RAISING DEFORESTATION AWARENESS THROUGH EDUCATIONAL GAMES

ROADBLOCKS TO ICT ADOPTION IN DEVELOPING COUNTRIES

A Thesis Prospectus
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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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The tropical rainforest is one of the most important biomes on the planet. Bradshaw, Sodhi and Brook (2009) note that rainforests support more than two-thirds of the world's species, despite covering only 7% of the Earth's land surface (p. 79). Unfortunately, the qualities that make these lush ecosystems great also makes them incredibly fragile and vulnerable to human exploitation; extinction rates from habitat loss and overexploitation are acute in the tropics, given the high species richness of these habitats. Bradshaw, Sodhi, and Brook (2009) also conclude that political corruption and poor governance are the leading socioeconomic threats to the conservation of tropical biodiversity. The technical project represents a long-term solution to this dilemma as it aims to generate interest in and concern for the Amazon Rainforest among grade school students. The technical project is tightly coupled with the STS research project which will first use the Technology and Social Relations model to examine some existing problems that hinder the current integration of technology among the educational sectors of developing countries. Pacey's triangle will then be applied to analyze the actors involved in such integration plans and policies through the broader lenses of cultural, organizational, and technical contexts; After this larger network is identified, the sociotechnical contingencies that govern the successful integration of educational technologies in developing school systems can be studied at depth, and the primary roadblocks to the proper use of such technologies will be made clear. The former project will be accomplished via the collaborative efforts of a software development team comprised of six undergraduate computer science students: Dylan Peters, Sammy Hecht, Ryan Coulter, Henry Clabby, Trevor Bedsaul, Rob Wallace, and Teddy Vallar. The technical project will be developed on behalf of Ben Eppard, communications specialist for the Amazon Aid Foundation, and overseen by capstone professor Ahmed Ibrahim. Both projects will be

accomplished over the course of two academic semesters; the timetable for the technical project is delineated by the Gantt chart in Figure 1 below.

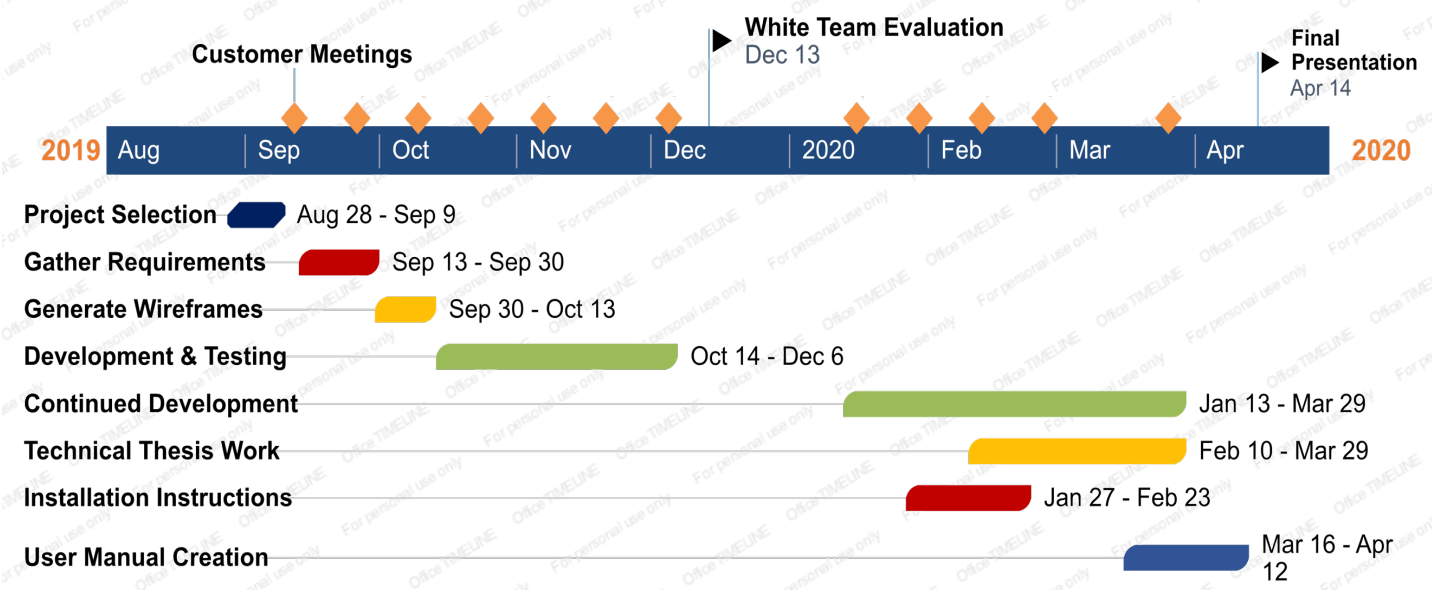

Figure 1: Gantt Chart: A chronological illustration of the tasks and milestones for the technical project.

RAISING DEFORESTATION AWARENESS THROUGH EDUCATIONAL GAMES

Human-related deforestation of tropical rainforests has been accelerating at an alarming rate across the globe. As noted by Lovejoy and Nobre (2018), two experts on matters of global biodiversity, the Amazon Rainforest comprises a majority of the planet's tropical forest, yet around 17% of this species-rich biome has already been destroyed as of 2018. They suggest that if deforestation climbs higher than 25% an ecological tipping point will be reached, shifting southern and central Amazonia from a tropical rainforest into a non-forest ecosystem called a degraded savannah (p. 1). The implications of Amazonian deforestation are much more far reaching than a mere reduction in global biodiversity, however. As explained by Laurance (1999), "The rampant pace of forest conversion is causing severe dislocations—even extinctions—of indigenous groups" (p. 110). He also explains how Amazonian forests are

"pharmacopeias of irreplaceable products" and that "the value of tropical forests to local residents — as sources of food, construction materials, remedies, and myriad other natural products — can exceed that produced by logging or felling the forests" (p. 111). Thus it makes sense, even from an economic perspective, to increase conservation efforts.

Even more concerning is the series of anti-environmentalist policies enacted by Brazilian politicians in recent years. Former Brazilian President Michel Temer eliminated multiple construction licenses previously required for companies to clear parts of the rainforest, while enacting policies which reduced public oversight and transparency requirements concerning such projects. Additionally, his administration cut the Brazilian Ministry of Environment's budget in half before freezing it for a twenty year period set to begin in 2018. Temer's successor, Jair Bolsonaro, has promised to continue increasing access to Amazonian resources (E. Pereira, Ferreira, Ribeiro, Carvalho, & H. Pereira, p. 8, 2019)

The technical project outlined in this prospectus aims to bolster middle school students' awareness of the aforementioned Amazonian deforestation through the continued development of an educational, gamified web application. This learning module will be integrated with and hosted by an existing online platform and Charlottesville non-profit organization called the Amazon Aid Foundation, whose mission is to garner support to protect and restore the rainforest using artwork, film, and other multimedia projects. This project is a continuation of a prior capstone project; the prior team began development of the "Grow A Tree" game module where users progress through levels of an Amazonian tree, thereby coloring its silhouette, by completing various tasks and mini-games. During the first semester, the current capstone team will solve both navigational and accessibility problems that currently hinder the application's effectiveness.

One example of such a tree silhouette is shown to the right in Figure 2. Currently, users have no way of returning to previously completed levels, designated by the greyscale strata to the right of the tree, and overall site navigation is minimal making class-wide discussions difficult. These levels should be clickable to allow for intuitive backward and forward navigation between previously completed levels of the tree for both students and teachers. In addition, although this application is targeted at middle school classrooms, the learning modules currently require password-protected accounts to track progress between logins. This requirement poses a serious barrier to entry because public middle school teachers require special administrative permission to use any websites which require students to make standalone accounts. The capstone team will therefore restructure the login process to use a class-wide code, distributed by the teacher, followed by a personalized four-digit code so that students can track their progress without needing a password.

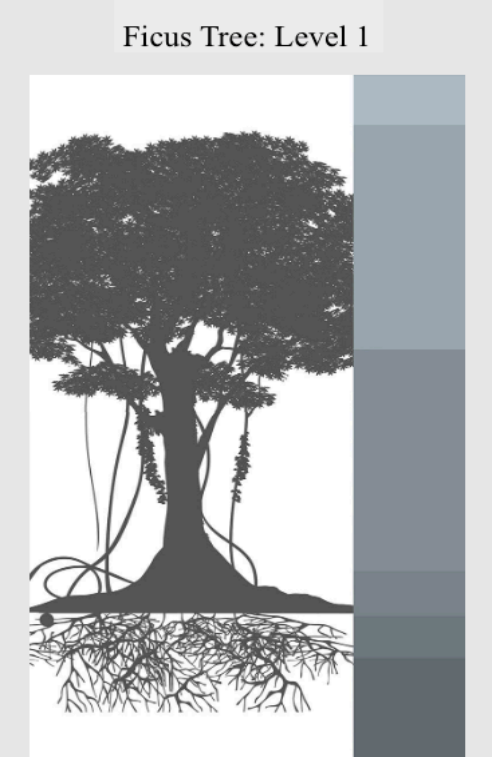

Figure 2: The sillhouette of a ficus tree shows the progress of a particular learning module in the Amazon Aid site but features no navigation functionality and fails to make clear the user's current level (Adapted by Dylan Peters from "My Trees", 2019).

During the second semester of the course, the capstone team will focus on the actual content of the learning modules, making the activities more engaging through the improved gamification of material. The site currently features small games and activities throughout the curriculum, an example of which is shown in Figure 3 (p. 3), however they suffer from the common pitfalls of serious games, or games designed for something other than pure

entertainment. As explained by Wim Westera, an expert in learning media, games that emphasize rote memorization without contextual framing, such as a crossword puzzle with only eight questions, aid in knowledge reproduction but fail to support deeper comprehension and general content understanding. Furthermore, games employing only extrinsic motivators like rewards or certificates suffer the same disadvantages when compared to games using intrinsic motivators, such as enjoyment of the game itself (p. 61-64, 2019). Though moderately enjoyable and informative, the crossword shown in Figure 3 simply uses the password to the following level as an incentive for completion. By developing games that require a deeper understanding, such as designing hypothetical ecosystems of plants and animals, the capstone team will make the learning modules more engaging and effective.

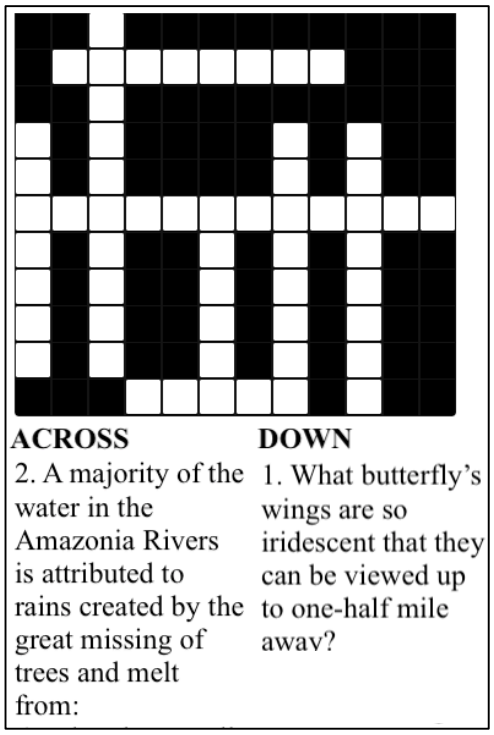

Figure 2: Crossword Puzzle: One of several embedded mini-games that use must complete to traverse through leve of a tree (Adapted by Dylan Peters fro "Ficus Tree", 2019).

While some may feel that no matter how engaging the game, the actual positive impact on the current state of the Amazon rainforest will be minimal, these people fail to consider the future implications. Bradshaw, Sodhi, and Brook (2009), experts in global ecology, concluded that the greatest long-term improvements regarding tropical conservation can be realized via good governance of tropical biodiversity resources. Soares-Filho (2006) corroborates this mentality by showing that the establishment of good governance and environmental legislation by 2050 could entirely eliminate deforestation in protected regions of the Amazon, while reducing it by 35% in unprotected areas (p. 85). It is therefore of great importance to instill the right values in the next generation of potential policy-makers, world leaders and engineers.

ROADBLOCKS TO ICT ADOPTION IN DEVELOPING COUNTRIES

Classrooms at all levels of education throughout the United States are becoming more and more tethered to technology. Public schools now provide at least one computer for every five students, and spend $3 billion dollars every year on digital content (Herold, 2016). But technological innovation in the classroom also demands innovation in the way teachers teach, apply and integrate the technology in order to be truly effective. This is especially true among developing countries that believe leveraging technology in the classroom can drastically improve the learning process, and possibly reduce cost by substituting for teachers and staff who are not affordable.

Integrating Information Communication Technology (ICT) within the curriculum is often the first step taken by disadvantaged schools to facilitate teaching and learning. ICTs include computers, telephones, calculators, projectors, and interactive white boards, among others. Many studies conducted in developing countries or developing school systems, however, have revealed a trend of ineffective implementation of ICTs in classrooms which can both lead to, and be the result of undesirable relationships in the classroom environment and in wider organizational contexts. These relationships are best modeled by a Technology and Social Relations STS model seen in Figure 4. Teachers adopting such technologies must first build working relationships with their school staff and administrators, who are represented by the bottom-left circle of this figure.

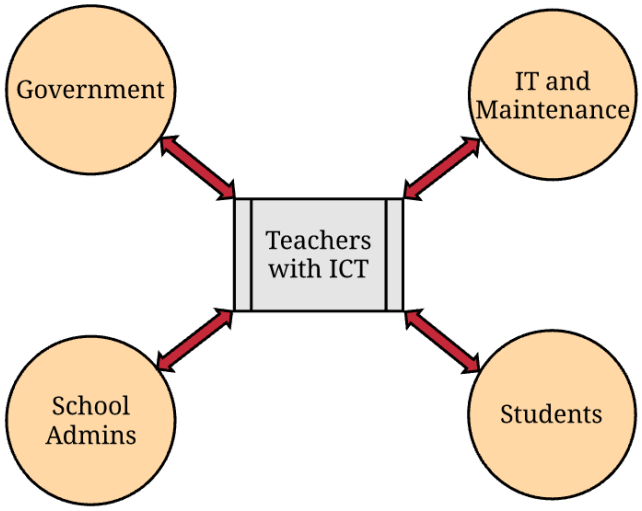

Figure 1: Technology and Social Relationships Model for ICT: Teachers must build and maintain social relations with various groups to implement ICTs effectively (Adapted by Dylan Peters from W. B. Carlson, 1992).

Francis, Ngugi and Kinzi (2017) conducted a study of ICT integration in Kenyan secondary schools and found that a main factor hindering this implementation is bad "school vision on ICT and administrative support" (p. 74). These authors also suggested that schools' management need to allocate more funds for the repair and maintenance of the already available ICT, concluding that "the schools should plan for the installation of ICT infrastructure as well as envisioning the need for regular training of teachers in ICT as a staff development program" (p. 82).

A stronger relationship must also be established between teachers using ICT and IT and maintenance personnel, the latter group being illustrated by the top-right circle in Figure 4 (p. 6). A recent study of the effectiveness of ICT integration in Ghana concluded that "training teachers to possess the requisite knowledge and skills to effectively support their students' ICT usage in classrooms is necessary", and that "training and competence are determinants of successful ICT integration in schools and classrooms" (Buabeng-Andoh, 2019, pg. 283). These results reveal the need for teachers to establish ongoing relationships with knowledgeable IT staff members and proper training personnel; A relationship between these three actors could improve teachers' confidence and competence surrounding the use of information communication technologies, ultimately leading to a more effective integration of available technology with existing teaching practices.

A third social complication also arises from the new dynamic between teachers and students, represented by the bottom-left portion of Figure 4 (p. 6), that arises when novel technology is introduced in a classroom setting. A case study of ICT implementation in Cameroonian schools found that students often became less obedient after ICTs were introduced, describing how "there are situations where some of them would refuse to allow others use of the available tools, while some of them would use the tools for their personal reasons" (p. 157). The

role of the teacher appears to be jeopardized when ICTs are introduced in a classroom, potentially due to a shift of power to the students themselves. One behavioral study on how the introduction of interactive whiteboards into Turkish secondary schools affects teacher authority found that "use of the Smartboard in class is also reported to have several negative effects on the teacher's role by making class management difficult and making it difficult for the teacher to be adopted by students" (p. 117). A shift in teaching pedagogy is therefore needed to ensure teachers maintain control and order in the classroom after integrating novel technologies.

Finally, a more general, yet arguably more important relationship between the government of an underdeveloped country and its school system is critical to ensure ICTs are implemented and used effectively. However, many such countries do not uphold or maintain certain policies regarding the implementation of technology and infrastructure, resulting in a homeostasis of ICT use among schools. For example, the government of Kenya has been keen on using information and communication technologies to increase access to education for Kenyan students. In 2004, a national ICT policy was developed by the Ministry of Education (MoE), which, using government funding, aimed to provide common ICT framework and direction throughout Kenyan public schools and integrate ICT in education management, teaching, and learning (MoE, 2006). However, as noted by Buabeng-Andoh (2019), in spite of these policies and strategies laid down, the MoE failed to anticipate certain challenges that would hinder effective integration. It has been reported that half of all the schools in Naivasha, Kenya have technology such as computers, TVs, and radios, but a large number of teachers and students rarely use them (Ngugi, 2012). In other counties, it has been found that the MoE has put in little effort to sustain ICT implementation projects for secondary schools (Nyaga, 2014).

While the social relations model in Figure 4 (p. 6) helps to identify some of the current problems that the developing school systems face when implementing education technologies, it fails to address the broader network in which the social relations are embedded. Thus it is useful to contextualize the various actors involved in the ICT diffusion process using the organizational, cultural, and technical aspects framed by Pacey's Triangle in Figure 5 below.

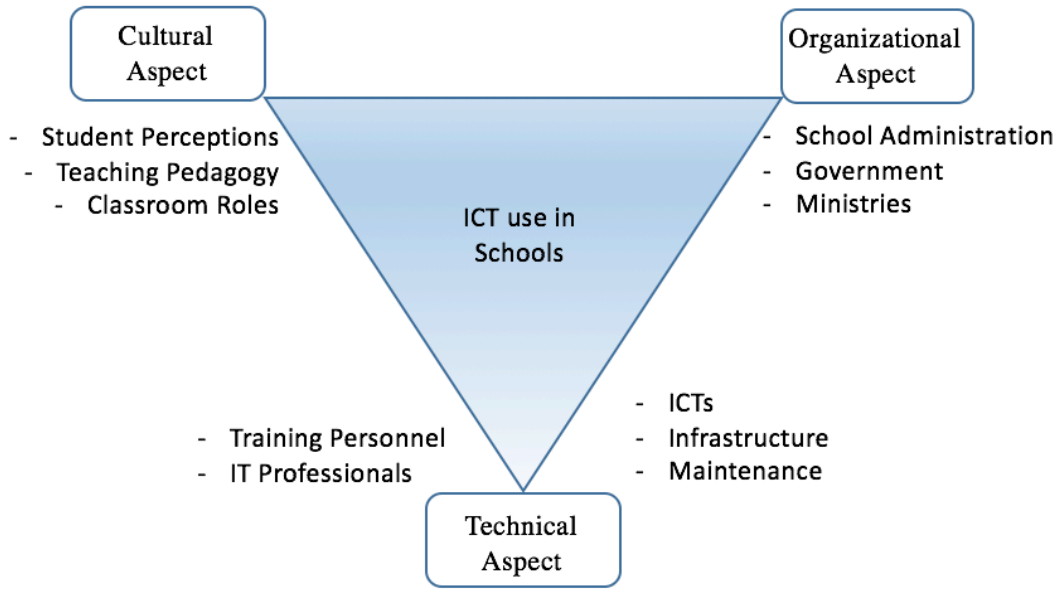

Figure 5: Paceys Triangle: Contextualizing the actors involved with integrating ICT in developing school systems (Adapted by Dylan Peters from Arnold Pacey, 1983).

This figure highlights how the actors involved in the technical aspects of ICT use also have influential sociotechnical roles within both cultural and organizational contexts. For example, IT professionals and those experienced with ICTs are situated on the bottom-left side of the triangle, which means they have influence within both cultural and technical contexts. In his doctoral thesis (2012), Peter Ngugi studied the use of ICT in education management within Kenyan secondary schools and found that teacher training programs primarily focus on the development of technical ICT skills, but fail to address how to actually apply these skills within current teaching practices. These integration programs involve technical personnel who are

unfamiliar with the pedagogical aspects of a classroom environment, and who are therefore unequipped to work within this cultural context. The interpretive flexibility of information and communication technologies could be a main reason why this cultural-technical barrier has been surmounted by school systems of developed countries, but still impedes progress in undeveloped countries; ICTs are versatile by nature, but without training that considers the cultural aspects of a school, teachers end up using these novel technologies at face value.

A second sociotechnical roadblock to effective ICT integration is made apparent by examining the actors at the bottom-right of the triangle in Figure 5 (p. 9). Specifically, the availability and accessibility of ICT infrastructure, maintenance and other related resources are key elements for facilitating ICT adoption; Obviously a teacher cannot use educational or communication software without access to computer-related hardware and proper network infrastructure. Many studies have found, however, that when a government, or its educational ministry, does fund integration programs, the provision of ICT resources in schools does not guarantee that it will be used by teachers (Gulbahar, 2008; Ertmer, 2005). Since the turn of the century, many governments have been heavily investing in integration plans by funding educational infrastructure and professional teacher training. The Kenyan government is one such example as for years they have been laying fiber optic cables across the country, provisioning computers, multimedia laboratories, and connecting schools to Local Area Network (LAN) (Francis, Ngugi and Kinzi, 2017). As explained, however, the Kenyan Ministry of Education failed to anticipate certain cultural and technical challenges, such as the need for proper ICT training and maintenance programs.

In summary, using Pacey's Triangle helps to consider various roadblocks that prevent developing school systems from adopting ICT through cultural, technical and organizational

lenses. Hopefully, by analyzing the overlap and interplay between actors in these contexts, novel sociotechnical solutions, rather than exclusively technical or social solutions, will be identified to streamline the diffusion process, making ICT integration more efficient and effective. This research is tightly coupled to the technical project because tropical rainforests exist primarily in developing countries, including Brazil's Amazon, where governments are rife with corruption. This dynamic means that the greatest potential for a long-term shift to good-governance, and ultimately the preservation of Earth's biodiversity, resides in the youth native to these developing, tropical countries. If the research using Pacey's Triangle is successful, then the door will be opened for novel solutions, such as the application presented in the technical project, to enter and inspire change.

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