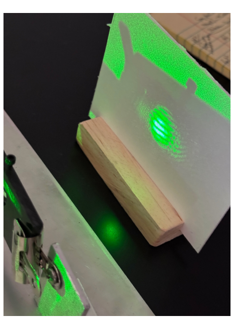
Project Outcomes

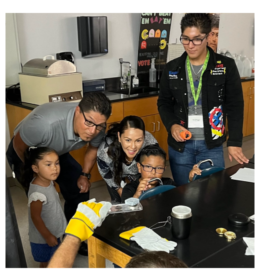
The National Quantum Initiative Act (NQIA), signed in December 2018, was to ensure the United States maintained a world leadership role in quantum information science and technology (QIST). QIST is foundational for economic and national security, commerce, and technology and in 2021, the Department of Defense requested funding for cybersecurity was more than $9.85 billion. The Quantum for All (QfA) project was designed to address the gap between the industrial need for a quantum smart workforce and K-12 education. The QfA project provided opportunities for secondary teachers and students to learn basic principles of quantum information science and thereby increase awareness as to the potential impact of QIST in future jobs. Topics were aligned to standards and STEM courses and included: Maglev, quantum levitation/locking, superconductors, spectroscopy, energy levels, quantum states and numbers, quantum atomic model, quantum gates, quantum key distribution (QKD), polarization, blackbody radiation, photoelectric effect, Heisenberg Uncertainty Principle, Malus' Law, and cryptography.

Major activities included a teacher professional development (PD) workshop for 4 days (8 hrs/day) followed by the teachers practicing their new pedagogical and content understandings of quantum by teaching students at a STEM camp (4 days @ 6hr/day). The project had over 110 unique teachers participate at least once in the workshop and camp PD experience. Over a third of the educators attended multiple years and the average number of hours per educator/participant was over 89 hrs. or approximately 2 years of attendance. This was due to many participants (both students and teachers) attending multiple years, especially since the topics varied each year. There were 10 teachers who attended all 4 years, 13 attended 3 years, 13 attended two years, and the rest attended one year. This number does not include the over 1000 unique educators (many attended multiple sessions) who attended shorter workshops and sessions at conferences. Broader impact was also achieved by educators replicating the camps in their own districts upon return from the PD. There were over 200 unique students attending the national camps and over 110 attending local district camps. Potential impact on students has been conservatively estimated to exceed 20,000 students. This number includes camp attendance and students in the classrooms of teachers attending the PD. This number will continue to increase exponentially as teachers continue to implement the lessons and resources in their classroom over the next few years. Some components of outreach, such as participating in Quantime are not included in this estimate, such as 250 kits that were distributed to teachers for classroom use through the *National Q-12 Education Partnership*. Broader impact activities also included a camp open house where students invited family and friends to the camp for an afternoon of show-n-tell.

The effectiveness of the project was evaluated utilizing both qualitative and quantitative methods. Monitoring the level of classroom implementation is ongoing. The level of understanding and confidence was measured by pre, mid and post content assessments, confidence surveys, case studies, and interviews. Data regarding the content (i.e. do they know the science) showed statistically significant increases in content understanding for all modules for both students and teachers every year. Some content was new to teachers and therefore had higher gains, but there were also modules where the teachers were already familiar with the content. Regardless of the initial (pre) score, educator gains were statistically significant either between the pre and mid (at the end of the initial day) or between the pre and post (after the camp).

It is important to note that the majority (60-75%) of the students attending the camp were entering 9th or 10th grade. This was unexpected and impacted the curriculum revisions and daily discussions since the younger students had not had higher math or science courses prior to the camp. Although this was originally a challenge, it turned out to be beneficial in that the curriculum adjustments are now more amenable to all STEM classrooms, regardless of prior courses, thereby increasing the potential implementation of the curriculum in classrooms and the number of students exposed to QIS/STEM/ICT concepts. In fact, final surveys from teachers indicated over 50% of the responding teachers felt the content was appropriate for middle school or elementary students. Feedback from teachers implementing lessons in their classrooms indicated over 62% taught the lessons to students in grades 11 and 12, 35% taught the lessons to grades 9 and 10, and some successfully implemented lessons in middle school. Teachers reported lessons averaged 1-1.5 hours with the average number of hours spent during the year being 9-10 hours. This translates to almost 2 weeks of instruction on quantum topics in the classroom. When queried about district curriculum that may have been omitted to accommodate the quantum topics, participants stated other topics were condensed or simplified to make more room for quantum lessons, but no basic curriculum was omitted.





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