Overview

Radio-frequency (RF) phased arrays systems have become powerful tools in science and engineering, with applications in particle astrophysics [1–4], polar research [5, 6], and 5G mobile [7]. Phased arrays are comprised of RF antennas working in tandem to boost received signal sensitivity, and to actively scan transmitted signals without moving parts. Future scientific work will be enhanced through phased array cost reduction and the use of open-source RF design software. The electromagnetic response of phased arrays is designed with expensive, proprietary software that does not interface with open-source machine learning tools [8]. They are then manufactured using costly and time-consuming traditional machining techniques. Ongoing scientific and engineering efforts will be enhanced by a solution that allows machine learning to flourish, reduces design and manufacturing costs, and diversifies participation by reducing financial barriers. Such a solution will enrich education with computational electromagnetism (CEM), machine learning, and 3D printing by integrating these topics into the curriculum.

Intellectual Merits

We propose to create the first open-source CEM and additive manufacturing ecosystem capable of 3D-printing phased arrays with conductive filament [8–10]. We have shown that open-source CEM tools used in photonics can drive the RF phased-array design process [3]. This research will support diverse projects like the Askaryan Radio Array (ARA), IceCube Gen2 (radio), and the Center for Remote Sensing and Integrated Systems (CReSIS). Phased arrays have increased the sensitivity of ARA to ultra high-energy neutrino (UHE-ν) interactions in the ice sheet beneath the South Pole [11]. The arrays are vertically polarized due to mechanical constraints within the ice. By combining machine learning with CEM, we seek a *horizontally polarized* design that overcomes these constraints to increase the chance of making the first UHE-ν observations in history. This research will *accelerate* and *diversify* research in UHE-ν, climate science, and RF engineering by *translating* successes in CEM and materials research. This work will be integrated into our curriculum at Whittier College, a Hispanic Serving Institution (HSI). This work aligns with three Big Ideas from NSF: Windows on the Universe, NSF INCLUDES, and Navigating the New Arctic.

Broader Impacts

This work will have positive impact on the education of diverse undergraduates. Whittier College has a proud tradition of providing access to higher education to Spanish-speaking and historically marginalized students. Though people of color and first-generation students make up 63% and 29% of our student body, respectively, our internal data indicate they receive lower grades than their peers in introductory STEM courses. Emphasizing the dignity and self-efficacy of our students can improve their performance [12, 13]. This emphasis makes students feel they *belong* in our courses, despite encountering adversity. To emphasize the dignity of our students no matter their background, we seek to create a bilingual (Spanish and English) mobile application (app) that introduces STEM concepts within a welcoming digital environment.

This approach has pedegogical precedent in the Duolingo method [14]. We seek to provide data insights about student learning to instructors through the app, which will lead to more efficient and customized classroom instruction. A prototype app is being built by Whittier College undergraduates. This project represents an opportunity for our students to enhance the learning experience of their peers while gaining valuable skills. In addition to algorithms presented within the Duolingo method, the educational data mining (EDM) literature provides examples of apps that boost engagement and success in introductory STEM courses [15–18]. Members of our community share that translating STEM exercises into Spanish aids in solving them. Our app will boost their skills and build confidence by offering them engaging, game-like physics training in the language of their choice. Finally, we propose to create a bilingual lecture series and recruitment events designed to welcome the broader community into the Whittier College environment.