and-a-half hours as a member-checking opportunity for participants to validate the findings from the interviews (Saldaña, 2015), give feedback, and offer any additional insight. The focus group for youth learners had a similar format but was scheduled to last up to one hour. The focus groups were conducted in a combination of Wolof and French languages, with a translator present to assist in the communications as necessary. The focus groups were conducted online through video conferencing.

Audio from interviews were transcribed and translated by a translator, into English text. Everyone that assisted with the translating and transcribing signed a letter of confidentiality, agreeing not to share any of the data from the study. The founders of Go4STEAM gave permission to present their organization name in this study; however, the study participants were assigned pseudonyms, with the key under a password protected file. Only the research team has access to the key and no identifying data will be released outside of the research team. The key will be stored on the cloud-based platform Google Drive under a Google Group and destroyed three years after publication.

Data Analysis

Sharan Merriam's approach to data analysis was used to interpret and consolidate what participants said and what the researcher has seen and read (Merriam, 1998). The data gathered

from the interviews was combined for source triangulation and corroboration, to create a rich description of the influences and educational practices that facilitate STEM education at Go4STEAM. A codebook was developed with predefined categories as headers to group evidence (Appendix F). The *ontogenic-level system, microsystem, mesosystem, exosystem, chronosystem* from the Ecological Systems Theory were used as categories to identify influences that facilitate STEM education. The National Research Council, *engage, respond, connect*, criteria for identifying productive out-of-school STEM programs categories were used to identify productive STEM education activities and opportunities occurring at Go4STEAM. Each category was defined based on literature and included a description of qualifiers that was used to recognize the categories within the data (Pearse, 2009). Using predefined categories helped to focus the coding on factors that are known to be important in existing literature (Miles, Huberman, and Saldaña, 2013).

To analyze the data, each transcript was reviewed and then open coded, assigning meaning to the data by labeling it with a code that reflected the data (Saldaña, 2015). The emergent codes that were strengths and assets were matched to the predefined codebook categories. The codes within each category were then analyzed to identify patterns and commonalities from the participants. Finally, the analyzed data was summarized into themes, with a definition written to describe each theme. The themes were shared with the participants for feedback as part of the member-checking process. Based on the validated findings, the researcher discussed the perspectives of the youth learners and educators at Go4STEAM. The discussions used the theoretical framework to draw conclusions and recommendations that describe and strengthen out-of-school STEM programs within the Senegalese STEM Learning Ecosystem.

Findings

In this section, the influences and educational practices as reported by the participants, are described in response to the research study questions. Seven themes are reported as influencing youth to learn STEM at Go4STEAM. Six themes are reported as STEM educational practices that occur within Go4STEAM.

Findings on Influences: Research Question 1

The following findings are influences in response to Research Question 1: What influences facilitate youth to learn at the Go4STEAM program?

Ontogenic-level System

Variables within an individual that influence their own development are part of the ontogenic-level system (Cicchetti & Lynch, 1993). These variables may include individual characteristics such as demography, psychology, personality and behavior. The Go4STEAM participant recruitment screened applications selecting youth learners that showed interest and motivation in pursuing STEM. The findings from the study confirmed that participants had characteristics that positively enabled their STEM learning. The following themes *Youth learners show active interest and engagement in STEM* and *Youth learners have a desire to pursue and succeed in STEM* are two influences described and categorized under the *ontogenic-level system*.

Youth learners show active interest and engagement in STEM. The youth learners showcase inquisitive and innovative characteristics that fuel their interest in STEM. These characteristics were desired when Go4STEAM was recruiting youth participants, thus these findings confirm the intent was accomplished. Khadija, an educator, describes the youth

curiosity as an advantage because it causes the learners to be engaged and communicative, which makes teaching them more effective and enjoyable. She stated,

The parts that are easy [when it comes to teaching] are the interaction with the girls.

When they arrive they are already interested and they want to learn. So when someone comes in wanting to learn, teaching them is easy. You can teach them what you want them to learn and even more. The kids are ma sha Allah [God willed it] smart, they are curious, they want to know. That's why classes are not enough, that's why we need more programs like this. They are curious, they want to investigate, so teaching is easier. They don't just come, sit quietly and just look at you. They pose a lot of questions, sometimes not even related to the subject you're teaching them. But it makes the teaching fun, and it's not just the teacher that is doing the speaking, it's more of an exchange.

Khadija's experience is consistent with previous studies that indicate youths' active interest and engagement in STEM activities are productive learning behaviors that causes them to be more attentive, productive and perform better (Lipstein & Renninger, 2006; Walkington, 2013). One of the youths, Aminata, specified that her interest in learning STEM comes from her innovative nature. She said,

Basically, I like everything linked to creating or innovating, that is what really motivates me to learn engineering. Even at home I like to make or create small things, I am like a handy woman. What really motivates me is that I want to have the best creation, avoid mistakes, follow guidelines, and perform well.

The learner's inquisitive nature and innovative spirits are a natural pathway to learning STEM because it allows them to create items and discover new knowledge, which are fundamental principles of STEM (Pawley, 2009; Adams, 2004; Koen, 2003; NGSS, 2013).

The youth learners shared that they enjoyed working on the Go4STEAM activities which included engaging with robot kits, electronics, programming websites, and crafting items that focus on mechanisms. By engaging in STEM activities, the youth are refining their understanding with practical use (NGSS, 2013; Braun et al., 2013). Many of the learners continued to work on their Go4STEAM activities outside the program hours. For example, Khady stated that they had a special electronics group, and after Go4STEAM sessions, they would debrief and exchange reflections. She often continued her STEM education from home. She stated,

At home, I went on google and I typed “engineering” and it gave results. And then I typed “electronics” and I was reading the results to learn more. I try to find more information to better understand what the teacher was saying. For example, if there is a new skill, on Arduino [Robot kit], I will watch videos about it. We also had remote cars and I went on google to do research on them.

The youth learners’ engagement in STEM even outside of Go4STEAM advances their STEM education. The additional research and practice they engage with at home extend their learning settings providing further opportunity to develop their cognitive and practical STEM skills (Niiranen, 2021; Barlex and Steeg, 2018).

Youth learners have a desire to pursue and succeed in STEM. The youth learners expressed their intentions to pursue STEM careers which included becoming programmers, engineers, and roboticists. Coumba shared, “I want to do computer science in the future. So I figured here [at Go4STEAM], I would have the opportunity to obtain some basic skills.” Some of the learners do not have a specific role in mind, but they want to somehow incorporate STEM into their work. Aida explained, “For my future, I would like to become a lawyer or a diplomat,

like my father. I would like to study sciences as well. I love science. I could find a solution to combine the two.” Broadening the youth’s thinking of how STEM manifests in different disciplines (Reeve, 2015) will help them craft their career aspirations.

Though not all of the learners have identified their intended career choice, they each described graduating high school and enrolling in university as the pathway to achieve their STEM goals. Amy stated “I have to study hard and get my diploma. I need my BAC S [high school scientific diploma]. I think after some years of training, it can be done. With a bit of motivation, I think I can do it.” The learners’ knowledge of behavior and skills needed for their future goals will guide them to success (Bandura, 1997; Mulder, 2017; Oyserman, Terry, & Bybee, 2002).

Aida, Mariama and Khady stated that their mothers motivate them to achieve success in STEM. Mariama stated,

What motivates me is that my mom has hope for me, I have older siblings, but I am the only child of my mother who is going to school. They all dropped out to work so that really motivates me, knowing what my mom wants for me. Knowing that education is what they’re asking of me, nothing else. So that motivates me to work hard, knowing that I am her only child in school.

Astou, Coumba, and Khady shared that they are motivated by the idea of using STEM to make a positive difference in the world. Astou stated “I want to create new things to help, especially Senegal to accelerate development. I want to help my country.” Whereas Khady said,

What motivates me is the fact that we have few girls doing engineering, and that’s what I want to do in the future. There aren’t many girls in the field, it’s mainly boys. It is interesting to me and when you’re older you can find a job in it. That is what I want to

work in, in the future. Once I know how to do this, I can teach other girls until they become successful too, and spread my knowledge around the country. If I master it, I will work with other people to help those who want to do engineering, so that we can make the engineering field bigger.

The youth learners' motivation to succeed in STEM, affirms that interactions with the youth, as well as their environment, influence their learning (Bronfenbrenner, 1979). Perseverance and passion for their long-term goal will enable the learners to obtain high achievement in STEM (Zimmerman, 2008; Duckworth et al., 2007).

Microsystem

People and contexts that the youth interact with directly, are part of the microsystem (Bronfenbrenner, 1979). These situations and interactions include direct engagement with youth and STEM related activities. The following theme, *Youth learners are encouraged to learn STEM by the people* is an influence that has been described and categorized under *microsystem*.

Youth learners are encouraged to learn STEM by the people close to them. The youth learners expressed that they were encouraged by family members to continue their STEM education. Parents may influence their children's career choice in positive ways by being an admirable role model (Otto, 1991) or being attuned with the child's interest and advising careers appropriately (Keller & Whiston, 2008). Amy shared,

My parents, my brother and sister, and especially my twin brother... Whenever I returned home, they were very interested in the things I learned. 'Ah, explain this, ah, that's interesting.' It really encouraged me to see that they were interested in this. My twin brother is good at computer science. So when I told him we learned Arduino [electronic

board] at Go4STEAM, he said ‘oh yeah’ and started explaining to me how to use the board.

Aminata explained that her father is passionate about the sciences and would ask questions about what she was learning at Go4STEAM. She said, “When I come home, he asks me questions like ‘Did you get to work on things? Did you get to access and understand things? Did you draw a link between real life and what you have learned there?’” Similarly, Khady’s mother would ask her questions which made her feel supported. Khady stated, “Everyday my mother was asking me questions on what I have achieved. I feel she was really influencing me and also encouraging me to keep going.” Mariama explained the importance of being supported. She said, “Learning is easy and not easy. Sometimes it is positive and you do good, sometimes you do bad on a subject. You really need people who can motivate and aid you and not insult or discourage you.”

The educators at Go4STEAM were also a source of encouragement. Khadija, an educator, encouraged the youth learners into STEM especially because there is currently a low enrollment rate among girls in STEM. She said,

What I want for their future is, for those who find science and engineering interesting, I want them to go far in their education, like get their masters and doctorates. And do research in biology and advance our community and economy. There are a lot of girls, so I wanted them to try out science and once they do it, they’ll see that it’s not hard and they’ll like it like I do or like other people. And once they start learning, they don’t run away, they continue to get their bachelors, masters, those who want to pursue doctorate. To have girls that create cars for example- that’s what I want. Girls that are leaders in STEM, that are decision makers, that will help us develop our communities.

Encouraging the youth to learn about the diverse range of STEM careers is an important aspect of STEM education (Houkes, 2009; Reeve, 2015; Van de Poel, 2013). The youth learners received encouragement from people in their immediate environment including family members and their educators.

Mesosystem

Connections between people and contexts within the microsystem that affect the youth's experience, make up the mesosystem (Bronfenbrenner, 1979). These include situations where actors and factors within the microsystem interact directly with each other in regards to the youth's STEM experience. The following theme, *Leveraging community resources & partnerships to organize the STEM program* is an educational practice that has been described and categorized under *mesosystem*.

Leveraging community resources & partnerships to organize the STEM program.

There are numerous ways in which the coordinators leveraged community resources and formed partners to organize the Go4STEAM program. To recruit youth participation, Go4STEAM distributed flyers to the community, advertised on tv and at youth mentorship programs, and visited schools to tell youth about the program. Schools in Senegal also share similar values as Go4STEAM in that they encourage youth to pursue higher education, careers, and improved life conditions (Sylla, 1985). School partnerships can be mutually beneficial for Go4STEAM because in Senegal science enrollment is particularly low among girls (World Bank, 2018). Having learners gain interest and skill from Go4STEAM can impact science engagement in school. The coordinators also used a school as a resource when they utilized the building as the program location. The school further served as a resource because when youth were presenting

their learnings, people walking around the school would be invited to come and listen as audience members.

Among community assets are human capitals, referring to individual knowledge and expertise that are used to benefit the wider community (Flora & Flora, 2008; Hawtin & Percy-Smith, 2007). At Go4STEAM, the volunteers and educators played a vital role in managing the day-to-day logistics of the program. Khadija explained,

We created a WhatsApp group that had everyone including the educators, the girls, the volunteers, and we also had subgroups for each subject like mechanics, electronics, etc. The volunteers managed the logistics for the groups; took care of the rooms, prepared the materials, replaced missing things, communicated with the girls, published to media, and some took care of the meals. The work was split into groups, and we would work together. We would have Zoom meetings to discuss needs, write them down and get it done.

The program had 2-3 educators per subject that collaborated to decide lesson plans, teaching style, and evaluation methods for their youth learners. The interactions between the educators allowed for morale encouragement and knowledge sharing. Mohamed stated,

We often work in teams. Because encouraging someone to move forward, intervening, getting involved if there are corrections to be made, bouncing ideas off each other- it's better. Because I too, can learn from someone whose approach is different. For example, we can have the same concept, but the approach can differ, the examples can differ.

By working together to organize and share knowledge, the volunteers and educators multiply their power and effectiveness (McKnight and Kretzmann, 1997). These various examples of leveraging resources and partnership describe situations of people that directly interact with

youth, now interacting with each other, to influence the youth's STEM learning experience (Bronfenbrenner, 1979; National Research Council, 2015).

Exosystem

Situations not directly involving the youth, but indirectly influencing their experience, is part of the exosystem (Bronfenbrenner, 1979). These include indirect influence on youth's STEM education experience without their presence or input. The following themes, *Educators' STEM interest and pedagogy* and *Strategic decisions made related to program preparation*, are two influences described and categorized under *exosystem*.

Educators' STEM interest and pedagogy. Collectively, the youth learners noticed and appreciated their educators' passion for teaching STEM. Khady, a youth learner, commented "The way they were teaching us spoke volumes. The way they explained to us, showed us how passionate they were regarding STEM education." The educators enjoyed the opportunity to promote STEM among the youth. They wanted the youth to be interested in the idea of becoming scientists and engineers that are inquisitive, innovative and have a basic understanding of the universe (Adams, 2004, Christenson, 2011, NGSS 2013). Mohamed an educator stated,

What I find interesting about teaching is to get them in a state of discovery about the understanding of our surroundings. For example, I went to Goree [island in Senegal] and it was fabulous to see a boat, a machine that can float and move on water. So, it's more in the sense of understanding the world that surrounds us, finding explanations for all these phenomena around us, and how things function.

The educators' teaching experience and inspiration varied, but they shared the common value of practical application. Their teaching approach encouraged real-world and hands-on activities (Braun et al., 2013; Jonassen, Strobel & Lee, 2006; NGSS, 2013). Some of the

educators at Go4STEAM received training in Senegal and some abroad, but they each expressed that there are Western influences in their teaching methods. One example is teaching while observing and adapting to the learners' interests. Mohamed, an educator, explained,

I base myself a lot on the work of Maria Montessori [Italian educator]. She prioritized observation and then catering to the needs of the child. So I give an activity to the students, then I talk about a concept and observe their reaction. And depending on how they react, I try to build towards that path. It's an adaptation method that we do.

The educators' teaching approach also includes learning through experience, which focuses on problem solving and critical thinking more than memorization (Dewey, 1938). The pedagogy of another educator, Diallo, expanded based on his experience with European professors that emphasized examples and comprehension. He said,

I have not had many professors from Europe but they all teach the same way, through examples. Concrete examples. Here [Senegal], there are some that do it through examples, but often professors just show us how to do it and then during exams, we recount what we've been taught. It's usually written exams. Also, with my European professors, I've noticed that their questions are focused more on comprehension, rather than on memorized material.

Though there were influences from the global community, the educators also explained that the knowledge exchange that occurs within Senegal also shapes their teaching methods. Khadija shared,

We are not the first people in Senegal that are doing this [teaching STEM]. There have been other people that did this before and are still doing it. There are many associations

and companies that teach these subjects. So sometimes we meet to discuss how they're doing and get inspiration from them, what techniques they're using.

The collaboration amongst the community of Senegalese educators enables them to share wisdom and build individual capacity (Baum, 2008; Nel, 2018). The educator's knowledge evolves with influences from external and internal knowledge systems (Onwu & Mosimege, 2004). Their interest in teaching STEM, and their teaching approach, in turn forms their pedagogy and influences the youth's learning experience.

Strategic decisions made related to program preparation. The youth learners did not take part in every decision related to the organization of Go4STEAM. There were some decisions, like offering the program over summer vacation, that were made without their input, but with their interests in mind. Khadija explained,

When we were doing the program, we wanted to do it during the summer vacation so they [the youth] aren't going to school, so they can come and learn from us and do the program. Once they start going back to school, you can't take their time from school to do this, so it is better to do everything over the summer. And during weekends also they may want to stay with their families or revise their schoolwork, so you can't tell them to do an extra program, it just adds to their workload. So, vacations and small breaks are better.

Another decision that impacted youth STEM learning was the choice of material for the STEM activities. The educators intentionally avoided ordering material from places like the United States or France. Instead, they purchased Arduino kits from sellers in Senegal, and for computers they purchased system units locally to accompany the computer monitors that the school already had. The decision to purchase material that would be interesting for the youth, yet

sourced locally, also relates to culturally relevant teaching. The selected STEM activities coincided with the youth learners' interest and environment (Dziva et al., 2012) because the educators chose STEM materials that were easy to acquire and use. Mohamed an educator explained,

When we're thinking of projects, before starting the program, we try to determine the required materials. We try not to make it hard for ourselves. If we see a project we would like to do, we try to find alternatives that are easier to realize. For example, using cardboard instead of using wood. We can use cardboard, then double it, to reinforce it. Cutting up wood is harder. We can instead use the reinforced cardboard with many layers to get the same thickness. It's easier to manipulate for the students as well.

For unforeseen situations that disrupted their plans, the educators improvised. Efforts were made to pivot lesson plans to use available material, while still conducting the STEM learning related to designing, solving, and using analytical skills (Brophy et al, 2008; Pleasants & Olson, 2019). Diallo, an educator, explained,

[If a tool or material is missing] we try to find it and if we cannot find it, we work quickly with the girls so that they can at least do something during this time. And this is improvisation. We improvise so they can do something. For example, with the car. Before making it, when we received the materials, it was incomplete. Since the girls were only there for a day, we improvised something else. We thought about it then proposed a piano. They were happy to make an electric piano. So, I quickly wrote the program while Oumou and Dr Bira, whom I work with, were showing them how to set up the piano.

Some of the decisions that the educators had to make in preparation of Go4STEAM were strategic in that it considered the youth learners schedule of availability, and their potential

interest in activities. The educators centered the youth learners and attempted to provide an experience that lined up with their norms and values, which is in alignment with cultural-based education (Kana'iaupuni, 2007). Additionally, Hawtin & Percy-Smith (2007) argue that all communities have assets, resources and capitals in their local area that are for the benefit of the community. By deciding to source STEM material locally, Go4STEAM is taking advantage of resources within their community.

Chronosystem

The constant changes that occur throughout the child's life and surrounding context, is part of the chronosystem (Bronfenbrenner, 1986). This includes personal transitions and societal events that over time impact the youth's STEM education. The following theme, *Program champions youth learners to pursue scientific track at school and university*, is an influence described and categorized under *chronosystem*.

Program champions youth learners to pursue scientific track at school and university. A major life event within a Senegalese student's educational journey at public schools that impacts their life (Bronfenbrenner, 1986) is the exam marking the completion of middle school. Students that pass the exam receive a diploma entitled Brevet de Fin d'Études Moyennes (BFEM) (Djité & Diakhate, 2019). The schools then notify their students informing them of which track they have been assigned to moving forward. If the grades related to math, science, and physics are sufficient, students are assigned to the scientific series. Once they receive their baccalauréate, similar to high school diploma, the students are then positioned to major in a STEM field at a university. Therefore, it is important for students to achieve high grades and pass the BFEM exam to be on track to pursue STEM in high school and university.

The Go4STEAM program took into consideration the Senegalese education system's timing of the grade levels that are vital to prepare students for STEM in high school and university. Khadija an educator explained,

That is why most of the girls we have chosen to participate are before grade ten [high school]. We want to make them aware of the importance of the science fields, and let them know that math and physics are important if they want to pursue STEM. This way, once they go back to school, they will do their best to be oriented into the scientific field.

That will allow them to major in STEM once they graduate.

For the youth learners who were already in the scientific field, the Go4STEAM program served to help them identify which career to pursue within STEM. Coumba said,

For me, Go4STEAM didn't influence me into the science track, due to the fact that I was already in the 11th grade science track. But it did influence my choice of career after high school. Before, I was still undecided, and now, Go4STEAM has influenced me to do computer science after high school.

Currently in Senegal, less than 25% of girls are enrolled in the STEM related, scientific track in high school (World Bank, 2018). Initiatives such as Go4STEAM are an opportunity to convince young people to seek the scientific series in high school and prepare by achieving good grades and passing the BFEM exam. For the girls that are already in the scientific series, Go4STEAM is beneficial to expand their STEM knowledge and provide information on potential STEM careers.

Findings on Educational Practices: Research Question 2

The following findings are educational practices in response to Research Question 2: What educational practices facilitate youth to learn STEM at the Go4STEAM program?

Establishing a supportive learning community (Engaging)

As the youth learners engaged in STEM education, efforts were made to establish a supportive learning community. Peer support was emphasized as educators encouraged the youth to resolve their issue by asking at least three other students for help before asking the educator for help. Coumba valued her peers' support, she said, "That's why when there's something I don't know, I ask my teammates and they help me. Because we complete each other, in a way." The supportive community established at Go4STEAM is reflective of the collective nature of many African cultures, which favors an interdependent concept of self (Ma & Schoeneman, 1997).

The youth learners also shared ways in which the Go4STEAM educators contributed to a supportive learning community. Khady stated, "When they [educators] teach, they teach with respect. They explain everything to you clearly without yelling at you to do this and that. We have a good, kind and respectful relationship." The youth learners described their relationship as more than just a student and educator dynamic. There was a friendly and informal aspect of their learning community and the youth called the female educators "tata" which translates to aunt, and called the male educators "tonton" which means uncle. Similarly the educators also felt a close relationship with the students. Khadija said,

Our relationship is like a mentor-mentee, or a big sibling - little sibling relationship. The advice I give them would be the same as if I was talking to my child or sibling... We tried to make it so that whatever comes to their head they feel comfortable asking. It can be about the course or not. They have our numbers. They call us aunties. Some of them are shy but they know if they need us, they can reach us, and if they want to ask us a question, they can ask.

Access to youth provides an opportunity to deposit ideals, values, and systems of knowledge (Givens, 2016). The Go4STEAM educators described using their opportunity to establish a supportive learning community that consisted of empowering the learners to try and solve problems on their own instead of relying on pre-established solutions and strict instructions. Fatou stated,

The method I am using is like what they do in sports, like basketball coaches, what they do. I don't tell them exactly what to do, I just let them do things on their own so that they can be able to manage things and solve problems by themselves. Once they are stuck or they need help, I explain and show them the way. But I don't just begin by telling them what to do because then they won't have autonomy.

The relationships and participation displayed at Go4STEAM is a reflection of their social capital (Flora & Flora 2008). Their communal cooperation and encouragement sets the stage for a supportive STEM education learning community.

Hands-on STEM activities (Engaging)

The youth learners described the various hands-on activities they engaged in during their time at Go4STEAM which included creating a simple web page where they introduce themselves, their resume, age, picture, etc; using math as tool to write algorithms on a computer for programming; basic overview of electronics and then assembling an electronic piano and car with Arduino [electronic board]; sketching and measuring pieces to build mechanism for paper tubes, seesaw, and cranes; assembling pieces from a kit to create and program robots; applying critical thinking in group work by sharing perspectives and collectively deciding which idea is easier, most practical, and solves the problem. The popular learn-by-doing or learning through experience favors hands-on problem solving and thinking over memorization and rote learning

(Dewey, 1938). Fatou, an educator, described deploying the approach with the learners. She said,

We do learn by doing, we learn and practice at the same time. Some of them don't have laptops with them but we always make sure that everyone practices [programming] during the day. Even if we are having two or three students working on one laptop or computer, we do it. Because programming is not something that you can do with just theory alone, they have to practice what they learn and see it in front of them.

Research shows the best learning occurs when something is being made and there is an interaction between thinking and action (Barlex & Steeg, 2018). Diallo, an educator, describes teaching STEM principles first followed by hands-on activities. He said,

We start by teaching them the basics of electronics, as they haven't all studied electronics before, so we do a quick overview of the basics. After this, we started some small electronic projects such as an electronic piano with Arduino, and a car controlled by Bluetooth. The most important thing is that it's the girls- we give them advice and instructions- but it's them who do the work.

Hands-on activities also highlight the meticulous nature of STEM (Koen, 2003; NGSS, 2013), because before coming to a conclusion it may require iterations of prototyping, testing and analyzing impacts (Cross, 2000; Dym & Brown, 2012; Kroes, 2012). Khadija an educator explained,

Also, [we teach] not waiting for solutions, but instead actively searching for it. And to not be in a rush. Know that science is step-by-step, you have to do testing. So when we say to construct something you have to start with something, see if it works then add to it and

see if it works, etc. Know there are stages instead of just trying to solve something all at once and then it doesn't work and you aren't sure what part isn't working, so take it slow. Research indicates that cognitive and higher-order thinking skills can be nurtured through practical application (Niiranen, 2021). The hands-on activities gave the youth learners the opportunity to build on their knowledge in real-time. Amy a youth learner said,

When you make something, at the end, you have to connect it to your computer and the software. But when you plug it in with a cable, if you see that it doesn't turn on... Even if everything looks like it should be ok... If you plug it in and there's a small problem, it will be obvious. It will not light up. So everything has to be proper. When you finally get the hang of it, it becomes easier.

Along with periodic questioning and evaluation, the youth learners had the opportunity to present their projects in a closing ceremony in front of 300 guests. The learners were engaged in a holistic education model which fosters the development of diverse competencies important to succeed in STEM (Niever et al., 2020).

Responsive STEM activities (Responsive)

There were 100 youth participants at Go4STEAM, and they were asked to select their top choices between participating in the robotics, mechanics, electronics, or web programming sessions. The coordinators reviewed each participant's preference and assigned them to a session that was within their top 2 choices, making sure that each session would have 25 participants each. From the onset, the youth learners' interests, including intellectual, were considered in their STEM education, which is a method of cultural-based education (Dziva et al., 2012; Kana'iaupuni, 2007). The educators made an effort to be in tune with the youth learners by

listening to them, guiding them, and offering content that they find relevant. Mohamed, an educator, explained his responsive teaching approach. He stated,

Well, I am an educator, not an instructor. Instructors give knowledge, but educators also accompany their students. So I also play a coaching role. I want to motivate them [the youth learners], inspire them to build things tomorrow. I listen to them a lot as well, I discuss with them. I sometimes give them breaks, life lessons, inspirations, and references to African scientists who have done great things.

Amy, a youth learner, recalled proposing an activity and being encouraged by the educator to execute the idea. She said,

I was browsing YouTube, trying to see what I could do using the kit they gave us, aside from what we already do in the program. Then I saw a car and thought it was interesting. So I shared it in the group, and we asked for Tonton Ali's opinion. And he said it was possible and it was interesting. We made it the following day.

The youth learners expressed that their STEM activities included familiar items such as creating a jewelry box or using material such as cardboards, wood sticks, hot glue guns, cutters and markers. Aida, a youth learner, described recognizing some of the STEM principles within her day-to-day experiences. She said, "I always see objects at home, and I don't know the mechanism behind them, how they work. And so when I chose mechanics, they explained it to us." Khadija, an educator, explained using content that the learners are familiar with to then expand and challenge their understanding, a method of culturally relevant teaching (Siwatu, 2007). She said,

The [teaching] methods that we use include concrete examples. We'll go through something that they're already familiar with. For example, in coding and IT, before

teaching them we show them a website like Facebook, Instagram, TikTok, something they are already familiar with. Then we ask them, ‘How do you think this works?’ When you ask them, some may already have an idea, for example from their older sibling, but you explain to them that to create Instagram you have to program it. From there you explain what programming is, what algorithms are, etc. Once they learn about coding you tell them, ‘Okay now solve this problem. For example, the objective of Instagram is to connect people so that is a solution. So create a page that can propose a solution.’

The educators taught STEM related tools, techniques and methods which is an important aspect of STEM education (Adams, 2004; NGSS, 2013; Reeve, 2015) while ensuring that activities and teaching methods would be interesting to the youth, not too easy or hard, and suitable to be completed within the length of the program. The youth learners expressed that many of the activities were explained clearly and were easy to understand. Oumou, an educator, explained that the images and videos were used as teaching tools used to engage and connect with the youth learners. She said,

For them to understand, we utilize images they can connect with. We also utilized videos to show them that on the internet, around the world, there are people who create things with practically nothing. Even in countries that are not as developed as the richer countries.

Through-out the program, Go4STEAM coordinators and educators acted in response to youth interests, selected activities with appropriate levels of difficulty given time constraints, used familiar content and material to build upon their knowledge, and incorporated various methods of communication to more effectively engage and inspire the learners.

Youth learners collaborate to develop socially meaningful projects (Responsive)

Towards the end of the program, the youth learners were tasked with collaborating in groups to execute a project of their choice. Aminata expressed her preference for teamwork because, “In teams we can share our knowledge, and we can communicate, which makes the work easier. Also we can rectify each other’s mistakes.” Collaboration is an important aspect of STEM education, promoting learners to consider perspectives and expertise that strengthen engineered solutions (Idhe, 2008; Niever et al., 2020). Also, by allowing the learners to collaborate and design their own projects, it provided an opportunity for them to form ideas that are culturally grounded, based on their values, knowledge and experiences (Kana‘iaupuni, 2007).

As the youth described their projects, it was clear that they drew inspiration from society and their observations of common behavior and needs of fellow community members. Coumba, a youth learner, stated that their project was “for a good cause.” She said, “The project was to create an online fund for women in prison, to get some donations for menstrual pads and basic things.” Khady, a youth learner, liked working on the traffic lights project because “it helps reduce accidents in our country.” The project used ultrasound sensors to detect incoming cars that turn on traffic lights. If no cars were present, the lights would turn off, which would save on electricity. Mariama, also a youth learner, explained that their online shopping platform would be beneficial, especially for women shoppers. She said,

My project was creating an online supermarket, so that you can be at home doing all your shopping and your products will be delivered to your house. The project name is “Kay Ndougulma” [Come Shop for Me]. Shopping is very expensive in the market, and we women are the ones doing the shopping, and having to find transportation. So this project allows you to shop from where you are, online. That will be cheaper and you tell the delivery man to deliver it to your house. It will be cheaper than going shopping yourself.

Fatou, an educator, recalled that one of the youth problems was developing a transportation and routing application specifically designed to help guide people to hospitals. She shared,

Some of the girls wanted to solve the problem of finding hospitals in Senegal. It can be complicated if you want to go to a specific hospital, which bus to take and exactly how to get there. There is Google Maps but not everyone uses it. So they wanted to create an app that can tell you what bus can take you to which hospital. You can write in the app the hospital you want and your location and the app can tell you transportation options and what route to take.

The real-world projects designed by the youth learners showed their engagement in important STEM education features including the ability for systems thinking (Dym et al., 2005; Feng & Feenberg, 2008), for example, a change in condition with incoming cars determines if the traffic lights will be off or on. The learners also reflect on the potential societal impact of their engineered solutions (Braun et al., 2013; Jonassen, Strobel & Lee, 2006) for example, the online shopping platform providing, especially women, a cheaper alternative to finding transportation to the market.

Evaluating STEM understanding (Engaging)

As the youth learners engaged in learning about STEM phenomena, materials, and sustained STEM practices (National Research Council, 2015), the learners had different ways of gauging their understanding. There wasn't a formal assessment required of students, although the educators were still invested in ensuring that the youth participants were learning. One indicator of STEM understanding identified in this study is being able to reproduce concepts independently, such as when Aminata was able to build cranes at home without referring to her notes or when Mariama suddenly lost her code but was able to reproduce it without help. The

learners also describe the work becoming easier as an indicator of STEM understanding. Aida shared, “For example, setting up an LED, at first it takes time but then it gets easier. It won’t be as hard. You come, you do it and go. Whereas before, you were thinking about it.” Producing correct work was also a major indicator of STEM understanding. Coumba said, “When you see that you’re doing the same thing as the professor is teaching, and you’re having the same results, that means you’re improving.”

The educators explained that they evaluated the youth learners' understanding by asking questions to determine if the youth were able to explain the concepts they were learning. Diallo, an educator, stated, “If someone does not understand, they will be like a parrot, they will just repeat things, like what they’ve previously written or what they were previously told. But if they understand, we can ask them whatever question and they will respond.” The educators aimed to teach youth to think critically and transcend learning through memorization and rote learning (Dewey, 1938; United Nations Educational, Scientific and Cultural Organization, 2005). The educators used discussion and quizzes as a method for asking questions to test the learner's understanding. Mohamed stated,

I ask them questions, for example, on a concept we learned about in class. For example, ‘What is a force?’ and the student would tell me what a force is. And I would push them to provide an example from their own lives. So there’s a discussion happening behind the evaluation. And besides that, there’s also a short multiple-choice quiz or a project that they work on. And we try to touch on all of the concepts that we studied.

The end-of-program group projects were also an opportunity to evaluate the youth learner’s understanding of the STEM concepts being taught. Amy, a youth learner stated, “The project is based on what we’ve learned. For example, they first teach you something, many things. Then

the project will entail all that you've learned so far." The group projects were an opportunity for the learners to work together to model and communicate their engineered solution, an important aspect of STEM education (Cross, 2000; Dym & Brown, 2012; Kroes, 2012). The educators were then able to assess the projects and validate if the learners understood the STEM concepts.

Expanding and linking STEM learning to different contexts (Making Connections)

The youth learners and educators described the Go4STEAM program as a learning setting that connects STEM theories learned from school with hands-on practice. Aida, a youth learner, stated, "What I learned in school and what I learned in STEM Mousso [Go4STEAM] are different. At STEM Mousso [Go4STEAM], we get to practice but at school, we do not practice. We learned the formulas, but we did not practice." Khadija, an educator, describes their approach of leveraging school curriculum to build upon the learners' knowledge. She said,

The kids will have some things that they already learned in class, but it's not clear in their head because they never practiced it before. So when I teach them something I also let them practice it. Like in the theory of electronics we talk about intensity, currents, transformation, and do calculations, but you don't really understand it. But when you start doing practical applications and start connecting wires, they're like 'Oh so this is electricity. When I do this and that, this happens.'

The learners also indicated that the knowledge they were gaining at Go4STEAM are building blocks that could be applied in other settings. STEM education should include learning, improving and creating tools, techniques and methods that can be used for STEM products and services. (Adams, 2004; NGSS, 2013; Reeve, 2015). Amy a youth learner said,

It's not like they're just lessons. The basics they teach you, you can build a lot upon it.

For example, Uncle Ali didn't just have the Arduino kit. With other things, he succeeded

in making something that could wash masks so that the masks could be reused during the COVID period. So it's a little thing that in the beginning, you underestimate, but you can do so much from it. But you have to know the basics first. When you know the basics, you can make many things.

The educators described that their activities and conversations were also a way for learners to connect what they were learning to different settings. For example, the concepts that the youth learned were represented in their group projects, which are situated in real-world scenarios. The youth are nurturing their knowledge through application to a practical context (Niiranen, 2021) as they connect their learning to different settings. The educators also connect the STEM content with other higher education and career opportunities. Khadija, an educator, stated,

The conversations can be about the subjects or more. We could talk about connecting electrical wires but then they begin anticipating what we'll do the next day, or about associated careers, or talk about my experiences, my education in these domains.

As the youth connect theory with practice, and build upon their knowledge learned in various settings, they are allowing internal and external interactions and influence to evolve their knowledge systems (Onwu & Mosimege, 2004). Leveraging knowledge from various sources is also a beneficial use of community assets (Nel, 2018) and can strengthen the youth's STEM education.

Discussion

In this section, the major findings are discussed to understand the Go4STEAM learning environment, including how youth are influenced to learn in the program, and what educational practices facilitate learning STEM. Recommendations are described on ways to consider the

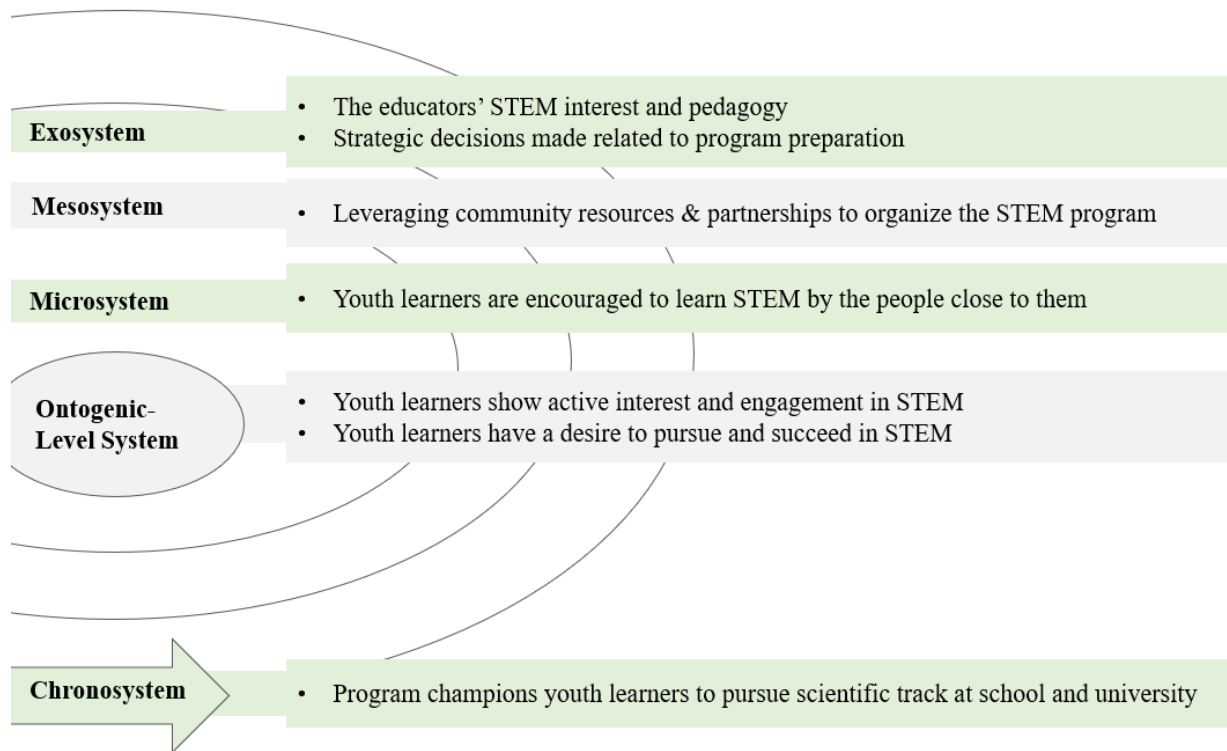
study findings to strengthen STEM education at Go4STEAM and similar out-of-school youth programs. Opportunities for further investigations are offered as suggestions for future studies.

Discussion on Influences: Research Question 1

The following is a discussion on the findings (Figure 3.3) for Research Question 1: What influences facilitate youth to learn at the Go4STEAM program?

Figure 3.3

The following themes are the seven influences that facilitate youth to learn at Go4STEAM.



A major finding from the study is that the youth learners at Go4STEAM are inquisitive, innovative and motivated to be successful in STEM, which were characteristics sought out during participant recruitment. These characteristics are strengths within the individual learners that influence their own STEM education. Inquiry and innovation are important foundations of STEM which principally includes investigating and creating solutions (Pawley, 2009; Adams,

2004; Koen, 2003; NGSS, 2013). Based on previous studies, the youth learners' continued engagement, passion and perseverance will serve them in the long-term to achieve STEM success (Zimmerman, 2008; Duckworth et al., 2007). The Go4STEAM learning environment welcomes and nurtures the youth's curiosity and creativity. As the learners develop these strengths, future studies can track if the active engagement experienced in non-formal learning programs influence the learners to think and behave differently when they return to the formal school setting. How will an increase in inquisitive and innovative minded learners affect the Senegalese school system that is notoriously known for its lecture-based, rote learning pedagogy (United Nations Educational, Scientific and Cultural Organization, 2005) with low opportunities of practical application (International Youth Foundation, 2015)? Will the youth's questions and desire for engaging activities cause frustration within classrooms, or will it inspire schools to adapt to more hands-on learning? Does the learners' curiosity and creativity peak during their time in the out-of-school program, and then lower during the school year?

Another major influence of the youth's STEM education is their educators' passion and pedagogy because it influences the learner's recruitment and retention into STEM. The educators are representatives of STEM. Not only do they present the learners with STEM content, but the learners also notice the educators' passion for STEM. The educators are intentional in seeking to spark STEM interest and engagement with the learners. The findings indicate that educators collaborate among each other and use new information to influence their teaching methods. Their openness to collaborate is a chance to share communal knowledge (Baum, 2008; Nel, 2018) and evolves their own thinking to incorporate other knowledge systems (Onwu & Mosimege, 2004). The resulting pedagogy used by educators at Go4STEAM influences the learners' experience with STEM education because it fosters their interest and engagement. This includes the

educator's approach of using practical application through hands-on activities, and encouraging learners to craft their own projects while developing their STEM skills.

The study findings indicate that parents can play an important role in enrolling their students to out-of-school programs like GO4STEM. Even if the learners' parents are not in STEM fields, or are not familiar with STEM in general, they can still influence and support the learners by expressing encouragement and fostering their interest. The BFEM middle school exams are important to students because once they pass the exam, their grades are used to orient them into the scientific or literary series (Djité & Diakhate, 2019). Until a change occurs at the national level of Senegalese educational system, extra effort should be made to expose youth to STEM to increase their interest, and encourage them to achieve high grades so that they have the choice to pursue the scientific track instead of not qualifying to even have the choice. Thus, more effort should be made to educate parents on the opportunities associated with STEM, and give parents at-home STEM activities to engage their children. Better equipped parents would be able to more effectively encourage their children into STEM. These STEM activities could include individual content that youth learners can do on their own, or collaborative ones in which they can do with their parents, siblings, or other members of the household. Also, the activities that require material could utilize common household items, to minimize expenses for the families.

Using an asset-based approach, this study found various influences that facilitate youth learning at Go4STEAM, but notably, the data did not indicate a major influence from the macrosystem of broader cultural influences. However, it was clear from the youth learner's group projects that they are aware and affected by societal influences. The lack of a broader cultural influence to participate at Go4STEAM, and the low enrollment of girls in STEM related school courses (Islamic Development Bank, 2019; World Bank, 2018) may be indicative of a

lack of societal push to encourage girls into STEM. All of the youth learners in this study were girls, so there was no opportunity to contrast findings for girls versus boys. Future studies can investigate if influences that facilitate STEM education differ among girls and boys. This could include exploring societal and familial expectations of girls, and the learners' own expectation of self as it relates to being a girl. Literature already indicates that many parents send their sons to school over their daughters, and that child marriage and adolescent pregnancy can also affect girls' education (Kohli et al., 2021). Each of the girls in this study attend school during the year. However, not all of the girls may continue onto the scientific track at school, or they may drop-out of school altogether- but that does not have to halt their STEM education. Another study of Go4STEAM could be conducted to see if the program could support girls who do not go to school or are not on the scientific track at school. Understanding the impact of gender dynamics and ways to outreach to more girls can help identify specific ways to influence girls to pursue STEM education.

Discussion on Influences: Research Question 2

The following is a discussion on the findings (Figure 3.4) for Research Question 2: What educational practices facilitate youth to learn STEM at the Go4STEAM program?

Figure 3.4

The following themes are the six educational practices that facilitate youth to learn STEM at Go4STEAM.

Engaging



- Establishing a supportive learning community



- Hands-on STEM activities



- Evaluating STEM understanding

Responsive



- Responsive STEM activities



- Youth learners collaborate to develop socially meaningful projects

Making Connections



- Expanding and linking STEM learning to different contexts

According to the findings from the study participants, Go4STEAM was successful in establishing a supportive learning community that engaged the youth. The findings indicate that the relationship between youth and educators was positive. The youth learners considered the educators to be kind, respectful, and encouraging. The youth referred to the educators as aunts and uncles. Similarly, the educators expressed caring for the learners as if they were family members. Their role included mentoring and advising the youth learners. The relationships at Go4STEAM showcase a strong social capital (Flora & Flora 2008) with their culture of communal cooperation and support. The supportive learning community is aligned with the African culture of collectivity (Ma & Schoeneman, 1997) attested by a youth learner who described her teammates as completing each other. At Go4STEAM, the learners were encouraged to investigate and create, and when they came across issues, they were encouraged to seek the help of fellow peers. The educators were also available for support, orienting the learners toward solutions instead of solving the problem for them. This indicates that even

among the supportive and collaborative environment, it is still important for learners to think critically and come to their own conclusion and understandings.

The robotics, mechanics, electronics, and web programming activities offered at Go4STEAM allowed the youth learners to engage in the firsthand experiences of various STEM phenomena and materials. The study found that educators engaged the youth using a learning through experience approach (Dewey, 1938) that encourages hands-on activities and real-world based projects, which studies have indicated are important for STEM education (Braun et al., 2013; Jonassen, Strobel & Lee, 2006; NGSS, 2013). The practical action of connecting theory and application required of the activities and group projects at Go4STEAM encourages critical thinking skills (Niiranen, 2021), and other skills such as iterating, prototyping, testing and considering impact of solutions (Cross, 2000; Dym & Brown, 2012; Kroes, 2012). However, the youth learners planned and prototyped without realizing their projects to fruition. The findings did not indicate that group projects had a real-world impact, and that is likely due to the relatively short-span of the program. The youth were not afforded time to execute their project ideas.

There were findings of responsive educational practices at Go4STEAM. The educators were intentional to acquire interesting and relevant learning materials locally. Also, the learners chose their own group projects based on their observation and experiences in society. These examples display efforts to engage youth learners within their interests and environments, which is responsive to the learner, and an aspect of culturally relevant teaching (Dziva et al., 2012; Kana'iaupuni, 2007). The required peer collaboration was also an important aspect of STEM education (Idhe, 2008; Niever et al., 2020) and gave the learners the opportunity to develop their teamwork skills, share perspectives, and help rectify each other's mistakes. However, the

Go4STEAM program could strengthen their responsive educational practices by positioning the educators as co-investigators and learners alongside young learners. The findings indicate that the educators served more as a coach to the youth learners by not outright providing solutions, but instead, orienting and supporting them to figure out solutions on their own. The educators serving as coaching is a great scaffolding technique to help build the learners skills and confidence, but to increase responsiveness, Go4STEAM should allow the youth learners to take more ownership and direction of their STEM education. By going one step further and shifting the educator's role to co-investigator and co-learners, Go4STEAM could have less pre-established activities, and instead allow the youth learners to decide what activities to pursue. This can also be advantageous for educators because they do not have to have solutions ahead of time. The educators can be investigating and learning alongside the youth.

The Go4STEAM program connects with the national education system of Senegal, by selecting a majority of students that have not taken their middle school BFEM exam. Once learners pass the exam, their grades are reviewed to determine if they qualify for the scientific track which impacts their access to STEM in high school and university. Future studies can explore how out-of-school programs like Go4STEAM and other community resources and partners can be used to complement the national school curriculum so that students acquire the interest and knowledge to earn qualifying grades for the scientific track. Educational practices that connect to other learning settings could be strengthened at Go4STEAM by brokering additional STEM learning opportunities. This could be in the form of activities that participants can do at home with their families or helping participants secure opportunities for job shadow and STEM internships. Senegal's geography includes diverse ethnicities and natural landscapes. Educators could consider indigenous knowledge and local outings to help expand STEM

activities. Opportunity to execute group projects could also allow learners to interact with the people and settings that are relevant to their projects. Go4STEAM can continue to build their network of partners to help identify and create these opportunities to help the youth learners and connect their STEM learning to various settings.

Limitations of Study

This case study was bounded so that only youth learners and educators at Go4STEAM were engaged in data collection. This introduces some bias in regard to the characterization of Senegalese youths' interest in STEM because youth learners at Go4STEAM expressed interest in STEM as they applied for the program. Also, their parents or guardians had to give consent before participation in the program. The interest and support of STEM education displayed in this study is not necessarily the norm for the majority of youth through-out Senegal.

The theoretical framework and the codebook categories developed to analyze data, are based on Western literature. However, in this study, the Western-rooted frameworks are used in the Senegalese context where assumptions and cultural values may differ. Both the theoretical framework and codebook categories acknowledge that influences and responsive educational practices vary per setting. Efforts are made in the research design to contextualize the research questions so that the acquired data is relevant and meaningful to the Senegalese STEM Learning Ecosystem. Member checking was conducted in focus groups to ensure that the findings captured during the individual interviews accurately represented their learning and teaching experience at Go4STEAM.

In designing the research study, the choice of methodologies was limited. Researcher observation at Go4STEAM was not an option because the program was not in session, so interviews and focus groups were selected as the main method of data collection. Also, an asset-

based approach was taken to study the Go4STEAM program. By intentionally identifying strengths as told by educators and youth learners, the obstacles to STEM education and unproductive educational practices are neglected. The strengths outlook adopted in the study provides only one lens of the Go4STEAM program, weaknesses would also need to be considered to have a more holistic understanding of the Go4STEAM program.

Conclusion

This research study documents the experience of youth learners and educators in the out-of-school program Go4STEAM, while providing insight into Senegalese STEM Learning Ecosystem. In this study we learn more about Senegalese girls that are interested and motivated to succeed in STEM. Examples are shared describing their personal drive along with family members and educators that encourage them toward STEM education. Families can be supported in their influential role on the youth learners by offering them more opportunities to engage with the youth in STEM activities and support the youth's progress within STEM. Educators play an important role in providing an environment that sparks STEM interest within the youth and facilitate their STEM engagement with fun and challenging activities that build upon their skills. In Senegal, for students to qualify for the STEM related courses in high school and university, they must receive good grades and pass the middle school national exam. Thus, it is important to prepare youth in elementary and middle school to be on track to qualify for the scientific track. By generally increasing STEM content in out-of-school settings, it can also support students who are not on the scientific track in high school and university to still gain STEM education through other programs and activities.

The Go4STEAM educational practices were determined to meet the National Research Council criteria of a productive STEM program. The learners expressed that they enjoyed the

hands-on STEM activities provided in the program. The supportive learning community included an opportunity for the learners to collaborate among themselves on socially meaningful projects. The educators showcased moments of culturally relevant teaching by sourcing material locally, and doing activities within the learners' interests, however, this method could be increased by engaging more of the learner's life experiences, indigenous knowledge, and interacting with Senegal's natural landscape. There is also an opportunity for educators to position themselves as co-learner and co-investigators, providing the learners more ownership of their STEM learning. To increase program responsiveness, learners could have a larger say in what they want to investigate and innovate, while still having the educators there supporting them along the way. Go4STEAM is an excellent case study that showcases strengths of the non-formal learning setting in Senegal. Stakeholders can learn from the various influences that lead to STEM education, especially for Senegalese girls, along with ways in which we can strengthen educational practices to promote productive STEM programs for youth learners.

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Conclusion

This multi-case study explores the Senegalese STEM Learning Ecosystem, specifically youth education in non-formal learning settings. Two cases are used to investigate learning spaces in Dakar, Senegal that educate youth within the range of 12 - 19 years old. The first case is the wood carpentry and metal joinery apprenticeships, considered to be within the construction and civil engineering sector (Walther, 2008). Six youth learners and six educators participated in the case study to discuss their engineering learning and teaching experience inside the apprenticeships. The second case is Go4STEAM, an organization that hosted a month-long out-of-school program, engaging 100 girls in STEM education. Seven youth learners and five educators from the program participated in the case study to discuss their experience learning and teaching STEM within the program. For both studies, all participants under the age of 18 had parent or guardian approval to participate in this research study.

Qualitative research methods were used to interview the youth learners and educators in both cases. The apprenticeship cases consisted of individual in person meetings that took place at the participants' workshop. The Go4STEAM case also consisted of individual interviews, along with focus groups, and each session was conducted online. The Ecological Systems Theory (Bronfenbrenner, 1979) was used to situate the cases inside the STEM Learning Ecosystem, referring to the dynamic interaction among individual learners, diverse settings where learning occurs, and the community and culture in which they are embedded (National Research Council, 2015).

An asset-based approach was used to analyze the apprenticeship and out-of-school program to identify the strengths of each learning setting, including the participant's motivations, educator's pedagogy, cultural and historic influences, and accessibility to content knowledge and

materials. Insight from the participants leads to a better understanding of influences that facilitate youth to learn in these two non-formal learning settings, and educational practices that facilitate the youth to learn STEM within their respective learning space.

Limitations of Study

To the researcher's knowledge, there is not an extensive body of literature published on the Senegalese STEM Learning Ecosystem, so this study adds to the scholarly literature, particularly for non-formal learning settings. However, the literature reviewed in this study was primarily conducted in English with a few French documents translated and reviewed. Senegal is a Francophone country, so there may be additional literature on the state of apprenticeships and emerging out-of-school programs, written in French, that was not reviewed in this study.

Another limitation to this study is generalizability. This is a qualitative research study thus the findings are not intended to represent all apprenticeship and out-of-school STEM programs in Senegal. Rather, the insight from the two cases gives insight into the Senegalese STEM Learning Ecosystem. The small sample size of 24 participants allowed for more time to be allocated per interview to gain rich responses from participants about their experiences teaching and learning STEM in the respective learning settings.

Summary of Findings

Results of the two case studies identify influences and educational practices that facilitate youth to learn engineering in the wood carpentry and metal joinery apprenticeships and STEM at the Go4STEAM program. Knowledge gained from this study contributes to the understanding of the Senegalese STEM Learning Ecosystem and highlights ways to leverage local resources and educational practices to increase, support, and strengthen STEM education for youth in non-formal learning settings.

Wood Carpentry & Metal Joinery Apprenticeships

The results of this study indicated eight influences that facilitate youth learners to participate in wood and metal apprenticeship. These findings span across the Engineering Learning Ecosystem to include the ontogenic-level system, microsystem, mesosystem, exosystem, macrosystem and chronosystem (Bronfenbrenner, 1986). The influences are summarized into the following themes: Youth learners are self-driven to succeed in the trade; Youth that are open to learning and have a basic educational foundation are at an advantage to learn the trade; Youth learners are encouraged to learn the trade by the people close to them; The educator's role is a combination of teaching and raising the youth learner; Parents of youth learners coordinate with the educators to facilitate learning the trade; Educators seek to pass down knowledge acquired from their own experiences; Learning the trade is an alternative to school and trouble; Advancement in skill level transitions the youth learners to more responsibilities. The various themes from this study confirm that an ecosystem approach was effective in identifying influences on youth learning in wood and metal apprenticeships.

The results from this study indicated five major educational practices that facilitate learning engineering in the wood and metal apprenticeships. The practices are summarized into the following themes: The educators give the youth learners guided instructions; Tools are acquired and used to educate the youth learners; The youth learners receive feedback on their work; The youth learners collaborate with peers and skilled workers; Knowledge from the trade can be used in various ways and acquired from numerous sources. Each of the educational practices showcased occurrences and opportunities for engineering education within the apprenticeships.

Go4STEAM Out-of-School Program

The results from this study indicate that influences that facilitate youth to learn STEM at Go4STEAM, are found in the individual's ontogenic-level system, microsystem, mesosystem, ecosystem, and chronosystem (Bronfenbrenner, 1986). The findings were organized into the following themes: Youth learners show active interest and engagement in STEM; Youth learners have a desire to pursue and succeed in STEM; Youth learners are encouraged to learn STEM by the people close to them; Leveraging community resources & partnerships to organize the STEM program; Educators' STEM interest and pedagogy; Strategic decisions made related to program preparation; Program champions youth learners to pursue scientific track at school and university. The STEM Learning Ecosystem is a useful tool to analyze positive influences within the Go4STEAM learning environment. The findings affirm that characteristics of the youth, as well as direct and indirect interactions with the youth, (Bronfenbrenner, 1979) can facilitate learners' STEM education.

The Go4STEAM program was found to have productive educational practices that were engaging, responsive, and making connections (National Research Council, 2015). The themes under the *Engaging* category were: Establishing a supportive learning community, Hands-on STEM activities, and Evaluating STEM understanding. The themes under the *Responsive* category were: Responsive STEM activities, and Youth learners collaborate to develop socially meaningful projects. Finally, the theme under the *Making Connections* category is: Expanding and linking STEM learning to different contexts. Collectively, these themes describe educational practices that engaged the young learners intellectually and socially, responded to their interests and experiences, and connected their STEM learning from the program to learning in other settings, particularly school and home.

Discussion, Conclusion & Recommendations

In this section, the findings from the wood carpentry and metal joinery apprenticeships case are compared and contrasted with the Go4STEAM out-of-school program case. Similarities of influences and educational practices are highlighted, along with the differences that make each learning setting unique. Recommendations and opportunities for future studies are shared in efforts to better understand and strengthen the Senegalese STEM Learning Ecosystem.

In both learning settings, the display and importance of self-drive is emphasized for youth learner's success. The findings indicate that learners must want success and actively work towards their goals. An interesting difference between the two cases is that the learners at Go4STEAM seem to be working towards a more distant goal than the learners in the apprenticeship setting. At Go4STEAM, the learners are encouraged to acquire skills and qualify for STEM fields through the high school and university route. For learners that are already on track, the STEM activities are an opportunity to develop skills and learn about various career options. However, in the apprenticeships setting, the learners are developing and executing their skills in real-time to assist in production at their workshop. As the youth learners develop their skills, they are given more opportunities and responsibilities until they master the trade enough to no longer be considered an apprentice. The findings indicate that the next step is for the learners to either get employed in a job related to their trade or become entrepreneurs and open their own workshop.

Unlike apprenticeships, which serve as an alternative to formal schooling, the Go4STEAM program is a supplementary activity that supports learners in formal schools. The data from this study did not indicate a broader cultural influence that encouraged participants to learn at Go4STEAM. With general low enrollment rates into the STEM fields in Senegal (World Bank, 2018) this may suggest a lack of societal advocacy that promotes learners, especially girls,

to gain STEM education. The case of apprenticeships is different because learners who drop out of formal school are discouraged from being idle and tempted into criminal activity. Thus culturally, youth who are no longer in school are encouraged to learn at an apprenticeship. However, the participants share that it is advantageous in the trade for learners to have a strong foundation in reading, writing, math and communication. As an apprentice in the wood carpentry and metal joinery trade, the learners are engaged with their time, learning engineering skills and earning a modest income to help support themselves and families. Both cases studied however, described people close to the youth, specifically family members, inspiring and encouraging them into their respective learning spaces.

Both cases in this study described people that coordinate learning opportunities on behalf of the youth. In the case of wood carpentry and metal joinery apprenticeships, the parents engage with educators to establish and maintain the educational experience. However, there was no indication of significant organizing and preparation required by educators to host the learners. The educators must agree to accept the learner into their environment and take responsibility for their well-being until they are no longer an apprentice, which can take years. In contrast, at Go4STEAM there was heavy coordination and strategic decisions made amongst the program organizers, volunteers, and educators to prepare and host the youth learners for the month-long program. In both spaces, the educators seemed to be knowledgeable in their subject matter and they wanted to share their knowledge with the learners. The data indicated that Go4STEAM had invested and caring educators, but their role and expectations are different compared to the educators in the apprenticeships. In the wood carpentry and metal joinery setting, the educators were described to be teachers, employers, and parental figures to the youth learners. The

educators are responsible to share knowledge of the trade, as well as tend to the learners' safety, teach them good values, and aid in their development into adulthood.

The educators from each case described their pedagogy, and there were differences in the teaching style. In the apprenticeship setting, the educators are either firm or approachable to the learners, but both styles teach using hands-on, specific instructions that learners must follow. At Go4STEAM, the educators also use hands-on activities, but they seem to focus on establishing a fun and interactive environment where learners work in teams, and educators coach them through issues. In both cases, the youth learners described moments in which they take ownership of their learning by expanding their knowledge and skills and working on their own projects in their free time. The learners in both settings also shared that they acquire STEM education from different sources including online content from Google and Youtube.

Both cases illustrated elements in which their educational setting connects STEM learning to the real-world. In the apprenticeship setting, the engineering content that the youth learn is dependent on the job, and relevant to the trade. Sometimes if tools are missing, they purchase or create new ones at the workshop. With Go4STEAM, they had predetermined subjects that are taught in the program, and materials were collected ahead of time. When material is missing, the educators improvise with a substitute material or change their lesson plan. Both learning spaces have a process for evaluating the learners' understanding. At Go4STEAM, the educators evaluate through conversations and group project assessments. The learners crafted their own projects that were found to be socially relevant and meaningful. Whereas at the apprenticeship, the educators assess the learners' method and work product in real-time. The youth learners' products have real-world consequences because they have clientele to satisfy.

Based on the case findings, recommendations to increase and strengthen STEM education are offered for both learning settings. In the wood carpentry and metal joinery apprenticeships, the trades are already specialized in wood and metal products. However, they can continue to engage in engineering education relevant to their trade. Unlike Go4STEAM, the educators in the apprenticeships are also running a business, so recommendations may also consider content that can benefit the educator and their workshop such as optimizing their work processes and innovating tools for their work. For this learning setting, it is also recommended that the learners have opportunities to increase their literacy in reading, writing, math and communication. In terms of increasing engineering education, creative opportunities can be presented to the youth learners in the form of trainings, competitions and apps in which they can view and upload content for knowledge sharing. With increased engineering skills, the youth learners will be better equipped with transferable skills that can be used at other worksites or to better their communities.

At Go4STEAM, the subject matters vary and incorporate robotics, mechanics, electronics, and web programming. The diversity in topics allow for a variety of ways to connect their STEM learning to different contexts in their environment. The educators can take on the role of co-investigators, to allow learners to take more leadership of projects that they want to pursue. Also, all of the learners attend school during the year so the program could choose to emphasize STEM content that compliments the theories that are being learned at school. The Go4STEAM participants all expressed interest in STEM in their initial program application, and the data suggests that their curiosity and creativity was apparent during the program. Thus, it is important to continue to nurture their interest in STEM. This could include extending the length of the Go4STEAM program and supporting STEM education through at-home engagement. The

youth learners may also benefit from a cultural shift to encourage youth, especially young girls, to engage in STEM education.

Results from the study also reveal opportunities for the two cases to inform and collaborate with one another by leveraging each other's strengths. The Go4STEAM program can mimic the real-world nature of the apprenticeships by allowing the youth learners to work on projects with consequences like the apprentices that work on products for clients. The apprenticeship learning setting was described to be heavily reliant on educators' instructions. This learning setting can draw inspiration from Go4STEAM by encouraging a fun learning environment that prompts the learners to collaborate and contribute their ideas to the work. With support, the youth learners from the two settings could also be given opportunities to collaborate with each other. For example, when Go4STEAM needs certain tools or products, the learners from the apprenticeship setting could be contacted to help make them. An advantage of Go4STEAM is that there is a variety of topics that are covered in the program, so the learners from the apprenticeship would have a chance to widen their scope to work on the wood and metal aspects of the Go4STEAM projects. An advantage of the apprenticeship space is the access to workshops, so Go4STEAM learners would have the chance to collaborate with the apprenticeship learners that have the equipment to actualize their projects.

The findings from these two cases allow for a better understanding of the Senegalese STEM Learning Ecosystem. Future studies can expand on this research by observing the non-formal learning settings for additional influences and educational practices that facilitate learning STEM. An asset-based approach can continue to be used to map potential resources and partnerships in Senegal, or abroad, that can benefit youth education. The educators in these learning settings are invested in the education of their learners. A study could be conducted

among educators to examine the ways in which educators interact with each other, share knowledge, and their suggested best practices for Senegalese youth education.

Significance of Study

Senegal is a country in which about half of the population is under the age of 18 years (United Nations Population Fund, 2014). This study explores ways in which STEM education is providing opportunities to encourage science and engineering skills for the youth. In the STEM Learning Ecosystem, the individual youth and the environment that they are embedded in, influences their STEM learning. In the case of Senegal, the social structure can encourage or limit youth's STEM education in various ways including gender, socioeconomic standing and geographic location that impact expectations and accessibility for youth to attend school. Formal schools in Senegal offer a track to become scientists and engineers, but the enrollment rate for both boys and girls is relatively low in these subjects (World Bank, 2018) and the middle school dropout rate is relatively high (Education Policy and Data Center, 2018). Thus, alternative forms of education, which includes the non-formal learning spaces, are important for youth education. This study makes important contributions to the understanding of apprenticeships and out-of-school programs in Senegal.

The findings from the wood carpentry and metal joinery apprenticeships provide cultural insight into the motivations and pedagogy that lead to the learning and teaching of engineering within the trade. Traditionally, apprenticeships in Senegal are an educational alternative for families that cannot afford to send their children to school, and youth who are uninterested in learning in the formal school system. As society begin to recognize and appreciate the impact of enhanced engineering education taught at apprenticeships, such as optimizing, innovating and

problem-solving skills, it could attract more support and work opportunities for the youth learners and educators.

This study also gives insight into the recent emergence of out-of-school STEM programs that are changing the dynamic of the Senegalese STEM Learning Ecosystem by presenting youth a new pathway to pursue STEM education. In Senegal, girls especially have a low high school enrollment rate in STEM, so supplementary programs such as Go4STEAM encourages interest and preparation to pass the BFEM exam and achieve qualifying grades to pursue STEM-related subjects in school. The positive impact that out-of-school STEM programs have on the youth's school experience, career aspirations, and community projects, may help to improve society's consideration of girls' education as important, and increase the support of additional out-of-school STEM programming.

The Ecological Systems Theory used to assess the youth, their learning setting, and the larger Senegalese environment, provided insight into the influences and educational practices that facilitate STEM education in these non-formal settings. Recommendations are shared for each learning setting to strengthen STEM education and support youth to acquire knowledge and skills that they can use to benefit themselves and their communities. Future research may continue to learn more about the Senegalese educational settings, including the learners, the educators, the support system, the historical and cultural influences. The results may continue to facilitate thoughtful and thorough strategies to strengthen STEM education for youth in non-formal settings.

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Appendix A: Recruitment Flyer

Please Join the Senegalese Engineering Education Research Study!

Hello, my name is Fatima Kebe and I am a student at Virginia Tech, a university located in the United States. I am conducting a research study on Senegalese educators and youth engaging in engineering education through apprenticeship and out-of-school programs.

This study will focus on apprenticeship and out-of-school programs that use engineering related teaching and learning methods such as: Investigation, goal creation and/or constraint identification; Iteration, systems and impact thinking; Use of math, science, and/or technology; Designing, innovating and/or problem solving; Modeling, prototyping and/or testing; Teamwork and/or collaboration; Creative, critical, and/or analytical thinking.

I am inviting Educators that meet the following criteria:

- Educator must be able to speak Wolof, French or English
- Educator must be teaching engineering related knowledge in an apprenticeship in the construction and civil engineering sector or out-of-school program setting.
- Educator must be in a role that teaches a minimum of one youth ages 12 - 19.
- Educators must be in their role for at least 6 months.

I am inviting Youth that meet the following criteria:

- Youth must be able to speak Wolof, French or English
- Youth must be learning engineering related knowledge in an apprenticeship in the construction and civil engineering sector or out-of-school program.
- Youth must be between the ages of 12 – 19.
- Youth under the age of 18 must have parent or guardian permission to participate in the study.

Participants of this study are asked to complete a pre-interview questionnaire (approximately 15 minutes to complete), individual interview (approximately 1.5 hour long for educators and 1 hour long for youth) and focus group meeting (approximately 1.5 hour long for educators and 1 hour long for youth). Participants will be asked to answer questions to understand the activities, interactions, successes and challenges they have experienced as educators teaching and youth learning engineering in Senegal.

The interviews and focus groups will be in person and audio recorded, but in case of emergencies such as COVID-related issues, the meetings will be conducted virtually via a video conference call.

Participation in this study is completely voluntary and I will keep all names, phone numbers and email addresses confidential. If you decide to participate in the study, you can withdraw at any point in the process with no penalties or consequences. All study participants will receive a copy of the final research study publication.

This study has been reviewed by the Virginia Tech Human Research Protection Program and the reference for this study is #22-119.

If you would like to be a part of this research study or if you have any questions, please contact members of the research team Fatima Kebe or Hannah Scherer.

Fatima Kebe, fkebe@vt.edu, 221 76 249 6275

Hannah Scherer, hscherer@vt.edu, 1-540-231-1759

Appendix B: Consent Forms & Pre-Interview Screening Questionnaire

Title of research study: Positive Influences and Educational Practices in the STEM Learning Ecosystem: An Asset-based, Multi-Case Exploration of Non-Formal Youth Education in Senegal, IRB # 22-119

Principal Investigator: Hannah Scherer, Agricultural, Leadership, & Community Education, Virginia Polytechnic Institute and State University, hscherer@vt.edu, 1-540-231-1759

Other study contact(s): *Fatima Kebe, Agricultural, Leadership, & Community Education, Virginia Polytechnic Institute and State University, fkebe@vt.edu, 221-76-249-6275*
Kim Niewolny, Agricultural, Leadership, & Community Education, Virginia Polytechnic Institute and State University, niewolny@vt.edu, 1-540-231-5784
PS Polanah, Africana Studies/Sociology Dept., Virginia Polytechnic Institute and State University, ppolanah@vt.edu, 1-540-231-5650

Key Information: The following is a short summary of this study to help you decide whether or not to be a part of this study. More detailed information is listed later on in this form. This study will be used to understand Senegalese educators and youth experiences as they teach and learn engineering in youth apprenticeships and out-of-school engineering programs. The study includes a pre-interview questionnaire, interview and focus group. In the research study, participants will be asked to answer questions to capture the activities, interactions, successes and challenges they have experienced as part of the STEM Learning Ecosystem in Senegal, West Africa.

Detailed Information: The following is more detailed information about this study in addition to the information listed above.

Who can I talk to?

If you have questions, concerns, or complaints, or think the research has hurt you, talk to the research team Hannah Scherer or Fatima Kebe, contact information provided at the top of this page.

This research has been reviewed and approved by the Virginia Tech Human Research Protection Program. You may communicate with them at 540-231-3732 or irb@vt.edu if:

- You have questions about your rights as a research subject
- Your questions, concerns, or complaints are not being answered by the research team
- You cannot reach the research team
- You want to talk to someone besides the research team to provide feedback about this research

How many people will be studied?

We plan to include 12 educators and 12 youth from apprenticeships and out-of-school engineering programs in Dakar, Senegal to be a part of this study.

What happens if I say yes, I want to be in this research?

If you agree to participate in this study, please sign your consent below and then complete the pre-interview questionnaire. Your response will be used to determine if you are eligible for this

study. If you are not selected to be a part of the study then you will be notified and your response will be discarded. If you are selected to be a part of the study, then your response will be used as part of the study and you will be asked to participate in two meetings: the first is an individual interview and the second is a focus group. Each meeting will last approximately 1.5 hours long for educators and 1 hour for youth. The meetings will be audio recorded, and take place in person. In case of emergencies such as COVID related risks, the meetings will take place through an online video conference.

What happens if I say yes, but I change my mind later?

You can leave the research at any time, for any reason, and it will not be held against you. If you decide to leave the research, there will be no penalty against you. You are also free to choose to not answer any question or to not respond to what is being asked of you, and this choice will result in no penalty. If you decide to leave the research, contact the investigator so that the investigator can promptly destroy any information about you and any data that you have provided.

Is there any way being in this study could be bad for me?

There are no known risks to participating in this study.

What happens to the information collected for the research?

We will make every effort to limit the use and disclosure of your personal information, including research study, only to people who have a need to review this information. We cannot promise complete confidentiality. Organizations that may inspect and copy your information include the IRB, Human Research Protection Program, and other authorized representatives of Virginia Tech.

The data that are collected from you during the meetings may include information that could potentially identify you, such as your name, email and place of work or study. Your identity, and that of any people whom you mention, will be kept confidential.

The audio recordings from the meetings will be transcribed by the research team. False names will be used for your name and for the names of any other people whom you mention. Also, any other information in the audio recording or artifacts collected that could potentially identify you or anyone else whom you mention will be altered during the transcription process. If the interview transcript and artifacts are used for the research, these false names will also be used to develop the written report of the results.

The audio recording of the interview, all paper and electronic copies of the interview transcript, artifacts, and all paper and electronic copies of the data analysis will be stored securely when they are not being used. Only the research team will have access to the data and consent information. Also, at no time will the research team reveal identifying data or any other identifying study-related information to anyone without your consent. The audio recording of the interview will be erased, and the signed consent form discarded three years beyond the end of the study.

The results of this research study will be included as part of a dissertation and may be presented in summary form at conferences, in presentations, and academic papers.

Participant’s Consent

I have read the above information, and have received answers to any questions I asked. I consent to take part in the study.

(Online check box) I have read the Consent Form and the conditions associated with this study. I have also had all my questions answered. I hereby acknowledge the above and give my voluntary consent to participate in this study.

(Oral Consent) I have listened to a reading of the Consent Form and the conditions associated with this study. I have also had all my questions answered. I hereby acknowledge what have been said and give my voluntary consent to participate in this study.

Your Signature_____ Date_____

Your Name (printed)_____

Signature of person obtaining consent_____ Date_____

Printed name of person obtaining consent_____

Pre-Interview Screening Questionnaire (IRB 22-119)

FOR EDUCATORS

Upon giving consent to participate in the study, participants will be directed to complete this pre-interview screening questionnaire.

Thank you for your interest in participating in this engineering education research study. Please answer the following questions so that we can determine if you qualify to be a part of the study. If you do qualify then you will be invited to conduct an interview and group meeting. Please note that you can request to complete this form verbally. Someone on the research team can contact you to ask you these questions.

What is your name?

What is your phone number?

What is your email address?

Do you speak Wolof, French or English?

- Wolof
- French
- English
- None

Please describe your role as an educator:

How long have you been an educator?

What is your teaching setting?

- Apprenticeship
- Out-of-school program
- None

How many youth do you currently teach that are between the ages of 12 – 19?

If you are teaching in an apprenticeship, please tell us what you do by answering these questions. (Skip questions if you are NOT in an apprenticeship.)

- Do you do wood carpentry work? (Yes or No)
- Do you do metal joinery work? (Yes or No)
- Neither

If you are teaching in a program that occurs outside of school please write the name of your program. (Skip question if you are in an apprenticeship.)

- What is the name of your program?

Youth Assent Form & Pre-Interview Screening Questionnaire

Title of research study: Positive Influences and Educational Practices in the STEM Learning Ecosystem: An Asset-based, Multi-Case Exploration of Non-Formal Youth Education in Senegal, IRB # 22-119

Researchers: Hannah Scherer, hscherer@vt.edu, 1-540-231-1759

Fatima Kebe, fkebe@vt.edu, 221-76-249-62-75

Kim Niewolny, niewolny@vt.edu, 1-540-231-5784

PS Polanah, ppolanah@vt.edu, 1-540-231-5650

Hello, we want to tell you about a research study we are doing. A research study is a way to learn new information about a topic. Our research study will be used to understand Senegalese educators and youth experiences as they teach and learn engineering in youth apprenticeships and out-of-school engineering programs.

You are asked to be a part of this study because we are looking for 12 youths to share their feelings, interactions and overall experience related to engineering and their apprenticeship or youth program. If you agree to be a part of this research study, then please complete the attached pre-interview questionnaire (takes about 10 minutes). There are no right or wrong answers because this is not a test. However, more than 12 youth may want to participate, so we will review all questionnaire responses.

If you are not selected to participate in the research study, then your questionnaire response will be deleted and discarded so that no one can see what you wrote. If you are selected to participate in the research study, then we will use your information and you will be asked to participate in

an individual interview (speak with the researcher that takes about 1 hour) and focus group (do activities with people your age that takes about 1 hour).

We do not believe anything bad will happen if you participate in this study. Risks are no more than would be expected in everyday life. We do not know if you will be helped by being in this study. We may learn something that will help you and other children in the future, better learn engineering in apprenticeships and youth programs.

If you have questions at any time, or if you are angry or are upset about something that happened while in the study, please tell the researchers. If you are unable to reach the researchers, please tell your parent or guardian to contact the Virginia Tech Institutional Review Board (“IRB”) at 540-231-3732 or irb@vt.edu.

If you do not want to be in the study, do not sign this paper. Being in the study is up to you, and no one will be upset if you do not sign this paper or if you change your mind later. If you begin this study and later decide that you do not want to finish, then you can stop and no one will be upset.

If you sign this paper, it means that you have read this and that you want to be in the study. Your parent or guardian must give permission for you to participate in this study so they must also read and sign their paper. After you sign and submit this paper you will receive a copy to keep for yourself. You and your parent and guardian will be notified if you are selected to participate in this research study.

(Online check box) I have read this Assent Form and understand the study. I have also had all my questions answered. I would like to participate in this study.

(Oral Consent) I have listened to a reading of the Assent Form and understand the study. I have also had all my questions answered. I would like to participate in this study.

Youth signature: _____ Date _____

Youth printed name: _____

Researcher signature: _____ Date _____

Researcher printed name: _____

Pre-Interview Screening Questionnaire (IRB 22-119)

FOR YOUTH

Upon giving consent to participate in the study, participants will be directed to complete this pre-interview screening questionnaire.

Thank you for your interest in participating in this engineering education research study. Please answer the following questions so that we can determine if you qualify to be a part of the study. If you do qualify then you will be invited to conduct an interview and group meeting. Please note that you can request to complete this form verbally. Someone on the research team can contact you to ask you these questions.

What is your name?

What is your phone number?

What is your email address?

How old are you?

Do you speak Wolof, French or English?

- Wolof
- French
- English
- Both
- Neither

If you are learning in an apprenticeship, please tell us what you do by answering these questions. (Skip questions if you are NOT in an apprenticeship.)

- Do you do wood carpentry work? (Yes or No)
- Do you do metal joinery work? (Yes or No)
- Neither

How long have you been participating in your apprenticeship? (Skip question if you are NOT in an apprenticeship.)

If you are learning in a program that occurs outside of school please write the name of your program. (Skip question if you are in an apprenticeship.)

- What is the name of your program?

How long have you been participating in the program? (Skip question if you are in an apprenticeship.)

Parent Consent Form

Title of research study: An Asset-based, Multi-case Exploration of Senegalese Youth and Educators' Experiences in their Non-Formal Engineering Learning Ecosystem, IRB # TBD

Principal Investigator: Hannah Scherer, Agricultural, Leadership, & Community Education, Virginia Polytechnic Institute and State University, hscherer@vt.edu, 1-540-231-1759

Other study contact(s): *Fatima Kebe, Agricultural, Leadership, & Community Education, Virginia Polytechnic Institute and State University, fkebe@vt.edu, 221-76-249-62-75*
Kim Niewolny, Agricultural, Leadership, & Community Education, Virginia Polytechnic Institute and State University, niewolny@vt.edu, 1-540-231-5784
PS Polanah, Africana Studies/Sociology Dept., Virginia Polytechnic Institute and State University, ppolanah@vt.edu, 1-540-231-5650

Key Information: The following is a short summary of this study to help you decide whether or not you want your child to be a part of this study. More detailed information is listed later on in this form. This study will be used to understand Senegalese educators and youth experiences as they teach and learn engineering in youth apprenticeships and out-of-school engineering programs. The study includes a pre-interview questionnaire, interview and focus group. In the research study, participants will be asked to answer questions to capture the activities, interactions, successes and challenges they have experienced as part of the Engineering Learning Ecosystem in Senegal, West Africa.

Detailed Information: The following is more detailed information about this study in addition to the information listed above.

Who can I talk to?

If you have questions, concerns, or complaints, or think the research has hurt your child, talk to the research team Hannah Scherer or Fatima Kebe, contact information provided at the top of this page.

This research has been reviewed and approved by the Virginia Tech Human Research Protection Program. You may communicate with them at 540-231-3732 or irb@vt.edu if:

- You have questions about your rights as a research subject
- Your questions, concerns, or complaints are not being answered by the research team
- You cannot reach the research team
- You want to talk to someone besides the research team to provide feedback about this research

How many people will be studied?

We plan to include 12 educators and 12 youth from apprenticeships and out-of-school engineering programs in Dakar, Senegal to be a part of this study.

What happens if I say yes, I want to be in this research?

If you agree to have your child participate in this study, please sign your consent below and then they can complete the pre-interview questionnaire. Their response will be used to determine if

they are eligible for this study. If they are not selected to be a part of the study then you and your child will be notified and their response will be discarded. If they are selected to be a part of the study, then their response will be used as part of the study and they will be asked to participate in two meetings: the first is an individual interview and the second is a focus group. Each meeting will last approximately 1.5 hours long for educators and 1 hour for youth. The meetings will be audio recorded, and take place in person. In case of emergencies such as COVID related risks, the meetings will take place through an online video conference.

What happens if I say yes, but I change my mind later?

Your child can leave the research at any time, for any reason, and it will not be held against them. If your child decides to leave the research, there will be no penalty against them. Your child is also free to choose to not answer any question or to not respond to what is being asked of them, and this choice will result in no penalty. If your child decides to leave the research, contact the investigator so that the investigator can promptly destroy any information about your child and any data that they have provided.

Is there any way being in this study could be bad for my child?

There are no known risks to participating in this study.

What happens to the information collected for the research?

We will make every effort to limit the use and disclosure of your child's personal information, including research study, only to people who have a need to review this information. We cannot promise complete confidentiality. Organizations that may inspect and copy your information include the IRB, Human Research Protection Program, and other authorized representatives of Virginia Tech.

The data that are collected from your child during the meetings may include information that could potentially identify your child such as name, email and place of work or study. Their identity, and that of any people whom they mention, will be kept confidential.

The audio recordings from the meetings will be transcribed by the research team. False names will be used for your child and for the names of any other people whom they mention. Also, any other information in the audio recording or artifacts collected that could potentially identify your child or anyone else whom they mention will be altered during the transcription process. If the interview transcript and artifacts are used for the research, these false names will also be used to develop the written report of the results.

The audio recording of the interview, all paper and electronic copies of the interview transcript, artifacts, and all paper and electronic copies of the data analysis will be stored securely when they are not being used. Only the research team will have access to the data and consent information. Also, at no time will the research team reveal identifying data or any other identifying study-related information to anyone without you and your child's consent. The audio recording of the interview will be erased, and the signed consent form discarded three years beyond the end of the study.

The results of this research study will be included as part of a dissertation and may be presented in summary form at conferences, in presentations, and academic papers.

Parent / Guardian Consent

I have read the above information, and have received answers to any questions I asked. I consent for my child to take part in this study.

(Online check box) I have read the Consent Form and the conditions associated with this study. I have also had all my questions answered. I hereby acknowledge the above and give my voluntary consent for my child to participate in this study.

(Oral Consent) I have listened to a reading of the Consent Form and the conditions associated with this study. I have also had all my questions answered. I hereby acknowledge what have been said and give my voluntary consent to participate in this study.

Youth Name _____

Parent/Guardian Signature_____ Date_____

Parent/Guardian Name (printed)_____

Signature of person obtaining consent_____ Date_____

Printed name of person obtaining consent_____

Appendix C: Individual Interview Questions

For EDUCATORS

[Note: These are example questions that may be modified for clarity and flow of the interview. The nature of the questions will not change.]

Hello, thank you very much for being a part of this research study. My name is Fatima Kebe and I am a part of the research team. If it's okay with you, today I will ask you different questions to learn about your experience teaching using engineering related methods to Senegalese youth. If at any point you want to stop or take a break, please let me know. If it is okay with you, I will begin recording this meeting and I will start asking you questions.

With these first set of questions, I want to ask about your motivation and goals.

Part 1: Individual Perspectives

- What do you do as an educator in the apprenticeship or out-of-school program?
- What influenced (impacted or motivated) you to teach engineering through apprenticeship or out-of-school program?
- What do you find interesting about teaching?
- What makes your role as an educator easy?
- What works very well to get youth to learn?
- For the youth that you are teaching, what do you want for their future?
- How can people support you in your teaching?

Now I want to ask about your day to day activities as you teach.

Part 2: Non-Formal Educational Practices

- How do you communicate with the youth to teach them?
- How do you determine what to teach your youth?
- How do you evaluate their work and give feedback for improvement?
- What do you do if the youth is not understanding what you are teaching them?
- When does the youth get a chance to study or practice what you are teaching them?
- How can youth or others know they have mastered what they are learning?
- What do you do if you don't have a tool that you need?
- Aside from the youth learners, who else do you speak with to coordinate their work?
- How is what you're doing and teaching similar and different to who taught you?
- Are there techniques you learned here and some you learned from Western countries?

For these final questions I would like for you to share scenarios in which certain events have occurred.

Part 3: Engineering Education Practices

- (For Apprenticeship Setting) Describe an average day for you and your youth learner
- (For OOS Program Setting) Describe the learning opportunities that you facilitate in the youth program.

After they describe, look through their response and ask questions to elaborate on use of engineering education method. Use table to check mark what they mention and that can help see

what can be elaborated on. If methods are not mentioned, ask them to describe a scenario when they used that method.

- “I didn’t hear you talking about X, are there scenarios when you do it? If yes, please describe”

Eng Edu Method	Mentioned?	Notes
Youth investigates, creates goals, identify problems		
Youth uses new information or repeat tasks to improve or reach a goal		
Youth considers how things work together / impact each other before making decisions		
Youth use math, science or technology		
Youth create a plan, create new ideas or solve problems		
Youth explains plan (like talking, writing, drawing) before doing or test plan before completion		
Youth work in teams or work with other people to achieve a goal		

For YOUTH

[Note: These are example questions that may be modified for clarity and flow of the interview. The nature of the questions will not change.]

Hello, thank you very much for being a part of this research study. My name is Fatima Kebe and I am a part of the research team. If it's okay with you, today I will ask you different questions to learn about your experience teaching using engineering related methods to Senegalese youth. If at any point you want to stop or take a break, please let me know. If it is okay with you, I will begin recording this meeting and I will start asking you questions.

With these first set of questions, I want to ask about your motivation and goals.

Part 1: Individual Perspective

- What do you do as a learner in the apprenticeships or out-of-school programs?
- What influenced (impacted or motivated) you to learn engineering through apprenticeship or out-of-school program?
- What makes learning easy?
- What do you find interesting about what you are learning and why?
- What are the things that you do very well?
- What motivates you to perform your best as you learn?
- What do you do when the work you are doing is challenging
- What are your goals for the future?
- What kind of job would you like to have when you're older?
 - Do you know what you need to do to get that job?

Now I want to ask about your day to day activities as you teach

Part 2: Non-Formal Educational Practices

- Ideally, what do you want to learn?
- How do you know what you need to improve?
- How do you know if you have mastered what you are working on?
- How much schooling have you had?
 - How is what you are doing similar and different to what you did in school?
- What do you do if you don't have a tool that you need?
- How do you communicate with your teacher?
- Can you share a positive experience with your teacher?
- Aside from your teacher, are there other people who help you with things related to your education?
- How can people support your education?

For these final questions I would like for you to share scenarios in which certain events have occurred.

Part 3: Engineering Education Practices

- (For apprenticeship setting) Describe an average day for you and your educator.
- (For OOS program setting) Describe the learning opportunities that you participated in while in the youth program.

After they describe, look through their response and ask questions to elaborate on use of engineering education method. Use table to check mark what they mention and that can help see what can be elaborated on. If methods are not mentioned, ask them to describe a scenario when they used that method.

- “I didn’t hear you talking about X, are there scenarios when you do it? If yes, please describe”

Eng Edu Method	Mentioned?	Notes
Youth investigates, creates goals, identify problems		
Youth uses new information or repeat tasks to improve or reach a goal		
Youth considers how things work together / impact each other before making decisions		
Youth use math, science or technology		
Youth create a plan, create new ideas or solve problems		
Youth explains plan (like talking, writing, drawing) before doing or test plan before completion		
Youth work in teams or work with other people to achieve a goal		

Appendix D: Focus Group Questions

USED FOR EDUCATORS & YOUTH FOCUS GROUPS

Hello everyone, thank you very much for being here today. This group meeting is the last part of this research study. If it's okay with you, I will present to you my findings from the individual interviews so that you can give your feedback and tell me if you believe it is accurate or not. I want to give the chance for everyone in the room to talk. If at any point you want to stop or take a break, please let me know. If it is okay with everyone, I will begin recording this meeting now and we will go around the room sharing our names and then I'll begin the activity.

Appendix E: A priori Table

List of propositions and supporting literature related to each research question and associated interview questions and focus group activities.

Propositions	Supporting Literature	Research Questions	Interview Questions
<p>There are various influences within a STEM Learning Ecosystem that impact youth learning STEM, including direct and indirect interactions with youth and assets within their environment.</p>	<p>The STEM Learning Ecosystem developed by the United States National Research Council describes direct and indirect factors influencing a child learning engineering including <i>Direct Interactions to Participants</i>, people and settings that the youth interact with frequently and <i>Broader Cultural Influences</i>, the social aspects and cultural make up of society (National Research Council, 2015).</p>	<p>What influences facilitate youth to learn in their non-formal learning setting?</p>	<p>Individual Perspectives Section Focus Group Questions</p>
<p>STEM educational practices in non-formal settings should be interesting and culturally responsive for the youth learner.</p>	<p>The National Research Council puts forward that productive STEM Programs in Out-of-School Settings should engage young people intellectually, socially, and emotionally; respond to young people’s interests, experiences, and cultural practices; connect STEM learning in out-of-school, school, home, and other settings (National Research Council, 2015).</p>	<p>What educational practices facilitate youth to learn in their non-formal learning setting?</p>	<p>Non-Formal Educational Practices Section STEM Education Practices Section Focus Group Questions</p>

Appendix F: Codebook

Definition and description of categories for each research question, based on theoretical framework.

Research Questions	Categories	Definition of Categories	Qualifying Description of Categories
What influences facilitate youth to learn in non-formal settings?	Ontogenic-level System	Variables within an individual that influence their own development, part of the ontogenic-level system.	Individual's characteristics such as demography, psychology, personality and behavior.
	Microsystem	People and contexts that the youth interact with directly, part of the microsystem.	Situations and interactions that mention direct engagement with youth and engineering related activities, examples: home, school, apprenticeships, out-of-school programs, neighborhoods.
	Mesosystem	Connections between people and contexts within the microsystem that affect the youth's experience, part of the mesosystem.	Situations where actors and factors within the microsystem interact directly with each other in regards to the youth's engineering experience. Examples: interactions among examples listed in the microsystem.
	Exosystem	Situations not directly involving the youth, but indirectly influencing youth's experience, part of the exosystem.	Events that indirectly influence youth's engineering education experience without their presence or input, examples: parents' workplace; grant providers; institutions; geographic context.
	Macrosystem	The social aspects and cultural makeup of society that influence youth's experience, part of the macrosystem.	Mentions of societal ideologies, traditions, expectations, behaviors, examples government; customs; history; values.
	Chronosystem	The constant changes that occur through-	Mentions of personal transitions and societal events that over time impact

		out the child’s life and surrounding context, part of the chronosystem.	the youth’s engineering education, examples: marriage, childbirth, natural disasters, pandemics.
What educational practices facilitate youth to learn in non-formal settings?	Engage	Engage young people intellectually, socially, and emotionally.	Mention of firsthand experiences with phenomena and materials, use of STEM; engaging young people in sustained engineering practices such as creating goals, constraint identification, creating plans, designing, innovating, problem solving, modeling, prototyping, testing, creativity, critical and analytical thinking; establishing a supportive learning community.
	Respond	Respond to young people’s interests, experiences, and cultural practices.	Mention of positioning engineering as socially meaningful and culturally relevant; supporting collaboration and teamwork, leadership and ownership of STEM learning; positioning staff as co-investigators and learners alongside young people.
	Connect	Connect STEM learning in out-of-school, school, home, and other settings	Mention of connecting learning experiences across settings, systems and impact thinking; leveraging community resources and partnerships; actively brokering additional STEM learning opportunities.