Thesis Project Portfolio

Optimizing Web-Based Educational Simulations: Integrating Web Assembly to Improve Performance

(Technical Report)

Exploring Divergent Perspectives Between ELLs and Instructors: Revealing Adverse Mismatches Through Analogical Discourse Analysis

(STS Research Paper)

An Undergraduate Thesis

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Bachelor of Science, School of Engineering

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Sociotechnical Synthesis

(Executive Summary)

Bridging the Learning Gap Through Stories and Simulations

"All men by nature desire to know." - Aristotle, *Metaphysics*

Learning is humanity's most vital characteristic; as Vitruvius illustrates in *The Origin of The Dwelling House*, humanity's ability to understand led to civilization and refinement. Yet, quality education remains inaccessible to many, creating a significant learning gap. As a Spanish language learner, I understood that learning a second language is challenging. However, I could not grasp why 31.6% of English Language Learners (ELLs) did not graduate high school. This uncertainty motivated my STS research, which explores divergent perspectives between ELLs and their instructors to discover the hidden challenges that ELLs encounter in language learning. While separate, my technical project proposes using WebAssembly (WASM) to improve the performance of web-based educational simulations, making them more accessible to students with low-end machines. As a computer science student, I have used simulations such as binary tree visualizers to grasp complex topics. Yet, students with low-end machines cannot reap those same benefits. Although the projects appear unrelated, they share the same motivating goal of improving educational outcomes. STS research bridges technical solutions and human values by amplifying the voices of stakeholders who rely on systems like educational simulations and multilingual classrooms. By integrating their perspectives, engineers can design systems that are both effective and equitable.

In my STS Research, I investigated the analogies in ELL and instructor accounts to better understand their mental models and reveal two mismatches that may exacerbate the challenges faced by ELLs. In the first mismatch, I discovered how ELLs relate language learning to surviving in a harsh

environment. Instructors may reinforce this sentiment by viewing ELLs as "beyond repair," like a broken-down car. In the second mismatch, I found that instructors often discourage the use of a student's native language, believing it hinders English acquisition. However, this practice may contribute to ELLs' feelings of isolation and punishment by restricting their ability to communicate with peers and instructors. These findings reveal how the well-intentioned actions of instructors may unintentionally harm ELLs. If instructors employ more constructive mental models, they might better address the challenges ELLs encounter. For example, one supportive mental model is the view that ELLs learn better when using a mix of their native language and English. By adopting more constructive mental models, instructors can address the learning barriers affecting ELLs and improve their educational outcomes.

The technical portion of my thesis focused on improving the accessibility and performance of web-based educational simulations through the integration of WASM, producing an implementation plan to integrate WASM into a simulation and a testing plan to measure its performance. I proposed an implementation plan to integrate WASM in physics-based simulations alongside implementations in JavaScript, React, asm.js, and C++ native code. My proposal outlined C++ language features and functions that optimize CPU usage, including single instruction multiple data (SIMD) instructions, manual memory management, and optimized matrix multiplication. In addition to an implementation plan, I developed a testing plan to compare various performance metrics between each implementation, including scripting time, CPU usage, and manual code timing. Incorporating WASM into visual-based simulations can reduce CPU usage, allowing more students with lower-end machines to use these simulations. With more access to these simulations, students can better grasp complex topics, improving their educational outcomes.

Through developing my technical project and STS research, I better understand that creating a technical artifact is challenging. But, even when a technical artifact is produced, failure is likely without considering sociotechnical perspectives. In the STS prospectus, I initially struggled to define STS and technical topics, leading me to propose projects without understanding the stakeholders affected. By

taking a step back to analyze the sociotechnical systems I had experience with, I discovered the various stakeholders impacted by those systems. Listening to those affected revealed their needs and values, including access to educational simulations and the ability to use their native language. As Martin and Schinzinger emphasize in *Ethics in Engineering*, "Conceiving engineering as social experimentation restores the vision of engineers as guardians of the public interest, whose professional duty it is to guard the welfare and safety of those affected by engineering projects." Multilingual classrooms and educational simulations, for instance, can be seen as experiments involving subjects. STS highlights who these subjects are and how they are impacted. By listening to their voices, I hold an ethical responsibility to incorporate their perspectives and values to create more equitable solutions, whether that be less CPU-intensive simulations or promoting productive mental models that address the challenges faced by ELLs.