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4-H Senegal Community of Practice Developing STEM Curricula that Leads to Youth-driven Discovery and Innovation

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In 2015, Jeunesse en Agriculture (JEA), French for “Youth in Agriculture” formed 4-H clubs in Senegal, West Africa. JEA set out to develop culturally relevant STEM curricula for their 4-H youth learners. This led to the novel formation of the 4-H Senegal STEM Community of Practice (CoP), a group designed to create engaging content and activities that leverage local interest and resources. The CoP Practice used a conceptual framework that applies the United States National Research Council’s Engage-Respond-Connect framing as criteria contextualized for 4-H Senegal STEM learning. JEA team members and the CoP used a design-based educational research approach to developing and testing new STEM curricula. The STEM curricula use the Do- Reflect- Apply model for learning through experience, along with scientific inquiry and engineering design as methodologies for youth learners to investigate and develop solutions on topics of their interest. This research note describes 4-H Senegal’s development of meaningful STEM content that enables youth-driven discovery and innovation.

Keywords

4-H, STEM, Community of Practice, Experiential Learning, Youth-Driven, Scientific Inquiry, Engineering Design

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In 2015, Jeunesse en Agriculture (JEA), French for "Youth in Agriculture" formed 4-H clubs in Senegal, West Africa. JEA set out to develop culturally relevant STEM curricula for their 4-H youth learners. This led to the novel formation of the 4-H Senegal STEM Community of Practice (CoP), a group designed to create engaging content and activities that leverage local interest and resources. The CoP Practice used a conceptual framework that applies the United States National Research Council's Engage-Respond-Connect framing as criteria contextualized for 4-H Senegal STEM learning. JEA team members and the CoP used a design-based educational research approach to developing and testing new STEM curricula. The STEM curricula use the Do- Reflect- Apply model for learning through experience, along with scientific inquiry and engineering design as methodologies for youth learners to investigate and develop solutions on topics of their interest. This research note describes 4-H Senegal's development of meaningful STEM content that enables youth-driven discovery and innovation.

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Introduction

In 2015, Jeunesse en Agriculture (JEA), French for "Youth in Agriculture," established over 100 Positive Youth Development (PYD) 4-H clubs in Senegal, West Africa, under the Ministry of Higher Education, Research, and Innovation. This initiative was supported by the U.S. Agency for International Development Senegal mission (USAID/Senegal) and implemented by the Center for International Research, Education, and Development at Virginia Tech. PYD is a set of principles and practices to empower youth to gain the life skills that will facilitate the realization of their potential (Hamilton & Hamilton, 2004) and is a foundation of 4-H (National 4-H Council, n.d.). When addressing PYD in Africa and elsewhere, there is a need to critically reflect on the cultural appropriateness of concepts, programs, practices, and policies exported from the global North (Archibald et al., 2021).

Senegal has its own diverse contexts to be considered when designing and implementing educational activities. To address this need, a science, technology, engineering, and mathematics (STEM) Community of Practice (CoP) was formed. Guided by a design-based educational research approach (Easterday et. al, 2014), the CoP members designed curricula that could be utilized in any part of the country by creating space for local cultural context, values, and realities to be centered. Educational frameworks were researched and used to encourage youth participants to collaborate with their Facilitators to share their knowledge and engage with their community, as part of their learning experience. Curating curricula with relevant and relatable topics helps to make education more practical, impactful, and cultivates a sense of ownership and agency among PYD participants. In this research note, we describe the process by which we designed and tested the 4-H Senegal STEM curricula and share learnings and recommendations for educators to consider as they adapt U.S. based content and frameworks in international settings.

Development of 4-H Senegal STEM Curricula

We employed the six phases of the design-based research process as described by Easterday et al. (2014) to develop the 4-H Senegal STEM Curricula. This framework was useful in guiding the STEM CoP to create and test adaptable curricula with Senegalese youth and facilitators to gain insights and identify opportunities for improvement. The six phases of the design-based research process – focus, understand, define, conceive, build, and test – are used in this section to describe our curriculum development process and summarize the key decisions and insights that emerged from each stage.

Focus Phase: Initial STEM Education Vision

In the design-based research process, the purpose of the focus phase is to bound the audience, topic, and scope of the project (Easterday et al., 2014). As the STEM leads of the project, we achieved our focus by working with the JEA administration to craft a vision for STEM education in 4-H Senegal. In the Senegalese public school system, classes are often lecture-driven with rote learning methods that require students to memorize lessons (United Nations Educational, Scientific and Cultural Organization, 2005). Additionally, the curricula being taught to students is theoretical with limited opportunities for practical application (International Youth Foundation, 2015). The JEA team sought to develop a learner-centered approach that uses STEM-related disciplines to engage youth in making scientific discoveries and developing engineered solutions to local challenges. The learners were to be encouraged to work together and utilize their resources by engaging with experts, educators, their families, and community members. Though the curricula topics could vary depending on youth interests and niche topics in Senegal, climate change awareness and responsiveness were to be emphasized. The JEA team aspired for 4-H Senegal youth to become innovators in the climate change space, who share their work with networks around the globe.

Understand Phase: Operationalizing the Vision

STEM education literature was consulted as part of the understand phase (Easterday et al., 2014) to identify appropriate approaches and methods that were aligned with the team's vision and could be used to design a framework for developing STEM curricula and activities. The *Engage- Respond- Connect* framing developed by the United States National Research Council (NRC, 2015) reasons that programs should *Engage* young people intellectually, academically, 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 (NRC, 2015). The JEA team embraced the *Engage-Respond-Connect* framework because it could be adapted to create a 4-H Senegal experience that acknowledges the youth's background as an asset (Brown-Jeffy & Cooper, 2011); uses culturally relevant teaching methods (Siwatu, 2007); and teaches science and engineering that coincides with youth's intellectual interest, socio-economic status, and cultural setting (Dziva et al., 2012).

Another framework that was accepted by the 4-H Senegal team was *Do-Reflect-Apply*, a popular experiential learning model used by 4-H to promote learning through experimenting, reflecting, and real-world application (Diem, 2001). The team appreciated that experiential learning challenges the banking concept of education where educators deposit information for learners to receive, memorize and repeat (Freire, 2000) and instead posits learning to be a process where knowledge is created through the transformation of experience (Kolb, 2015). With the *Do-Reflect-Apply* framework, youth are presented with questions, problems, situations, and activities and allowed to make sense for themselves using their experiences, with minimal guidance from adults (Diem, 2001).

To emphasize science and engineering learning in 4-H Senegal, the team agreed that the STEM activities within the *Do* stage would be used to encourage youth to learn about a curriculum topic and then design and conduct their own inquiry-based investigations using the scientific method or create innovative solutions to local challenges they have identified using the engineering design thinking methodology (National Science Teaching Association, n.d.; NGSS Lead States, 2013). The *Reflect* stage would promote individual and group reflections to discuss the meaning and value of their experience. The *Apply* stage would be used to encourage the youth to share their findings and innovations with their community and the world around them.

Define Phase: Curriculum Design Goals

The 4-H Senegal STEM CoP was established to develop the STEM curricula and activities. The main characteristics of a CoP are domain, community, and practice (Wenger-Trayner & Wenger-Trayner, 2015). In the case of 4-H Senegal, the *domain* is creating relevant and engaging STEM curricula for the clubs. The *community* is the activities and discussions shared among the group to support the domain. The participants help develop the *practices* by identifying what interactions, tools and databases will be useful in knowledge sharing and management. Members of the STEM CoP consisted of JEA Staff, Pedagogical Coordinators and STEM Experts. The JEA Staff were from the administration team in country and at Virginia Tech, and they ensured the CoP was progressing and that curricula produced were aligned with the set vision. The Pedagogical Coordinators were from the seven regional poles housed at Senegalese public universities (Archibald et al., 2021), and their role was to engage the youth and community to understand their values and priorities to ensure the curricula developed properly reflect societal trends, needs and opportunities. The STEM Experts were professionals in Senegal who are adept in their fields, and they provided knowledge to ensure quality and accurate content for the curricula.

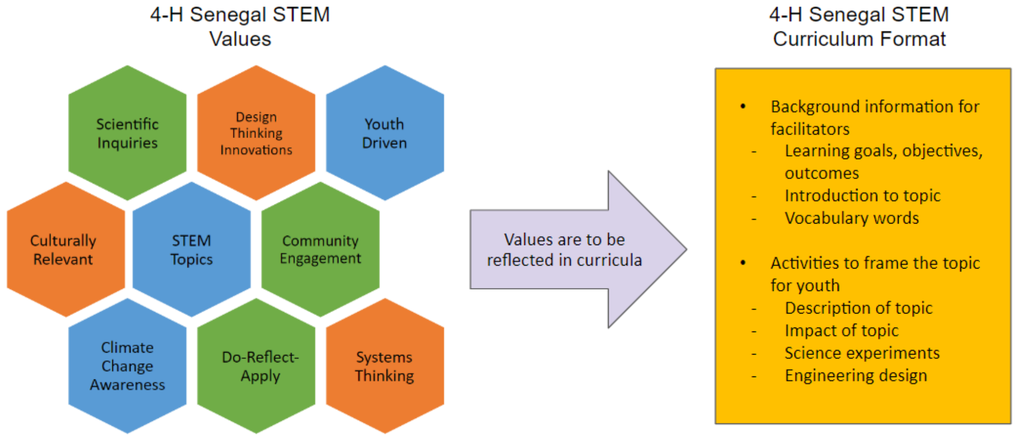
In the define phase of the design-based research process, the team is to set goals for the project (Easterday et al., 2014). The first task of the CoP was to evaluate the design elements that resulted from the focus and understand phase for its usefulness in the context of Senegal. The design elements resonated with the members and the goal was defined as developing curricula that met the *Engage-Respond-Connect* (NRC, 2015) criteria that are aligned with the 4-H Senegal STEM education vision; while incorporating the *Do-Reflect-Apply* model (Diem,

2001) to encourage the youth to learn through experience; and promote the use of scientific inquiry and engineering design methodologies so that youth learners achieve the goal of discovery and innovations for local challenges.

Conceive Phase: Designing the Curriculum Framework

In the conceive phase, a plan for the solution is designed (Easterday et. al, 2014). Through further deliberation, the CoP finalized the 4-H Senegal STEM curriculum framework by listing values that each curriculum should encompass, and a format that each curriculum would follow (Figure 1). It was intended that the resulting framework would be used to create youth-driven curricula that were evidence-based, adapted for Senegalese context, and vetted by Senegalese scientists and faculty before being released to the 4-H Senegal clubs.

Figure 1
Graphic representation of the 4-H Senegal STEM curriculum framework



As determined in the focus and understand phases of the design-based research process, the Senegalese public school system tends to rely on instructors to dictate and convey lessons for the youth. 4-H Senegal, however, sought to empower the youth to be actively involved in choosing activities, experiments and design challenges. To help facilitate this approach, the 4-H STEM curriculum was formatted to have two parts. The first part was background information for the facilitators to reference, including suggested learning objectives and introductory information about the topic. The second part of the curricula were activities that could be used to engage the youth using a hands-on approach. The curated list of 4-H Senegal STEM activities is designed to help introduce the youth to the curriculum topic; help them think through a systems consideration of how the topic impacts their society; and encourage them to design and execute their own scientific experiments and engineered solutions. Facilitators are expected to adapt the various learning activities to meet the needs of their specific club and are encouraged to assist youth to learn from inside and outside of the clubs such as organizing field trips to local farms, labs, learning centers, and nature sites.

Build Phase: Sample Curriculum

In the build phase, designers implement the solution in a form that can be used (Easterday et al., 2014), which in our case consisted of using the 4-H Senegal STEM curriculum framework established in the conceive phase to create sample curricula. The curriculum topics identified by the STEM CoP as relevant to Senegalese learners include floods, traditional medicine, biodiversity, and food processing. Here we use excerpts from the flood curriculum to showcase how the framework informed the curriculum.

The background information introduces a STEM topic from published research, reviews societal impacts, and key vocabulary words related to the topic. The floods curriculum covers a variety of topics including how the warmer climate, energy-intensive storms, and rise of sea levels increase the frequency of floods (Schafer, n.d.). The different types of floods are described to help recognize the type that are most common in Senegal, and there is information on the negative effects of floods such as the death of crops, destruction of buildings, and potentially positive effects such as the regeneration of natural environments (Nicklas et al., 2019).

The activities then encourage youth to reflect on the challenges, opportunities, and career options in their surroundings. In the flood curriculum, this includes exploring human-made structures such as dams and drainage systems that help to control floods in Senegal. The Facilitators are encouraged to collect and share programs, events, internships, advanced studies, and other flood-related educational opportunities so that the youth learners can leverage their community resources.

The flood curriculum also contains discussion guides to encourage youth to reflect on their knowledge of the topic. For example, one discussion point asks youth to consider the following question: “In your community, where does water come from and go to?” There is also an activity that encourages the youth to draw a map of their local watershed and locate where humans may be as well as any towns, parks, roads and farms (The American National Red Cross, 2007) to prompt thinking about how floods may affect their community.

Finally, the youth are prompted to identify what more they want to learn and what problems they want to solve related to floods. The *Do-Reflect-Apply* model is employed to facilitate youth in creating their own science investigations based on their curiosities, and to use their engineering skills to innovate. In this youth-driven process, Facilitators are expected to support the youth through their learning journey. Upon completion of activities, learners reflect on what they have learned and share their work with the community.

Test Phase: Pilot Study Results

In the test phase of the design-based research process, designers evaluate the efficacy of the solution that they have designed (Easterday et al., 2014). The 4-H Senegal STEM curricula activities were piloted with three groups of youth in Senegalese middle school classrooms, for a total of 70 individuals. Participants were provided with poster boards, sticky notes, markers, and had access to a chalkboard and chalk. Each group began with a large group discussion where the topics of climate change, droughts, floods, scientific method and design thinking methodology were introduced. Then the youth were split into smaller groups of 4 to 5 and given activities to further their thinking and document their observations and questions. The youths' work was evaluated for insights into their learning process, and feedback was obtained from the youth and Facilitators to validate and improve the STEM curricula and framework. In this section we will share results of the pilot study including observations and artifacts from the participants. Content that was written in French by the participants has been translated to English.

During the pilot study, some participants were instructed to create concept maps using arrows to describe how a phenomenon can cause an impact that can lead to another impact. One group noted that "floods" lead to "no transportation" which leads to "economic problems." Other groups identified questions they had related to the topics discussed. Their responses included "Why is there so much rain this year?" and "If ever there is destruction of houses will the minister of the environment help us?" The responses that the youth shared indicate they do indeed have knowledge that they are building on, they observe and make connections, and there are opportunities to help them investigate and innovate to address their questions and concerns.

For the 4-H Senegal STEM curricula and activities to truly be youth-driven, it is important for Facilitators to embrace that they are learning and discovering alongside the youth and to empower their youth learners to take the lead. This pedagogical approach was new for some facilitators. During the pilot study, one Facilitator expressed his surprise that the youth learners were able to produce so many examples of how floods and droughts impacted their society. Another Facilitator was so impressed by the youth's work that he wanted to hang their posters on the wall as a reminder of that day's activities. Observations from the pilot study point to the potential of the 4-H Senegal STEM curricula inspiring Facilitators to incorporate youth-driven learning in other settings, such as their formal classrooms.

When asked for feedback on their experience, the youth shared that they liked the activities, liked working in groups, and liked being able to give their thoughts on a topic. Some youth stated that brainstorming questions for scientific investigations was difficult. When asked what lessons from the activities that they would share with others, responses included to be careful with floods and that floods may cause sickness. Acquiring feedback from the youth participants required coaching and encouragement. It was obvious that most were not accustomed to sharing their feelings after conducting an activity. This observation highlights the disconnect between current educational practices in the Senegalese public school system and the experiential learning being used in 4-H Senegal. We noted that moving forward we must emphasize to Facilitators that they should be mindful of this potential challenge and deliberately encourage the youth to reflect and discuss so that they may build their communication skills and contribute to conversations more fluidly.

Conclusion, Implications and Recommendations

The six phases of the design-based research process helped us to accomplish the goal of creating adaptable, relevant, and youth-driven STEM curricula for 4-H Senegal. Our community of local experts played a pivotal role in ensuring that we were intentional in adapting existing United States frameworks to local context. However, our process lacked reiteration which would be useful in assessing the effectiveness of the curricula and ensuring alignment among the 4-H club youth learners and Facilitators. Their feedback could directly influence the build phase by providing input on curriculum topics. Once the clubs begin using the curricula on a longer basis, we can assess if they are integrating the intended values or if adjustments must be made in the curricula to better reflect the values. We could also get their feedback to understand if they agree on the framework values and format. If dramatic changes are required, we may need to reiterate to even earlier stages of the design-based research process. Overall, we recommend the design-based approach for other agricultural and extension educators that seek to contextualize United States-based frameworks in international settings. We believe that if this process is used in other countries, the resulting framework and curricula may be different depending on what the educators value as relevant there, but the design-based research process is still useful in helping to craft a vision, align frameworks and methods, and test solutions to ensure adaptable and relevant content for local participants.

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