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Towards a Scalable Digital Skills Training Architecture for Resource-Constrained Environments: The Case of Ayitic Goes Global in Haiti

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Abstract:

In developing countries such as Haiti, which are marked by high unemployment and gender inequality, online education has the potential to change lives. Returns on education are particularly high in Information Communications Technology (ICT)-intensive jobs and IT outsourcing offers opportunities for remote employment, providing alternatives for economic diversification and job creation that are particularly relevant for youth and women. However, the problem faced by many developing countries, is that traditional models, frameworks, architectures and platforms for online learning do not lend themselves well to their context and, therefore, it is important to develop context specific platforms. This need for suitable platforms has motivated the research question that this paper seeks to address, that is, "What is the appropriate architecture that supports learning strategies for delivering scalable digital skills training in a resource-constrained environment?" We propose an architecture that was developed specifically for blended learning in resource-constrained environments and describe how a prototype for this was designed, built, and deployed in Haiti. The initial findings from the application of the architecture have been extremely positive and are reflected not only in the testimonials of the participants but also by the interest of other countries of the region to adopting the proposed architecture.

Keywords: Digital Literacy, Scalable eLearning Architecture, Resource-Constrained Environments.

1 Introduction

Haiti is consistently ranked as the only country with low human development in the Americas (UNDP, 2016). It is still recovering from the devastating effects of the 2010 earthquake that severely damaged infrastructure, cost thousands of lives, and adversely affected economic activities. With over 5,000 schools damaged or destroyed by the earthquake, Haiti faces serious challenges in its educational infrastructure (Sider, 2014). For women the education deficit is exacerbated by persistent social beliefs and a historical pattern of discrimination and violence against women as a structural feature in Haitian society and culture[1].

In a context of high unemployment and marked gender inequality, online education for women is seen as a niche with great potential in developing countries such as Haiti (Olakulein & Ojo 2006; Hilbert 2011). Returns to education are particularly high in Information Communications Technology (ICT)-intensive jobs (Falck et al., 2021) and online outsourcing offers concrete opportunities for remote employment, providing alternatives for economic diversification and job creation that are particularly relevant for youth and women (Keuk et al., 2015). The project *Ayitic Goes Global: Empowering Women through Digital Markets*[2] had as one of its major objectives to build digital skills among young Haitian women in urban and rural contexts to create employment opportunities through online services. Although seen as a feasible response to the pervasive deficits in Haiti's educational infrastructure, achieving the sustainable delivery of online/distance education and digital skills training still has to contend with a broad range of issues, including: the availability of local trainers, facilitators and mentors; the development of current, context-relevant, language-specific training content; and training delivery mechanisms that enable on-line/off-line access modes to allow for limited bandwidth infrastructure with intermittent availability.

Rapid advances in digitization, web technologies, and available bandwidth have enabled the development of new models of education, teaching and learning (broadly categorized as eLearning). The delivery of Massive Open Online Courses (MOOCs) has emerged as a significant capability and competitive advantage for established higher education institutions and traditional education models. MOOCs typically share a number of common attributes: online mode of delivery; short videos; online quizzes and assessments; peer and self–assessment; online forums. These characteristics are based on certain pedagogical assumptions including: availability of high bandwidth; learners who are digital natives; pervasive mobility, and on-demand learning consumption (Glance, Forsey, & Riley, 2013).

However, as is often the case, context matters greatly. The typical assumptions about the availability of adequate civil and digital infrastructure, and the evolution of social and cultural habits towards normative behaviors in the digital economy are rigorously challenged in many developing countries such as Haiti (Nielsen, 2017; Foster & Heeks, 2013; Verma & Ryan, 2016). Therefore, the traditional models, architectures and platforms for online learning do not lend themselves well to these contexts. The nature of such learning architecture design projects in developing contexts brings with it some limiting constraints of resources such as electricity and internet access (Singh et al., 2021). Implementations are typically remote and not connected to the internet. In other cases, the connectivity may be available, but is intermittent (Chetlur, 2014). Such environments require a distributed architecture to handle the service needs at the core and the edge of the network (Verma & Ryan, 2016).

Recognizing the importance of developing platforms suited to the context in which they are to be used, our research was motivated and anchored by the need to develop an architecture that enables learning strategies for delivering scalable digital skills training in a resource-constrained environment.

In this paper we describe our approach to designing an architecture that can address the issues of providing online education in the context of limited bandwidth and resources. We consider an architecture as the overall design of a computing system and the logical and physical interrelationships between its components[3]. This architecture provides a blueprint for converting the strategic goals of any IT project into a plan (Pearlson et al., 2019). This plan provides for the flow and processing of information, as well as the infrastructural components of hardware, software, data, and networking. These components are then assembled into a platform forming a system, which, in turn, enables and fulfills the overarching strategic goals of the project.

[1] Report of the Inter-American Commission on Human Rights (IACHR)
[2] http://ayitic.net; https://www.youtube.com/watch?v=X-zu8ZOEl7Y
[3] https://www.gartner.com/en/information-technology/glossary/architecture

We then propose a specific implementation of the architectural plan into the software (mobile apps), hardware (tablets), data (analytics), and networking (cloud backend) (Hay & Muñoz, 1997) and describe how each of these components supports the specific needs of resource-constrained environments. Finally, we discuss the results of evaluating the implementation of the architecture in Haiti. The initial results have been extremely encouraging.

In section 2 we examine some of the literature that was used to frame this research. In particular, we examine the applicability of Moore's vintage transactional distance theory to modern eLearning design and pedagogy. In section 3 we describe the blended learning model that was used to support the design, the architectural design as well as the specific components that make up the architecture. In section 4 we evaluate the design by describing the results and insights from the Ayitic Goes Global project in Haiti. Finally, in section 5 we discuss the findings and consider the strategies and challenges of scaling digital literacy in the Caribbean, which could provide an architecture design template for other developing contexts.

2 Literature Review

In this section we discuss some of the literature that we used to inform our research question and develop our proposed solution. First we look at the literature relevant to the context of the research and then we discuss the literature relevant to the theoretical background of the work. In terms of context, Section 2.1 describes the need for Information Communication Technology (ICT) specific to the context of developing countries. There has been a call for inclusive innovation with a focus on developing ICT solutions that are relevant and available to low-income groups. More specifically this section highlights the need for ICT education solutions specific to the developing country context.

Digital literacy is now considered a must have skill to enter the workforce, however, training in this area is lacking in developing countries generally, and specifically in the Caribbean. The literature posits that digital skills training is critical for all Caribbean youth (Sharma & Lucini, 2016). This requires innovative ways to ensure that this training and education for digital literacy is accessible to all and so must be provided and supported through the use of ICT solutions specific to the context of developing countries. Given that digital literacy is defined and viewed in many ways, Section 2.3 defines digital literacy for the purposes of this study and emphasizes the importance of competency-based learning for developing digital literacy skills.

We then move from the literature relevant to the context of the research to the literature relevant to the theoretical background of the work. Section 2.4 outlines the pedagogical concepts that were considered and then focuses on the one that is particularly relevant, Connectivism.

We conclude the literature review with Section 2.5, a discussion of a theory that has underpinned this research, namely Moore's transactional distance. This theory provided a useful conceptual framework for designing our proposed architecture.

2.1 ICT Innovation in Developing Countries

Although it has been accepted that ICTs can play a pivotal role for developing countries, further studies are needed in ensuring their relevance in the context of these countries (Nielsen, 2017). Nielsen (2017) points to the lack of research on digital technologies and the significance of digital innovation for developing countries. He identifies literature that speaks to the need to consider the context in which ICTs are to be implemented and used. Sundermeier et al. (2020) highlight the importance of human diversity (e.g. age, gender, and socioeconomic status) in all aspects of digital value offerings, from their development to deployment, from use to management, and importantly, their impact. Foster and Heeks (2013) call for inclusive innovation which they define as the means to make innovation relevant to low-income groups (Foster & Heeks, 2013). This could mean addressing problems relevant to the poor, enabling the poor to adopt the innovations or creating innovations to improve the livelihoods of the poor. Based on this definition, our research would be categorized as an inclusive innovation as it focuses on improving the livelihood of the poor.

Nielsen (2017) also emphasizes that the contexts of developing countries pose unique challenges to ICTs and, therefore, require different technologies and implementation approaches. They provide some examples of these unique challenges including resource constraints such as weak ICT infrastructure and

electricity outages (Singh et al., 2021) which result in issues with internet connectivity. Haiti is a prime example of a developing country that is faced with such challenges.

In the area of education, digital learning platforms (DLPs) are deployed across multiple locations for online learning and virtual training (Mehta et al., 2021). However, Mehta et al. (2021) point to the danger of using standardized DLPs given the significant cultural differences across various locations and regions. Chetlur et al. (2014) point out that while there is high-quality online content available through resources such as MOOCs, the intermittent internet and high infrastructure costs associated with these make it difficult for developing countries to benefit from them. They call for alternative educational models that can work in countries and regions with fragile and intermittent internet connection and limited resources. Pankomera and Van Greunen (2016) also highlight the challenges that resource-constrained countries face in harnessing the benefits of ICT for education.

2.2 Digital Literacy

It has been widely accepted that today's citizens must acquire basic digital literacy competencies given the demands of the workforce, especially in the context of closing the digital divide (Cung & Yoo, 2021). There are a variety of conceptions of digital literacy (Rosado & Bélisle, 2006), which fall into two broad categories of definitions. There are those primarily concerned with technical skills versus those that are focused on cognitive and socio-emotional aspects of working in a digital environment (Eshet-alkalai, 2004). An example of the former comes from the Cornell University Digital Literacy Resource that define digital literacy as "the ability to find, evaluate, utilize, share, and create content using information technologies and the Internet" (Techataweewan & Prasertsin, 2018). In essence, digital literacy involves more than the mere ability to use digital tools or work with digital media.

Martin (2008) synthesizes the literature and integrates several previously existing "literacies of the digital" (e.g., ICT literacy, information literacy, media literacy, visual literacy, communication literacy) to offer the following comprehensive definition of digital literacy:

> *The awareness, attitude and ability of individuals to appropriately use digital tools and facilities to identify, access, manage, integrate, evaluate, analyze and synthesize digital resources, construct new knowledge, create media expressions, and communicate with others, in the context of specific life situations, in order to enable constructive social action; and to reflect upon this process.*

This definition promotes competency-based learning (Voorhees, 2001) which is important given the job-demand-driven nature of the training requirements suited to many developing countries such as Haiti and those of the wider Caribbean. The merits of a competency-based approach to learning include:

- **Increased Learner Engagement**: The learner engagement model of competency-based education tends to be much higher because learners have ownership over their learning experience through learner-centered approaches and structure that enable greater flexibility and self-paced modes of delivery.
- **Skills-based Approach**: One of the key benefits of competency-based education is that learning centers on real-world skills and competency development.
- **Explicit Linkages to Bloom's Educational Taxonomy**: Competency-based education makes learning outcomes measurable and increases the probability of more effective assessment and validation.

Battat et al. (2016) make the point that there is a gap in the literature as it relates to competency-based curricula delivery through distance learning in developing countries. They describe the research they have done in the development of a competency-based continuing medical education curriculum for physicians in rural Haiti which was delivered using distance learning.

Based on the existing literature and the context of our research, the following amendment was made to the adopted definition of digital literacy:

> **Digital literacy** is the *knowledge*, *skills* and *attitude* of individuals to appropriately use digital tools and facilities to identify, access, manage, integrate, evaluate, analyze and synthesize digital resources, construct new knowledge, create expressions, communicate with others, in the context of specific life situations, in order to enable construction action, and to reflect upon this process.

We use *knowledge*, *skills* and *attitude* rather than *awareness*, *attitude* and *ability* as *knowledge* and *skills* are more amenable to measurement and assessment than ability according to Bloom's taxonomy, and *knowledge* will incorporate *awareness*.

2.3 Digital Literacy in the Caribbean Context

Digital is rapidly becoming the dominant mode of interaction for commercial, social, and economic activity, hence the digital economy. Data is the oil that fuels the digital economy and data literacy is the ability to collect, organize, manage, evaluate, and apply data to various business scenarios and activities. This ability is rapidly becoming an essential in-demand employability skill. With the rapid evolution of the digital economy, digital literacy/data skills have become an imperative and a right, no longer a privilege (Murray & Pérez, 2014).

The Global System for Monitor Communication (GSMA) report "Connected Society: Digital inclusion in Latin America and the Caribbean", identifies the lack of digital literacy and skills as one of the biggest barriers to digital inclusion in Latin America and the Caribbean (Sharma & Lucini, 2016). Additionally, the United Nations has held discussions with political leaders[4] to ensure commitment to scale up digital learning and skills and close the digital divide as they posit that this is essential to accelerate the progress towards the UN's Sustainable Development Goal SDG 4. Target 4.4, which seeks to "increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship", emphasizes this imperative (Montoya, 2018).

2.4 Pedagogical Considerations

Pedagogy is the discipline that deals with the theory and practice of teaching or the means by which education achieves its objectives. At a conceptual level, pedagogical strategies are informed by the principles of teaching and learning as well as theoretical concepts including behaviourism, cognitivism, constructivism and connectivism (Ertmer & Newby, 2013). At a programmatic level, the concern is with the *what* and so it is about identifying target competencies, learning objectives, sequencing and organizing of content, specifying learning activities, and deciding how to deliver content. At an individual lesson or module level, instructional design is concerned with the *how* (Wiley et al., 2002; Gustafson & Branch, 2002). The focus is on which specific instructional, navigational, and assessment methods are best suited for the course content, modality and learner.

Traditional theories of learning describe how knowledge is absorbed, processed, and retained during learning: behaviorism, cognitivism, constructivism and connectivism (Siemens, 2004). Connectivism is an attempt to construct a new learning paradigm for the digital age that takes into account the effects and possibilities of technology-enabled learning in a networked context (Goldie, 2016). It requires the engagement of learners in an overtly social and networked learning experience and emphasizes the connections that develop among the participants, materials, and learning. Such an approach amplifies learning, knowledge, and understanding through self-education structured as a distributed network, and aggregated using technology. The solution we propose in this paper is focused on connectivism, ensuring that the students, while in remote locations physically, can still develop connections and have active engagement through technology.

2.5 Learning Models for Under Resourced Countries

A number of technologies have emerged that have led to new models of education, teaching, and learning (e.g. MOOCs). Many of these new models typically share a number of common attributes (e.g. online mode of delivery, short videos, online quizzes and assessments). However, these characteristics are based on certain pedagogical assumptions including: the availability of high bandwidth, learners who understand and are exposed to technology, pervasive mobility, and on-demand learning consumption (Glance, Forsey, & Riley, 2013).

Gulati (2008) points out that many of the solutions to improving access to IT infrastructure, even in developing countries, have focused on the "urban elite". There is an urgent need to refocus on basic educational infrastructure to support low cost, higher quality access in rural and deprived areas in developing countries as there is still a high percentage of people from lower social classes, females, and rural areas, who continue to be marginalized due to their lack of access to adequate learning resources

[4] https://en.unesco.org/news/digital-learning-way-forward-high-population-countries-rally-around-initiative

and basic education (Gulati, 2008). Poankomera and Van Greunen (2016) also speak to the challenges that resource-constrained countries face in harnessing the benefits of ICT for education.

The architecture we propose was implemented using existing blended learning components, tools, and technologies that are suited to the issues of serving under-resourced communities, such as those that lack electricity and reliable network connectivity.

2.6 Moore's Transactional Distance

Moore's transactional distance theory (Moore, 1973, 1993) is based on the assumption that the most profound impact on distance education is pedagogy and not the physical or the temporal distance that separates the instructor and learner (Gorsky & Caspi, 2005). It is a relative measure of the physical, psychological, and communications separation between the learner, the content, and the instructor/facilitator. The extent of transactional distance is a function of three key variables, namely dialogue, structure, and learner autonomy. Dialogue speaks to the degree of interaction/communication between teachers and learners; increasing the dialogue reduces the transactional distance. The second dimension, structure, addresses the rigidity or flexibility of the course's educational objectives, teaching strategies, and evaluation methods. A high degree of structure increases transactional distance. Autonomy is the extent to which learners are able to decide on when to learn, what to learn, how to learn, and how much to learn. A greater degree of autonomy is associated with increased transactional distance. Figure 1 shows the effects of these three variables on transactional distance.

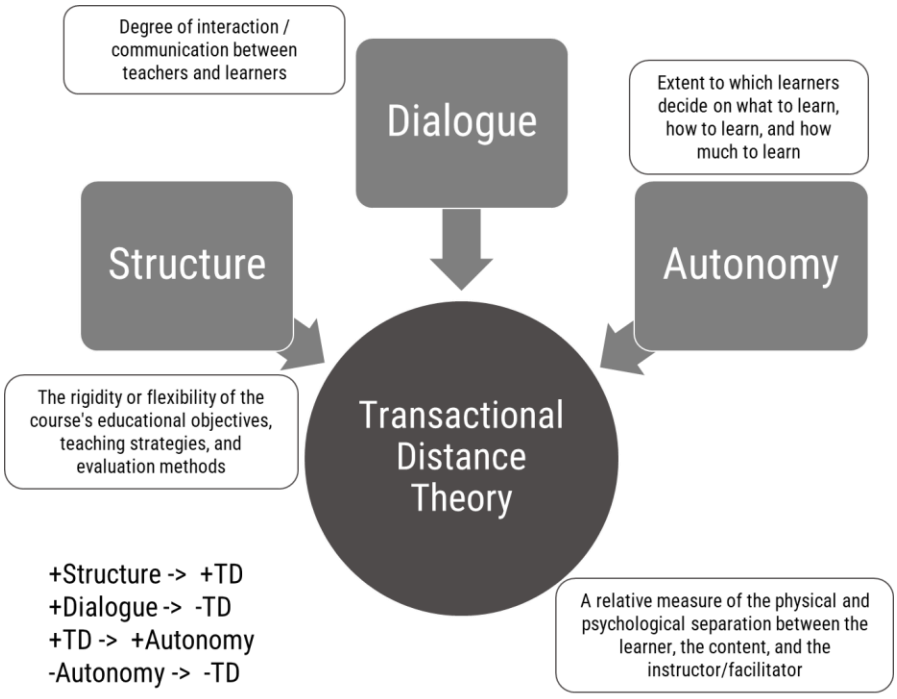

Figure 1. Transactional Distance

These variables must be accounted for in the design of any online learning environment. The transactional distance theory (Moore, 1973, 1993) predates the onset of the internet and today's high-bandwidth, internet-enabled digital models of education, teaching, and learning. While some critics have accused the theory of being tautological (Gorsky & Caspi, 2005), and it could be considered vintage, transactional distance has continued to be a useful framework for design or interrogation of distance education pedagogy in its various manifestations (Benson & Samarawickrema, 2009; Huang et al., 2016; Quong et al., 2018).

In general, according to the Transactional Distance theory, the effectiveness of distance teaching (on-line learning) is significantly influenced by the extent to which the institution and the individual instructor are able to provide the appropriate opportunity for, and quality of, dialogue between teacher and learner, as well as appropriately structured learning materials. Furthermore, learner characteristics, and in particular,

the optimum degree of autonomy, are important determinants of this balance, and considerable time and effort has to be devoted to understanding the needs of target learner populations, and individual learners.

This theory is particularly important for the design of our proposed architecture as Huang's (2002) consideration of transactional distance and other elements of adult learning theory (Brookfield, 1995) in the design of constructivist online learning for adult learners is particularly relevant to the empirical context of developing countries such as Haiti. These considerations include:

1. **Importance of a structured curriculum**: Learner's need to know how learning will be conducted, what learning will occur, and why learning is important.
2. **Interactive learning**: Interactivity motivates and stimulates learners. Active learning through interactions with instructors, other learner's and content is a crucial function in distance learning.
3. **Self-directed learning**: The ability to take control of the techniques and of the purposes of learning.
4. **Experiential learning**: Prior experience of the learners creates individual differences and could be a valuable resource in a collaborative and socially constructed learning environment.
5. **Critical reflection and problem-solving orientation**: A form and process of learning whereby adults think contextually and critically. In particular, they can learn best when knowledge is presented in real-life context.
6. **Motivation to learn**: Adults are highly motivated to learn when they can gain the new knowledge to help them to solve important problems in their lives.
7. **Instructor's role as facilitator**: The instructor's role becomes more of a consultant, guide, and resource provider with a responsibility to monitor and manage the quality of learning and peer discussions.

3 Architectural Design – Scalable eLearning

The design and implementation of the architecture considered the connectivism theory of learning which, as mentioned earlier, amplifies learning, knowledge, and understanding through self-education structured as a distributed network, and aggregated using technology. This distributed approach supports one of the important objectives of our solution - that it should be scalable.

The design is also strongly influenced by the resource-constrained environment in which the teaching and learning are delivered. Such environments can provide unique infrastructure, technical, and social/cultural constraints (Anderson et al., 2012).

In the case of Haiti and our specific research, a combination of factors exacerbate the constraints:

- Capacity and quality deficits in civil infrastructure such as schools, roads and transportation services limit opportunities for traditional approaches to education. The recurrent disruptions of civil unrest and the attendant security concerns increase the value opportunity for remote/distance teaching.
- The Caribbean region, which lies at the geographical axis of continental giants North and South America, is a multilingual region with a colonial legacy of English, Spanish, French, Dutch and a variety of local dialects. Therefore, an eLearning design that is scalable at a regional level will need to incorporate multi-linguality as an essential design attribute. Internet infrastructure in many countries such as Haiti is severely limited and/or expensive for the target participants and access will likely be constrained (low and/or intermittent bandwidth) for the foreseeable future (e.g. in 2017, only 12% of the population in Haiti has Internet access penetration[5]). ELearning design has to contemplate and make provisions for delivery modes that allow for remote, disconnected access and that is not dependent on continuous Internet access (Battat et al., 2016), factors quite different than what the traditional online models (e.g. MOCCS) were designed for.
- While Haiti has one of the lowest Internet penetration rates in the Caribbean, access to mobile phones has increased rapidly, and smartphone access is also growing (Sider, 2014). Mobile devices will therefore be an important learning device for access and consumption of learning content.

[5] ITU Statistics (2013)

Given these resource constraints together with aforementioned pedagogical considerations, the transactional distance and connectivism theory provide a useful conceptual framework for informing the proposed eLearning architectural design and implementation process. In relation to the primary transactional distance factors, the following considerations applied:

1. **Structure** - Of necessity, the job-demand-driven nature of the training requirements dictated a competency-based approach to the curriculum and course content design, with structured learning outcomes that can be measured and evaluated. The target learners (young adult women) needed to be presented with a clear structure of how learning will be conducted, what learning will occur, and why learning is important in order to relate the program to their specific social context and generate high motivation to learn and gain new knowledge.
2. Course content was organized in alignment with explicit learning objectives, and the materials were lock-sequenced with a progressive, directed learning path that enabled students to achieve incremental mastery of a concept before moving on to the next. This approach was in keeping with Risdale et al. (2016, 2015) who recommend a module-based learning approach to digital literacy, which allows students to achieve learning outcomes in stages and to build upon previously learned skills. It also allows the learners to build confidence in their abilities in a gradual way.
3. **Autonomy** - Notwithstanding the highly structured curriculum, course content, and organization, it was necessary to allow for flexibility in terms of how learners engage with the program. A blended learning approach, combining synchronous and asynchronous modes of delivery, provides learners (particularly women) with the time flexibility to pursue training opportunities while maintaining their essential livelihoods, and helps to mitigate the risk of high attrition rates that are typically associated with eLearning delivery. A key element of the blended learning delivery approach was the explicit incorporation of the instructor's role as a facilitator, which became more of a mentor, guide, resource provider and problem solver.
4. Learners were issued with mobile tablet devices as part of the program, an important instrument for designing and deploying the program as self-paced, mobile-enabled courses employing the flipped classroom concept. This provided learners with the flexibility to access learning content on demand and outside the constraints of physical classroom sessions and limited internet access.
5. **Dialogue** - An important consideration was for the program delivery architecture to enable a significant degree of dialogue (interactivity) in the instructional design as this is key to reducing transaction distance in a blended environment. The courseware was designed as modular eLearning objects with a variety of interactive elements and embedded quizzes that work well on the mobile tablets. This design allows for active learner interaction, versus the traditional passive learner experience that comes from just reading (e.g. pdf documents). Each course module incorporates built-in activities that invite the learner to reflect on the learned concepts and cognitively apply them to familiar contexts.
6. Weekly, interactive face-to-face sessions between learners and facilitators are an important component of the blended learning model. In addition, an online virtual learner community provides for facilitator-student and student peer-to-peer interactions in the online domain.

3.1 A Blended Learning Model

We propose the blended learning model illustrated in Figure 2, as it enables the seamless integration of online (synchronous) and offline (asynchronous) learning methods that are needed to meet the requirements described above.

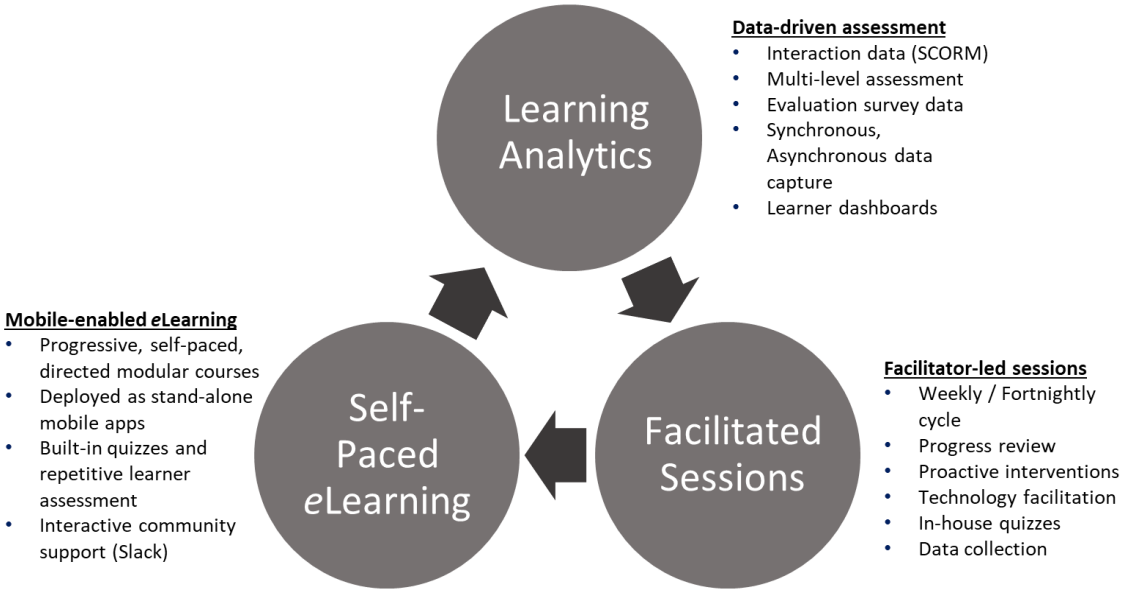

Figure 2. Blended Learning Model

The blended learning model outlined in Figure 2 consists of three main components: facilitated sessions, self-paced eLearning, and learning analytics. Although these three main components are not unique to our proposed architecture, they have been operationalized within the context of resource-constrained environments as described below:

1. **Self-Paced eLearning Component**: This component provides progressive, self-paced directed modular data literacy courses. The components were designed in this way to support competency-based learning where the students were required to demonstrate the defined learning outcomes as they progress through the course material. For example, the design includes built in quizzes and repetitive assessments so learners can ensure they grasp the content of one module before moving on to the next.

   Students' progress through the curriculum at their own pace, depth, etc., ensuring competencies are proven for one topic before progressing to the next topic. This is important given the target audience, as it allows the learners to have the flexibility to complete the components at times suited to their other demands (e.g. family commitments). Additionally, the flexibility is important given the lack of resources and the need for these learners to be able to get to locations where they can access the needed resources. Finally, the model suits the devices available to the participants, namely tablets.

   One important consideration in the design of this component is supporting the need for dialogue, as this interaction is seen as essential for reducing the transactional distance between facilitator and learner and, as importantly, between students themselves. In an online environment there are tools that can be used to support this interaction e.g. Slack and Google Classroom.

   In order to address the issue of limited resources, our design allows students to download material and work offline which was an important consideration given the issue of intermittent network connectivity and access to transport. More importantly, the results of the activities, such as assessments, even when done offline, can be uploaded once the student reconnects. Therefore, the data from all activities is being captured and can be used for learning analytics to manage the progression of each student at an individual level.

2. **Facilitated Sessions**: the course delivery is designed to have a number of tutor led face-to-face sessions. These sessions can be held periodically (e.g. fortnightly) and be used to review the progress of the students. These facilitated sessions also provide an opportunity for the students to discuss any issues they may have encountered doing the self-paced activities that they were not able to clarify in the online interaction. Therefore, the course design is modular and self-paced to facilitate flexibility but it is expected that a given cohort is moving through

modules together. The facilitated sessions can then be used to focus on any topics that the facilitator sees as weak, based on his assessment through the analytics, and for the sharing of learning experiences by peers.

3. **Learning Analytics**: an important feature of our blended learning model is the learning analytics component. Learning analytics is relatively new, but as Cooper (2013) discusses, learning analytics draws techniques from a number of communities (Cooper, 2013). These include statistics, business intelligence, web analytics, operational research, artificial intelligence, data mining, and social network analysis. For our project, we only avail techniques from statistics and web analytics. Chatti et al. (2014) propose a conceptual framework for processing data consisting of four stages: (i) Establish an activity to measure (typically within an application), (ii) collect data about the measurement, (iii) analyze collected data, and (iv) report the outcome to the stakeholder(s).

   In the blended learning model proposed analytics can provide support both in terms of the tracking of the progress and performance of students as well as the administration of the programme. We reflected on the importance of active learning through learner interactions with instructors, other learners and content. The ability to measure, collect, report and analyze learner interactions becomes a key component of the eLearning architectural design (Chatti, Dyckhoff, Schroeder, & Thüs, 2013). Learning analytics provides an opportunity to reduce the transactional distance given that more interaction can be provided based on the data that is available for activities done even when the student is offline. Importantly, the way that the architecture is designed allows the data needed for the analytics to be captured once a student reconnects even when the learning activities are done offline.

   Not only was the need for analytics appropriate for various stakeholders, it was also different in the way the information would be reported (Verma, 2018). In order to provide reporting, both at the core and at the edge, we required a distributed architecture to process the four stages of Learning Analytics and service the needs of the core and the edge with one system.

3.2 Architecture and Infrastructure

In this section we discuss Figure 3, our architectural design and the various technology components used to implement this design. This design supports the blended learning model that was proposed above. The architecture was implemented using existing blended learning components, tools, and technologies that are suited to the issues of serving under-resourced communities, such as those that lack electricity and reliable network connectivity.

In order to manage deployment costs and allow for scalability, we integrate open-source tools, cloud-based software-as-a-service platforms, and custom software-developed components. The use of distributed components enables the architecture to scale through replication.

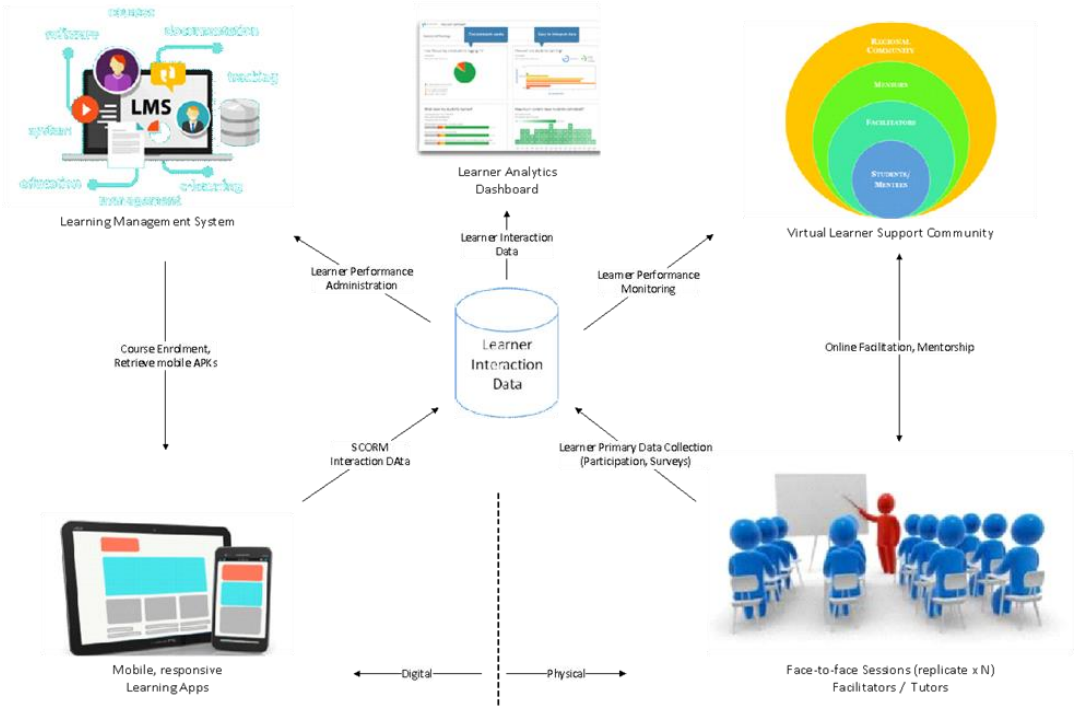

Figure 3. Blended Learning Architecture

A description of the components of the architecture and the technologies used to implement them is provided below:

3.2.1 Learning Management System

A learning management system (LMS) is a key component for blended delivery. A number of options are available, so it is important to choose the one most suited to the given context. In our case, Google Classroom was deployed as the learning management system. Beyond providing an electronic repository for the courseware and related content, Google Classroom provided more of a “social media” learner experience compared with more conventional LMSs such as Moodle. This social character, together with features that mimicked a real-world classroom metaphor, enabled managed student-to-student and student-to-facilitator interactions that encouraged a "community spirit" within cohorts and promoted peer-to-peer learning. We considered this support of interactions to be essential in reducing transactional distance in an online environment and best suited to the age of the target population. Therefore, Google Classroom was considered as a suitable option for supporting the self-paced e-learning component required (see Figure 2) as it facilitated the flexibility of delivery while supporting the community support required.

3.2.2 Learning Analytics

The four stages of learning analytics, measure, collect, analyze and report, are captured to assess learner interactions. The learner interaction data is the “glue” that integrates the various components in our distributed learning architecture. All courseware (web/mobile) was designed to capture and record learner interaction data as standard shareable content object reference model (SCORM) objects. Although SCORM was designed primarily as a standard for sharing course content among different eLearning systems, in our case, we use it as the means of collecting, packaging, and transporting interaction data from the distributed eLearning objects to the learning analytics system. Learner interaction data was subsequently stored on a custom-developed online data portal which enabled facilitators and course administrators to track students’ progress as well as record in-course assessment performance. Additionally, the design allows data on the students’ offline activities to be captured and then analyzed when the students come back online. This data allows the facilitator to identify, for example, areas of weaknesses, students who are falling behind and thus better plan for the asynchronous engagement with students.

3.2.3 Responsive, Mobile-enabled, Learning Apps

The use of the ADAPT[6] open-source framework and authoring tool supports the design of highly modular eLearning objects that combine text and graphic components on a scrolling page to create a rich, interactive and responsive learner experience. The responsive design allows the courses to be deployed on any device: mobile phones, tablets and desktops. The authoring tool also facilitates interactive engagement and dialogue thus the content is delivered through the application in an interactive way which reduces the transactional distance of the learners even when they are remote.

Additionally, the ADAPT open-source authoring platform allows single source content to be deployed in multiple languages, an important feature in the context of the Caribbean region, and may be a consideration if the proposed architecture is to be adapted in other areas with similar constraints.

The stand-alone mobile editions of the courses were generated as mobile apps (apk objects on android devices) that provided learners with the flexibility of stand-alone disconnect operation that does not require continuous Internet connectivity.

The choice of ADAPT supports the need for multiple language deployment, modular design and interactive engagement – all of which are important for the proposed Blended Learning Model. Additionally, ADAPT and the tablet devices (as described below) together address the issue of limited internet connectivity.

3.2.4 Tablets

Tablet devices were an important component of the learning architecture and provided the primary basis by which courses were accessed and used by learners. This was particularly important for deploying the program as self-paced courses using the flipped classroom concept, especially in an environment where Internet access was unreliable for most course participants. The interactive design of the courses, with built-in quizzes and reflections, also worked well on the tablets and allowed for active learner interaction and engagement, even while disconnected. All user interactions with the course materials were recorded as standard SCORM activity and was intermittently uploaded for subsequent analysis. Thus the tablets were an important choice for the support of both the Learning Analytics and Self-Paced eLearning components described in Figure 2.

3.2.5 Virtual Learner Support Community

Online learning (distance teaching) can be an isolating experience that leads to high attrition rates. Engagement of learners in an overtly social and networked learning experience that emphasizes the connections that develop among the participants, materials, and learning, is an important design consideration. The use of Google Classroom provided a structured social context within the virtual classroom and encouraged interactions and collaborative learning within student cohorts. We further experimented with wider online support communities using platforms such as Slack that put learners in communication with actors such as other cohorts and mentors. Transactional distance may be reduced through mechanisms of social constructivist learning.

3.2.6 Scalability

The scalability of our solution comes from leveraging the cloud architecture with Google Cloud. This backend gives us an elastic component to scale up and down as necessary. Additionally, the offline provisioning and occasional synchronization of the Android apps allows our architecture to be distributed. Some of the processing happens on the offline device, while the rest happens on the cloud backend. By combining the scalable cloud backend and distributed frontend, we get a scalable distributed architecture.

4 Evaluating the Case of Haiti: Ayitic Goes Global

The project *Ayitic Goes Global in Haiti* provided a unique socio-cultural context for evaluating our architectural design for digital skills training within a resource-constrained environment. The project was a pilot initiative of the International Development Research Centre (IDRC) and the Latin America and Caribbean Network Information Centre (LACNIC) which sought to increase women's access to

[6] https://www.adaptlearning.org/

employment in Haiti by building digital capacities in the field of information technology and by strengthening internet development (Sundermeier et al., 2020). Haiti is one of the countries with the lowest Internet penetration in the Caribbean (42% average penetration)[7], they score 0.636 (152nd out of 162 ranked countries in 2019) on the Gender Inequality Index, which is a score that ranges from 0 to 1 and reflects the degree to which women are disadvantaged in relation to reproduction, empowerment, and the labor market (UNDP, 2020). Haiti also ranks 170th in the Human Development Index out of 189 ranked countries and is the least developed country in Latin America and the Caribbean (UNDP, 2020). This provided the optimum context to evaluate the proposed architecture.

The project was a two-year programme and had three main objectives: i) the building of the digital skills ii) access to employment, and iii) improving the availability and reliability of internet access. The empirical domain consisted of a digital/data literacy skills training program for 300 young women learners between the ages of 17 – 29, conducted over three cohorts during a 15-month period, and was characterized by significant infrastructure, technical and social/cultural constraints. Infrastructure constraints included: limited internet connectivity, unreliable electricity supply, high cost of transport, and lack of access to a device at home. Socio-cultural constraints included: time availability and domestic responsibilities that limited opportunities to pursue education opportunities; financial constraints; baseline digital skills and language; gender bias and cultural stigma about women in technology.

The trainees were selected after going through an interview process and review of their qualifications. The average age of the trainees was 24 years, they had a high school degree and were mostly unmarried (6% were married or engaged) and had no children (6% reported having one or more children). They spent a significant portion of their time engaged in household daily duties (on average 5.7 hours), which is typical among women who reside in developing countries. This demonstrates the importance of the participants having the flexibility to do the courses at times suited to their schedule. Participants reported having the ability to handle basic internet tasks such as using a browser search bar, downloading an application, and viewing videos on user-generated content sites such as YouTube. Using the Internet for informative measures such as bookmarking websites and signing up for newsletters were rated lower in comparison.

The specific courses and their modules are outlined in the Figure 4.

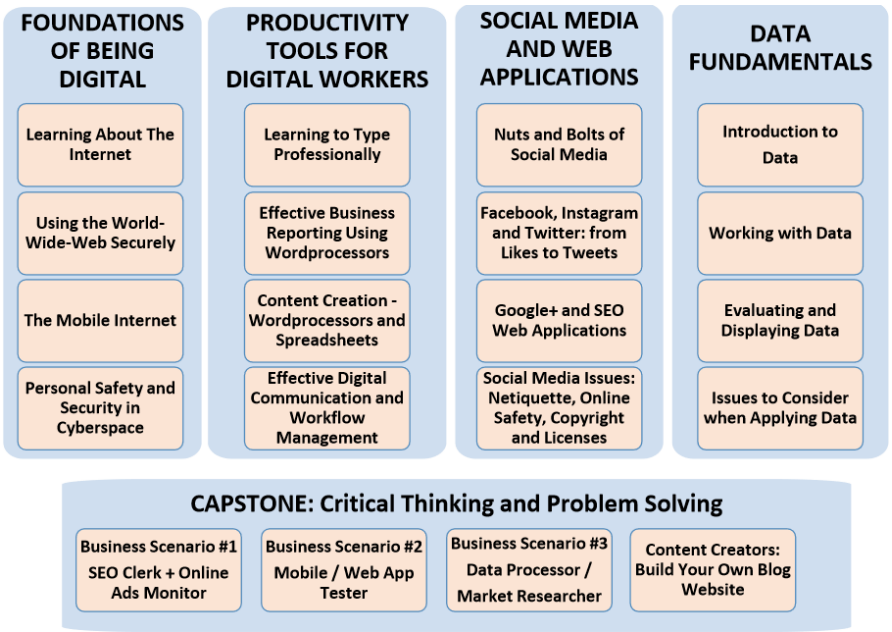

Figure 4. Digital Literacy Courses and Modules

[7] https://datareportal.com/reports/digital-2022-haiti

The architectural design components employed demonstrated the potential to meet the pedagogical requirements of the target adult learner constituency, even within these constraints; specifically:

- The adverse impact of capacity and quality deficits in civil infrastructure, Internet access, and transportation services was diminished by the deployment of stand-alone mobile editions of the courseware that provided learners with the flexibility of disconnect operation that did not require frequent travel to a physical teaching space, or continuous Internet connectivity. This benefit was especially evident when protracted civil unrest and the attendant security concerns disrupted the program but did not prevent learners from continuing to engage with, and progress through the course materials.
- Active, self-directed, experiential learning, which are all important attributes of distance learning for adult learners, were facilitated through the social, collaborative components of the architecture (e.g., Google Classroom) that enabled the creation of cohort sub-communities and encouraged continuous interactions between learners and instructors, leaners and learners, and the content.
- The learning analytics component can be used for administrative purposes as well as for tracking student progress and performance. It mitigates the transactional distance challenge of online learning by generating a constant stream of learner interaction data that enabled facilitators and course administrators to track students' progress as well as record performance in in-course assessments. Data was collected and measured at all points of interaction of the students with the program and was continuously presented through dashboards that enable cohort facilitators and program administrators to track student progress and performance, and administer to overall program delivery. Some examples of the use of analytics across the program life cycle are illustrated in figures 5 to 8. Figure 5 shows the results off the self-assessment instrument which was administered on entry to the program and provides a baseline measure of how students perceive their digital proficiency. Figure 6 shows the Cohort Progress / Tracking which allows facilitators to monitor and track student progress across the various course modules which are accessed by students according to a pre-determined learning pathway. Figure 7 shows the Cohort Quiz Performance, a summative Quiz is administered at the end of each course, and Facilitators can monitor and track student performance for each cohort. Finally, Figure 8 displays the Student Reward Points. Students are incentivized throughout the program by the allocation of points awarded for various factors such as academic performance, progression, attendance, participation (community posts). The program provides an element of gaming by way of a leaderboard, and students receive token prizes for accumulated points.

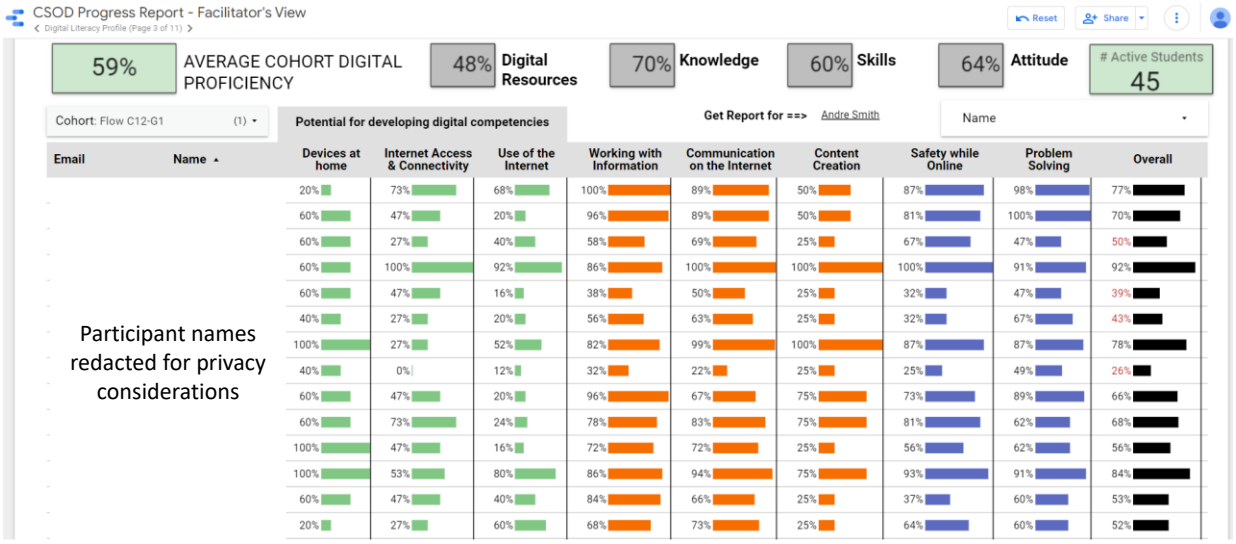

Figure 5. Student Digital Proficiency

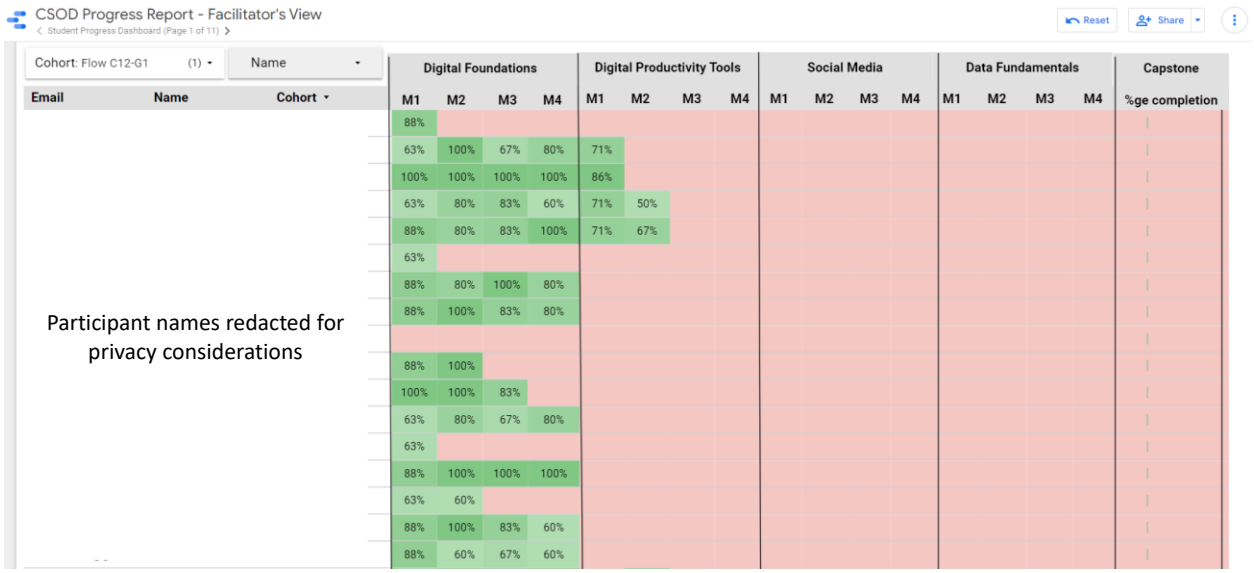

Figure 6. Cohort Progress/Tracking

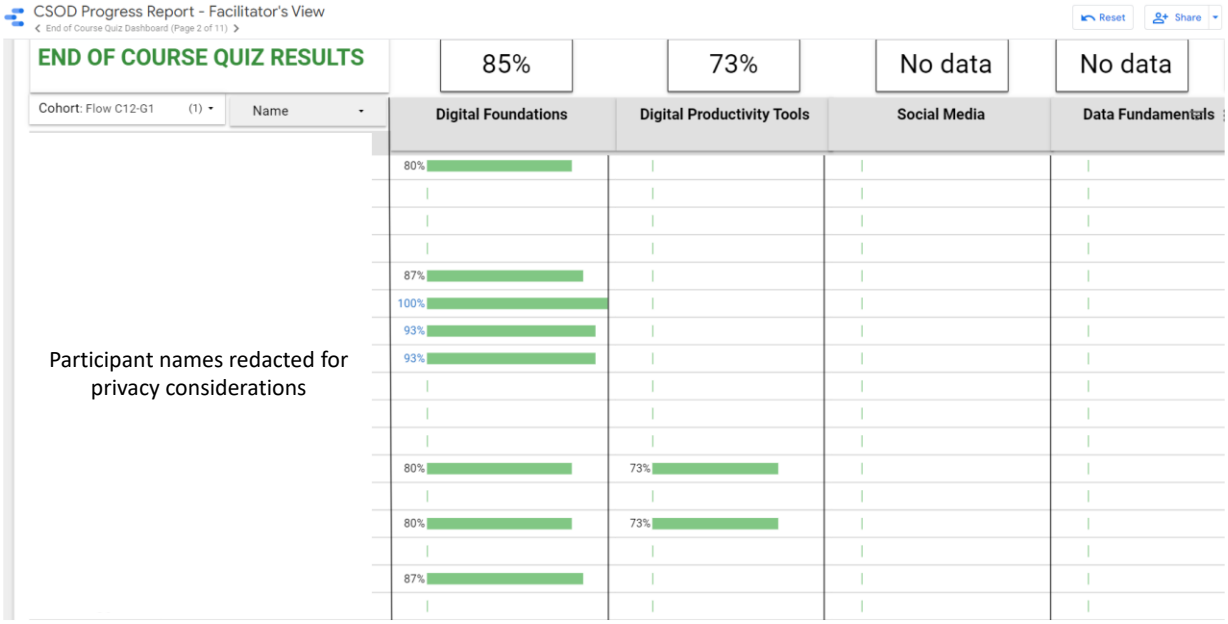

Figure 7. Cohort Quiz Performance

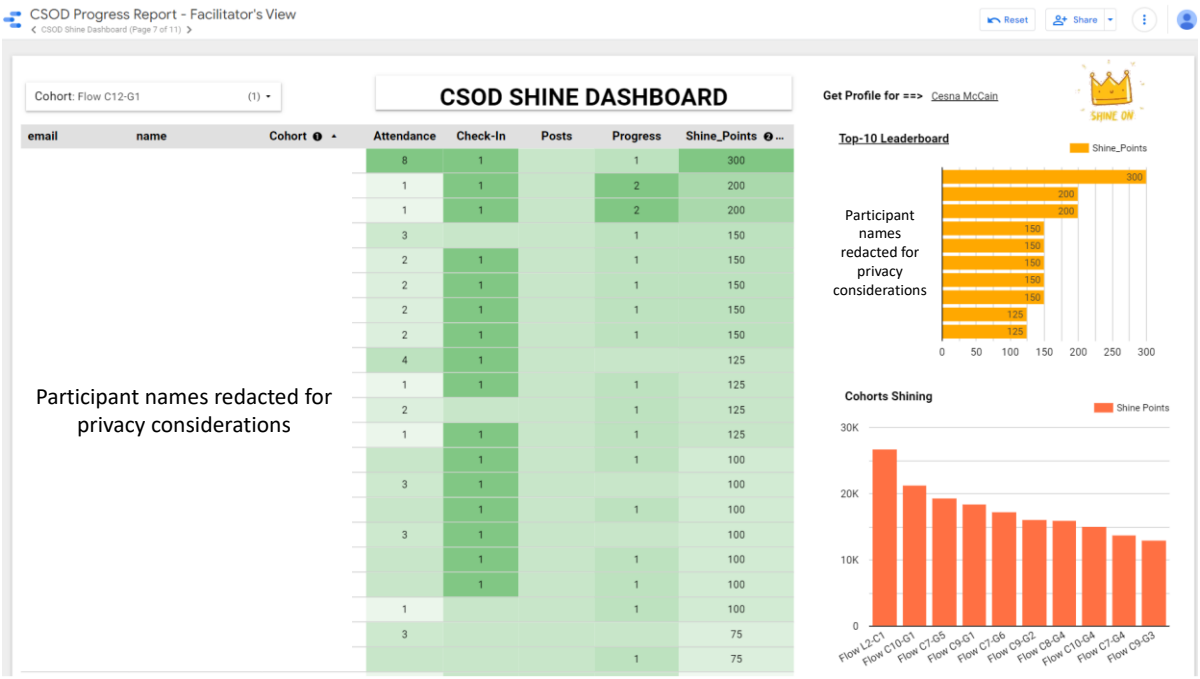

Figure 8. Student Reward Points

4.1 Results and Lessons Learned

This architecture was extremely effective in delivering digital skills training for the approximately 300 target learners that have been through the programme. The results of the training intervention are summarized as follows:

- The online blended learning model was successful, yielding high graduation, and low attrition rates.
    - Graduation rate (average): 85 percent
    - Attrition rate (average): 3 percent
- This low attrition and high throughput rate is a testament to the approach. Attrition is a significant problem for some of traditional online learning models (e.g. MOOCs) that are known to have high dropout rates (Khalil & Ebner, 2014).
- Infrastructure deficits (power+connectivity+transport) were effectively mitigated and did not correlate negatively with grades/graduation.
- The role of the instructor as a facilitator was identified as one of the most critical success factors to the high retention rates, and students valued their facilitators as tutors, mentors, guides, and role models.

Beyond the visible program results, as measured by successful completion and formal assessment mechanisms, qualitative surveys of the participants post-graduation highlighted a number of intangible impacts, as perceived by program beneficiaries:

- Experienced an increased confidence in the ability to navigate the online world and access resources to increase their knowledge.
- The different tools they learned helped them to better manage time, bring discipline and planning into their lives, and manage tasks and workload.
- Increased requests for technical support from friends and family indicated a change in how graduates are perceived.
- Ability to mentor younger siblings, friends, and youth in similar programs, sharing knowledge and taking leadership roles.

- Graduates experienced a greater acceptance of work role and less expectations to do household work at home. (“Overall Assessment Report”, 2019)

5 Discussion

The deficit of digital literacy and data skills is considered one of the biggest barriers to digital inclusion in Latin America and the Caribbean. Digital literacy and data skills have rapidly become in-demand employability requirements and can now be considered an essential competency for Caribbean youth.

New emerging models of education, teaching, and learning that leverage current advances in digitization, web technologies and available bandwidth hold the promise for scalable digital literacy training delivery to address these deficits. The popular emerging platforms for scalable digital training, such as the MOOCs, make assumptions about the availability of high bandwidth infrastructure and the characteristics of target learners that are not consistently valid for many developing contexts.

The primary motivation of the research was to formulate a specific architectural design process for a learning platform that fulfills the goals of blended learning in a resource-constrained environment. The design choices were informed by transactional distance theory, as well as aspects of adult learning theory.

Two key components of our architecture are:

1. **Tablet devices**: The decision to provide each of the course participant with a tablet device was an important enabler for overcoming many of the infrastructure deficits (e.g., internet access, and travel costs), as the mobile device provided the flexibility to access learning content on demand and outside the constraints of physical classroom sessions and limited internet access. In addition, it enabled the design of a high degree of interactivity and dialogue in the modular eLearning courseware.
2. **Learning analytics**: Although not an explicit element of the transactional distance framework, learning analytics are considered to be an important aspect of the dialogue dimension. The ability to measure, collect, report and analyze learner interactions is a key capability, and the “glue” that integrates the various components of the distributed eLearning architecture. In addition to facilitating tracking of student progress as well as recording in-course assessment performance, learning analytics opens up opportunities for analyzing and understanding student interaction patterns and learning behaviors. The choice of technologies to implement the architecture allows data about the activities of the students while they are offline to be captured and analysed once they come back online.

Scalability is, perhaps, the most important design goal of our architecture. The integration of open-source tools (ADAPT eLearning framework), cloud-based software-as-a-service platforms (e.g., Google Classroom) and custom software-developed components (e.g., the analytics portal) has provided a distributed learning architecture with the potential to scale through replication. This is a different scale-up model compared to the popular MOOCs that rely on a heavy, centralized server infrastructure.

6 Conclusions

This work combines existing components of blended learning into an overall architecture that suits the needs of resource-constrained regions. The architecture was implemented using technologies that support these specific needs, e.g., technologies that can collect data about student activities even when they have to be offline due to issues such as intermittent electricity and internet. The design of our architecture and the choice of components was intended to reduce the transactional distance of the delivery.

We demonstrated the architecture for a project in Haiti and the results have been extremely positive. We are currently adopting the approach as well as the curriculum in other contexts and other countries across the Caribbean region. The Caribbean School of Data[8] is a current funded initiative that will use our distributed learning architecture across seven countries in the Caribbean to deliver accessible digital literacy and data skills training to marginalized youth. More details of the success of this initiative will be published in further work. We foresee that other developing countries with similar constraints will adapt

[8] http://coi-csod.org

our proposed architecture in way(s) they see fit. Thus, the architecture will continue to evolve as it is adapted to more contexts.

From a research perspective, our architecture and its implementation are a response to the call for more work in identifying ICT solutions and, more specifically, learning solutions for the developing context given its ongoing problem of resource constraints. From a practical perspective our work addresses a very critical and real problem in the developing context i.e., preparing the youth, and even more specifically women, for job opportunities, by designing an architecture that provides scalable digital skills training.

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