Thesis Project Portfolio

ALEC: an Audio Learning and English Companion

(Technical Report)

Addressing the Digital Divide in Low-Income Education Through Realigning Networks

(STS Research Paper)

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Technical Project Abstract

The Audio Learning and English Companion project, also known as ALEC, aims to develop an offline, interactive tool to enhance English vocabulary and comprehension skills for non-native English-speaking primary school-aged children without internet access. The device integrates a custom-made keyboard, XMSJSIY Mini Computer Speaker, and a Midas Displays LCD screen controlled by an STM32F407G1-DISC1 microcontroller all in a 3D-printed plastic case, printed from PLA filament.

ALEC guides users through a language-learning process in which a word is spoken in the child's native language, followed by the English translation. The child then types the English word using the custom keyboard, receiving visual, textual, and audio feedback. Audio playback is managed using embedded C code, a FAT file system, and a digital-to-analog conversion to output .wav files stored on a USB drive. The keyboard was specially designed to support a simple letter matrix, tactile mechanical switches, and essential function keys like "Help" and "Start", tailored to younger learners. Atomic operations and interrupt-driven scanning ensure real-time responsiveness.

The project addresses the inequality of language access, particularly in underfunded, non-English-speaking communities, by offering a low-cost solution for improving English listening comprehension skills offline. ALEC targets both educational inclusivity and engineering ingenuity, with scalable hardware and adaptable firmware to multiple languages and skill levels. As a prototype, it successfully demonstrates the potential for embedded systems to support equitable learning without relying on internet connectivity.

STS Project Abstract

The STS paper investigates the persistent barriers to equitable digital access in low-income communities, particularly within educational settings. Despite many government and corporate initiatives to expand broadband access and digital tools, millions of students are still disconnected from vital educational opportunities. This research applies Actor-Network Theory (ANT) to investigate how the misalignment of interests among key actors–governments, technology providers, educational institutions, infrastructure systems, and digital tools–sustains the digital divide. I also suggest strategies for realignment of actor interests by borrowing from successful examples in Asia such as Google's Skills Ignition SG Program, Lenovo and Microsoft's EdVision Program, and Alibaba's Revitalization Fund. I also suggest improvements for past government programs, such as the Affordable Connectivity Program, and corporate initiatives like the ConnectED program in Marion, Alabama, as they failed to appropriately enroll actors for sustained success.

Long-term collaboration between actors is essential to address the digital divide. It can not be solved by any actor acting in isolation; it is about actors recruiting, aligning, and strengthening their relationships with one another. The study argues for strategic realignment through collaborative Corporate Social Responsibility (CSR), equitable infrastructure investment, and inclusive technology design. Importantly, this paper also calls for engineers to embrace their ethical responsibility in this alignment by designing tools that are low-cost, offline-capable, and accessible for users with low digital literacy. This work ultimately presents a framework for future educational technologies and policy reform that centers accessibility, social equity, and systemic alignment.

Relationship Between Technical and STS Project

My technical project, ALEC, addresses a key barrier contributing to the digital divide: the accessibility of technical design. Most modern educational tools require high-end material and internet access, creating obstacles for low-income communities. ALEC eliminates this barrier by providing an offline educational tool to enhance English vocabulary and comprehension skills for young learners. The design targets underfunded, non-English-speaking communities to reduce inequalities in language-learning resources.

My STS project broadens this focus to examine how existing technological, socio-economic, and institutional structures sustain the digital divide in these communities. Using Actor-Network Theory (ANT), I propose strategies to realign stakeholder interests and improve digital education and inclusivity. This alignment fosters equitable access to educational tools, ultimately helping marginalized communities to close the digital divide. The project critiques short-term, politically motivated initiatives and suggests long-term strategies, including inclusive design practices and Corporate Social Responsibilities (CSR), to realign actors within the network.

My technical project is a direct response to one of the most pressing challenges in my research–the lack of accessible, inclusive educational technology. My STS project complements this work by situating ALEC within a broader socio-technical context. Together, these two projects demonstrate how engineers can address systemic inequalities through purposeful design. ALEC represents a tangible example of how technical innovation, when informed by socio-technical insight, can help shift the trajectory of the digital divide and promote more equitable educational outcomes.