PI Final Report/Summary
Karen Matsler Jan 2026

Preparing Secondary Teachers and Students for Quantum Information Science

Background

The National Quantum Initiative Act (NQIA) was signed in December 2018 to ensure that the United States developed technology applications to maintain a leadership role in quantum information science (QIS). QIS is imperative to economic and national security, commerce, and technology. The future workforce (current K-12 students) must have an understanding of QIS, yet the principles of quantum mechanics are generally not taught to students unless they are physics majors. Development of a “quantum smart” workforce needs to begin before college, but most K-12 educators are not prepared to teach QIS principles and applications because they were not physics majors, and even if they were, the understanding of QIS has changed significantly in the past 10 years. In fact, research has shown that secondary teachers could not explain the photoelectric effect in depth, yet the photoelectric effect is considered to be one of the foundations for quantum mechanics. The logical venue for exposure to quantum would be a physics course, but according to the American Institute of Physics (AIP), nearly 100,000 students (in 2012) attended schools where physics was not offered. Since most students will not major in physics, it is vital to expose K-12 students to quantum concepts that surround them everyday such as credit card security, phones, computers, and basic technology. This project, *Quantum for All Students (QAS*), provided opportunities for students to learn about quantum, regardless of whether they had an opportunity to take a physics class. *QAS* also provided opportunities for secondary educators to learn about quantum information science (QIS) and practice teaching it.

Goals and Activities

The goal of *QAS* was to impact a minimum of 100 teachers and 600 students. Project components included:
1) Professional development for STEM teachers to learn about quantum effects and effective curricular connections through carefully planned and vetted resources with learning cycles appropriate for high school students. Teachers co-taught student camps following the PD.
2) Student camps provided opportunities for students to learn about quantum mechanics while teachers practiced their new skills and understandings by working with peers to teach the camps. The camps were led by educators, who participated in the PD, and the result was an increase in the teacher’s level of confidence as well as an increase in their own understandings of how quantum can be integrated into STEM curricula. The camps were either in conjunction with the teacher PD or in the home districts of teachers attending the workshop/camp.

The project leadership modeled appropriate pedagogy for the teachers during the PD and the participants in turn practiced that pedagogy during the camp. The level of understanding and confidence was measured by pre and post content assessments, confidence surveys, case studies, and interviews. Participants voluntarily provided input as to the effectiveness of the resources and curriculum in the classroom and the potential level of classroom implementation. Results of the project are briefly outlined in this report. More detailed information can be obtained through the yearly reports, searching publications, or visiting the website quantumforall.org.

Major activities included teacher workshops (4 days) followed by teachers utilizing their new pedagogical and content understandings of quantum to teach students at a quantum camp (4 days). Teachers were given the opportunity to be supported in taking the information back to students in their own districts.

The project had over 110 teachers participate at least once in the workshop and camp PD experience. The average number of hours per participant was 89 hrs.or approximately 2 years of attendance. This is due to the fact that many of the participants (both students and teachers) attended multiple years, especially since the topics varied each year. (10 teachers attended all 4 years, 13 attended 3 years, and 13 attended two years).

In addition to the workshop/camp PD, there were many conferences where resources were introduced to teachers for use in their own classrooms through workshops or sessions. Although these conferences had sessions averaging 1-1.5 hours, there were over 1000 (unique) educators who participated between 2022 and 2025. There were also sessions offered online and F2F for colleagues and legislators, which are not included in these estimates. Even though the teachers attending the conferences did not have the full experience, they were interested enough to attend one (many attended several) session and hopefully implemented it in their classrooms.

Impact on Students:
The potential impact on students is calculated using camp attendance and estimating the average number of students/teacher as 100 since most of the teachers attending taught physics for the majority of the school day. Using these two sources, the project impacted over 20,000 students. The number of students directly impacted from the participant teachers is estimated to be over 18,000 students (based on each teacher having 100 students per year). If the participants only taught one (or several lessons) for one year the impact would be 11,000. However, many participants came multiple years and provided feedback and documentation for their classroom implementation, which translates to 100 students impacted each year. Estimating an impact of 100 students for each year they attended the workshop/camp, the total is 17,900. For the 74 teachers who only attended one year, if only a third taught the lessons on multiple years, the impact exceeds 20,000 students directly impacted by teachers attending the workshop/camp. In addition, there were approximately 200 unique (some attended more than one year) students who attended the 4 days of camp (for 6 hours/day) at one of the national sites. Documentation also shows an additional 106 attended district or local camps held by teachers in their own districts. (the district camps replicated the national camp in content and topics). Through a partnership with *National Q-12 Education Partnership* and Quantime, the project disseminated over 250 kits to teachers to be used in classroom across the nation for World Quantum Day Events. These additional students were not included in the impact calculations.

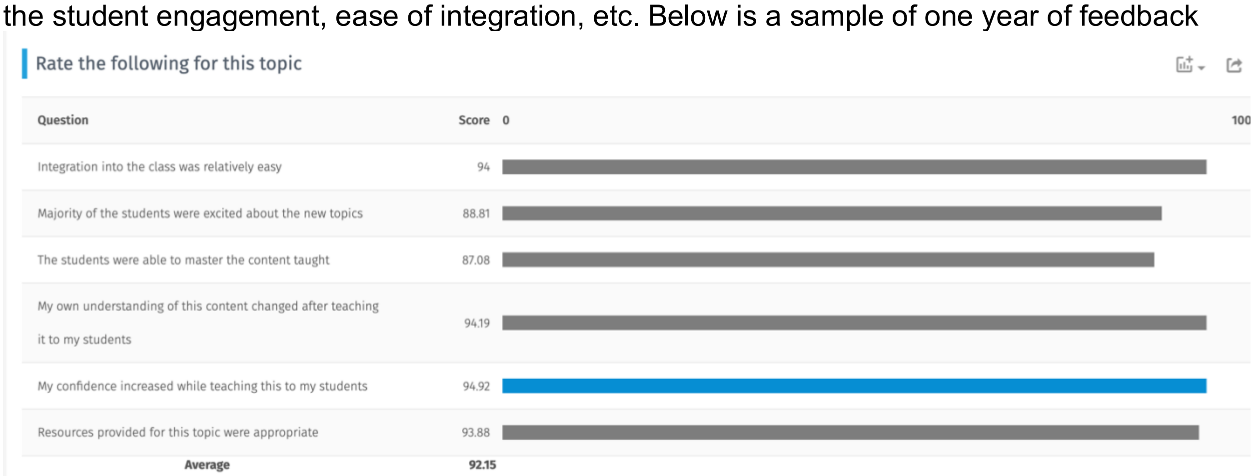
Objectives and Accomplishments
The 4 objectives of the project and supporting evidence are given below:
1) *To increase STEM and ICT career awareness by providing opportunities for teachers and students to learn about how STEM content disciplines can fully integrate technology and engineering and 2) Provide professional development for STEM teachers to learn about quantum effects and effective curricular connections.*

Evidence: Professional development was provided to a variety of secondary STEM teachers including teachers of chemistry, physics, computer science, physics, math, and IPC. The main PD was conducted in the summer with follow up activities/sessions during the school year. The summer PD included 4 days of learning content and pedagogy, and 4 days of practical implementation by having teachers take leading roles in teaching a student camp (4 days). Between Summer 2022 and Summer 2025 there were 176 teachers attending the 8 days in the summer for total of over 9500 hours between 2022 and 2025. Of the 176 teachers attending, over 110 were unique participants due to the fact that some attended more than one year. Of the 100+ participants, over a third of the educators (i.e. 37) educators attended multiple years.

Participants logged an overall average of 87 hrs/participant, but this does not include the participants who attended conferences. Over 1200 educators were provided PD utilizing online or F2F conferences/workshops. These sessions lasted between 1 and 3 hours providing an opportunity for educators and administrators to engage in learning about quantum information science and experience lessons appropriate to take back to their classrooms. Although most of the participants were secondary teachers, some were also elementary and some were district or state coordinators. The professional conferences utilized to disseminate information included: TSAAPT, APS, NSTA, IEEE, Edulearn, GIREP, PTRA, AAPT, CAST, and Q-12 sponsored World Quantum Days.

Changes in student understandings were measured with pre and post content assessments administered at the beginning and end of each day of the camp. The content scores for each year are given in the yearly reports but there were statistically significant gains in all areas every year. 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 as well as the number of students exposed to QIS/STEM/ICT concepts.* By the end of the workshop, over 50% of the teachers stated that the content was appropriate for middle school or elementary students. When teachers returned to their classrooms to implement lessons, over 62% taught the lessons to students in grades 11 and 12 and 35% taught the lessons to grades 9 and 10 with some successfully implementing lessons in middle school. Regarding the time spent on the lessons, about 70% spent 1-1.5 hrs. on a single lesson, with the rest spending over 2 hrs. This would translate into 2-3 days of instruction with many allocating 6-9 hours of additional quantum instruction on multiple topics! When queried about components of the lessons that may have been omitted due to relevance, time, or equipment, no omissions were cited and participants stated other topics were condensed/simplified to make more room for quantum lessons.

In addition to implementation, teachers were asked to give feedback on the topics by rating the student engagement, ease of integration, etc. Below is a sample of one year of feedback



3) *Provide student summer STEM camps to engage students in technology-rich STEM/QIS experiences.*

Evidence: Approximately 300 students attended the 4 days of quantum camp (6 hrs/day = 24 hrs/student). Approximately 2/3 (i.e.190) attended the summer camp after the teacher workshop(s) and others attended multiple district camps provided by participants upon return to their hometowns/regions. In addition to providing a camp for the students, the project hosted an open house on the last day of the camp where parents, family, friends, and other members of the community were invited to come see what the students had learned. Students selected 7-9 activities they enjoyed the most and they were then responsible for explaining the content and the activities to their guests. This turned out to be a very powerful component of the project as it allowed interaction with the community and students were very excited and proud to share what they had learned. Initially there was not an IRB to collect feedback from the visitors, but in 2024 we had several parents inquire as to how to continue the camp and how to change their child's schedule to include more courses related to quantum. Therefore, in 2025 an IRB was approved to collect the following data during the open house:

Open House Parent Feedback 2025

SD= strongly disagree, SA = strongly agree

	SD	D	N	A	SA	NA
My child/student seemed to enjoy the camp				2	13	
My child/student was excited to share the experiences of the camp with family and/or friends				5	10	
The camp increased my child/student awareness of the importance of science and math				3	12	
The camp positively influenced future courses my child/student wants to enroll in over the next few years (for example they want to take more science, math, etc now)			1	4	10	
The camp increased by child/student's understanding of quantum related concepts				2	13	

Written Comments

- "He loved it and we love the AISD/UTA partnership'
- "Adjust start and stop time to help our schedules"
- "Great hands-on experiences and a lot of information'
- "This is too good and I wish we included higher levels of quantum physics that include calculus. Experiments made a lot of sense and astonished the why behind with algorithms, theory, thesis, etc. Excellent program for all physics, quantum enthusiastic students. THANKS for pulling all this together. Happy we made it"

One of the participants sent an email from one of the students attending the district camp. Although this does not quantify the impact on students, it shows the potential impact on student careers and motivation. "The STEM camp that you taught has had a significant impact on both my personal and academic scope. I personally have never learned about quantum in any of my science classes before. Before being in your class, I had never considered quantum engineering, and now I am. The class you taught truly shaped my educational outlook for the better."

4) *Research a new professional development (PD) model designed to increase positive teacher and student experiences with ICT, STEM, and QIS in a manner that promotes student knowledge and interest in pursuing future STEM careers in an appropriate amount of time*

Evidence: Surveys, sticky notes, case studies, and interviews collected during the project provided valuable feedback regarding the implementation of the PD and improvements during the project. Participants agreed on components that were both unique and beneficial such as: 1) providing time for peer collaboration to deepen content understandings, 2)providing opportunities to work with colleagues to plan lessons for the camp that can be implemented in their own classrooms, 3) providing an opportunity to practice what they had learned within a week of the workshop to students in a non-threatening environment, 4) access to lessons/resources based on research, effective pedagogy, and applicable to courses they teach, and 5) opportunities to watch and learn from peers during the initial workshop as well as the student camp.

There has been substantial qualitative and quantitative data collected and analyzed regarding effectiveness of the PD model, some of which has been incorporated into publications linked on the NSF portal and the QfA website (quantumforall.org). Generally, comments were positive regarding the workshop/camp model. A few of the participant comments are given below, but one participant clearly described how the components of the PD model worked together: "We were learning like a typical workshop and it wasn't till day two that I'm like oh these are the activities we are teaching to kids and I need to be looking at this in a slightly different lens so that I can be able to teach it to the kids! So I was really just trying to take all the information in without also thinking how am I gonna teach this. I think those four days were very helpful. Helped us see here's one way to teach it and then the OK let's plan it….I have been to lots of workshop, even on quantum but it was way above my head and certainly the kids. The beautiful part of the QfA model is that we were first put in the position of a student who is coming in not sure if we're the dumbest person in the room or not assuming that we are not knowing some stuff having to get the confidence to ask a question and then the next week being on the other side of that and just being able to look around the room and see which one of my kids is struggling a little bit because you just came out of that yourself so being a student is good for a teacher….shows that you're willing to put yourself forward. "

Samples of more teacher comments are below:

- "I have been a teacher for 13 years and I have never had a more effective professional development model. The vast majority of the content and instructional strategies we covered in this camp over the last two weeks will make its way into my classroom and that is generally not the case with other PD I have done in the past."
- "The PD helped me significantly to teach because they were hands on activities that were scaffolded and connected to prior topics.'
- "Usually quantum concepts require equipment that is inaccessible. However, this has showed we can teach quantum with household/low-cost items."
- "The PD+camp makes me feel more confident in my knowledge and more willing to get out of my comfort zone with the students."
- "The combination of learning and then application (i.e. camp) is the BEST. As science teachers we know this and use it in our classes. Having camp to practice teaching and not just practicing the science, is even better."
- "Love the ability to run lessons with kids."
- "The hands-on student focused demonstrations were amazing and allowed the students to grasp difficult concepts."
- "I think this is model is very useful. The teaching portion gives a time to try to do the lesson in a low risk environment."
- "This has been rich with learning, practicing and with take home equipment. Much superior to other PD."
- "I think this framework is one of the better models for PD, too often PD gets you interested with not enough time to figure out how to use the material and it ends not being used (in the classroom)."

- “I enjoyed being able to apply what I just learned immediately and with a huge support system from the leadership team and the other participants. I appreciate how these activities fit in well with what I already teach.”
- ‘I felt the opportunity to use the activities with the students was the most important element as it provided a proving ground to immediately test.”
- “The PD activities helped me see how they can be used in the classroom.”
- “Being able to run activities with students has given me confidence to use this in my classroom. I was able to have one on one conversations with students even when I wasn't leading the activity.”
- “I enjoyed the mentorship and pedagogy discussions during the PD. It was wonderful to work with veteran instructors with so many different experiences. So what I'm saying is the crew assembled was very effective and I don't find a suggestion for improvement.”
- “Having now gone to my first year teaching I realize how much this kind of different from other PD's and how much more beneficial is to apply what we learned. I hope to return again as I feel like I gain deeper understanding each time.”
- “I have more confidence with the topics and experience troubleshooting the equipment. I also have the model of other presenters and how to handle various situations that come up with real students. The presence of the students during the second week is very valuable in field testing my new skills and knowledge.”
- “This PD is 10x better than anything I have ever done. It is focused on my content area and I am surrounded by people with similar interests and classroom experiences. Most other PDs have been a complete waste of time.”
- “This opportunity is unique and impactful. It is important that we are able to try these activities so I feel more confident they work and can be done with my high school students.”

Research Questions and Supporting Data
Research questions for the project included:
1) Does this structure of professional development intervention produce significant change in teacher classroom practice as designed? The main research question can be subdivided into two components, content and pedagogy. Do they know the science? Are they comfortable with the pedagogy and technology integration?

Ans: Data regarding the content (do they know the science) showed statistically significant increases in content understanding for all modules. Some content was relatively new to teachers and therefore had higher gains, but there were also some content modules where the teachers were already familiar with the content. Regardless of the initial (pre) score, the 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). Yearly summary results are posted in prior reports, with a few specific examples given in the tables below.

During the project, the leadership team identified several specific topics as slightly problematic regarding teacher’s understanding by consistently reviewing assessment results and feedback. Regardless of the topic, collected data/research indicated teacher confidence was a contributing factor in supporting classroom implementation. When the teachers already knew most of the content (i.e. had a high pre score), the content and confidence was increased after the camp. An example of this was in 2024 where the daily topic included atomic models as well as less familiar topics of quarks and antimatter.

2024 Day 1 (Particles: Quarks, Higgs, Atomic model, CERN, antimatter)

N=25	**Pre**		**Mid**		**Post**	
6 questions	*Content*	*Confiden.*	*Content*	*Confiden.*	*Content*	*Confiden.*

Average	3.84	2.01	4.28	3.53	5.16	3.87
Std Dev	1.46	1.33	0.84	0.92	1.03	0.80

In contrast, if teachers were unfamiliar with the content, significant gains were shown at the end of the workshop day rather than after the camp. In fact, some of the topics revealed a slight decrease after the camp which has been attributed (via interviews) to the students asking questions during the camp that forced teachers to question their own understanding. Although there were often decreases between mid and post, the confidence scores never went back down to the original level and statistical significance was noted for both content and confidence. Two examples are shown below where the mid score was higher than the post score. One was in 2023 where Day 1 topics included Maglev, quantum levitation, superconductors, and quantum locking and the other was in 2024 when the daily topics included polarization, Heisenberg, and double slit properties. In the 2023 example the confidence dipped very slightly after the camp yet in 2024 the content dropped slightly, but confidence in what they knew continued to increase.

2023 Day 1 (Maglev, Quantum Levitation, Superconductors, Locking)

N=25	**Pre**		**Mid**		**Post**	
7questions	*Content*	*Confiden.*	*Content*	*Confiden.*	*Content*	*Confiden.*
Average	3.52	2.34	5.04	3.92	4.76	3.85
Std Dev	1.50	0.89	0.89	0.99	0.97	0.93

2024 Day 4 (*Polarization/Superposition, Golden Rules, Heisenberg, LIGO, double slit)*

N=27	**Pre**		**Mid**		**Post**	
7 questions	*Content*	*Confiden.*	*Content*	*Confiden.*	*Content*	*Confiden.*
Average	3.89	2.51	4.70	4.14	4.59	4.21
Std Dev	1.12	1.12	1.23	0.83	1.33	0.82

Topics indicating the need for more content support were generally ones that teachers had never been taught (i.e. in college) or never taught as part of the curriculum in their own classroom. This is understandable since many of those topics would not have been part of a teacher certification program plus there are limited opportunities for in-service teachers to learn this content and address gaps or applications related to their own content understanding. There is a need for further analysis of these topics to revise supporting curriculum to specifically address these gaps. For example, 2023 included the topic of laser cooling. Although a large percent of the teacher participants were physics teachers, their understanding of how general physics concepts (i.e. momentum, energy, Doppler effect, and magnetic fields) related to the quantum concept of laser cooling was initially lower than other content areas. In fact, even the post score was lower than the pre on some assessments.

2023 Day 4 *(Momentum, Energy, Doppler)*

N=22	**Pre**		**Mid**		**Post**	
6 questions	*Content*	*Confiden.*	*Content*	*Confiden.*	*Content*	*Confiden.*
Average	1.92	2.77	3.54	3.95	3.77	3.95
Std Dev	1.00	1.41	1.00	1.00	0.86	0.95

Most teachers were not comfortable initially in teaching quantum information science (QIS) concepts to students (especially in front of peers), but the post surveys and interviews demonstrated a shift in their comfort level. Confidence levels were statistically significant after teaching the QIS/ICT/Quantum concepts to students in the camp. One teacher commented: “it's a beautiful model. It's a very powerful to watch. I learned a lot. You don't have to take everything from them, but if you're if you're watching, you can learn a lot from others and I think that's important.”

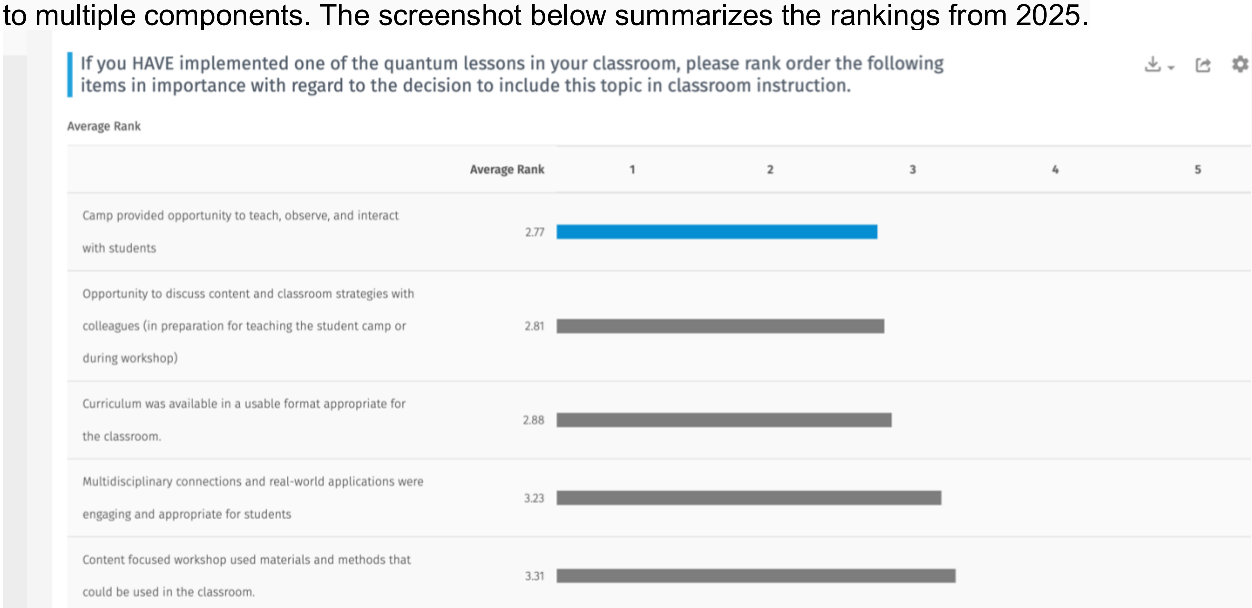
Teachers indicated they implemented something from the workshop/camp in their classrooms, but some implemented more than others. There were significant challenges to measure specifics of how much had been implemented in the classroom. Since the objective of the project was to embed quantum concepts into the curriculum they were already using or were familiar with, separating out the QIS components was challenging and gathering quantitative data regarding the time spent on quantum is estimated. To gather classroom implementation data, a survey link was available for teachers to submit what activity(s) they did during the year. Responses regarding implementation increased over the duration of the project. This is likely due to teachers gaining confidence in the content, especially since over a third of the teacher participants attended multiple years. In 2022-23 there were only 9 responses, 2023-24 increased to 15 responses, and 2024-25 had over 30 responses. Responses for 2025-26 are still being collected. Some of the teacher responses indicated they not only shared their new resources and knowledge with students, but also with their district colleagues and peers.

The leadership quickly determined that the surveys were not providing the implementation feedback that would be useful to further development of the model or the curriculum, therefore the IRB was changed to include interviews, follow up sessions, or group discussions. Below are a few examples shared regarding implementation or sharing of resources after they returned to their classrooms:

- “I shared how enlightening and fun the conference was to my Chemistry team as well as the activity about how liquid nitrogen can be used to create super-conducting magnet and we have integrated the Quantum nature of atomic structure into our lessons for Advanced Chemistry.”
- “This year, I have used the Quander games, quantum coin toss, quantum cryptography with the IQC box, and the Heisenberg Uncertainty lab so far across astronomy and physics courses.”
- “I shared the quantum locking/flux pinning to both my students in chemistry and physics in addition to several thermal concepts such as heat flow. I demonstrated the superconducting puck and demonstrator I purchased from Quantum Levitation.com and then demonstrated these to high school teachers at the following weekend GO4ST8 physics meeting.”
- “I shared a lesson on spectra observation and engaged my students in the activities we did in the training. The feedback was overwhelmingly positive, as the lesson proved instrumental in deepening their understanding of the electromagnetic spectrum, particularly its correlation with frequency and energy.”
- “I have used the 'Spectra Observations' activity in class. The students enjoyed the activity and they were highly engaged. This allowed learners to be more interested in learning the relationship between wavelength and energy. I also incorporated the 'Beyond Bohr Model' activity when students were learning about the orbitals. Students were highly engaged in this activity and they were able to visualize the shapes of the orbitals. It was also wonderful to see the amazement among students as they see the orbitals taking shapes as they do the activity.”
- “This has given me the confidence I needed. There are things that we can and absolutely should be doing in high school. The kids are interested in things like this (not something sliding down a ramp). This is relevant to kids and relevant to curriculum and was well designed to be implemented in the classroom.”

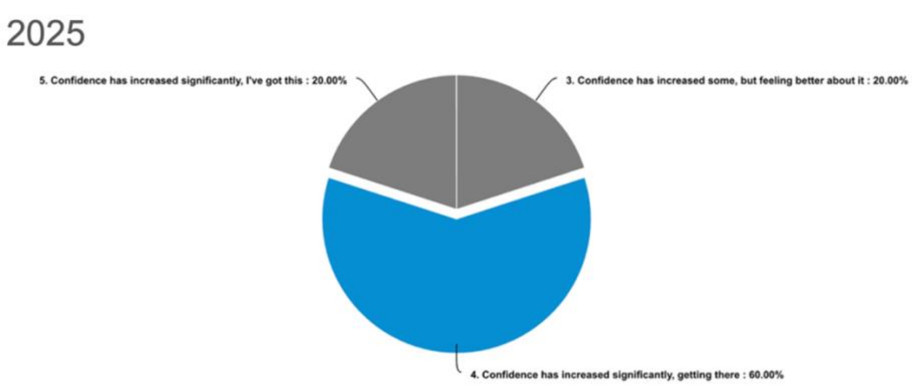
- "The combination was great. You couldn't have the camp without the workshop but of those two the camp helps because I'm seeing all the things that could be stumbling blocks with how I say the order of doing things the pacing all those sorts of things watching the teachers absolutely helps."
- "Getting to see other teachers teach the content to the students is an excellent way to learn how other people see the same content and try to relay it to students. This helps the **learning and teaching process** tremendously"
- "It feels a lot less scary moving forward because I've been able to practice with a group of kids while I had a lot of help from peers and workshop leaders during that first time. It's easier to wait months to teach it again because I didn't have to wait months to use it for the first time."
- "I feel prepared with content and some equipment to take back to use in my classroom. The connections to physics curriculum and history are super helpful for taking these back and implementing them"
- "I have learned countless demos from my peers this week that extend from lessons that were taught at the camp - the coffee stirrer on the Perimeter electron wave for the electron cloud, the parade of photons through the polarizer."

There were multiple opportunities for feedback including sticky notes at the end of each day, surveys on each topic, discussion groups, interviews, and survey rankings to identify which components of the PD were most important to support classroom implementation. Contrary to what was predicted, the survey did not identify a top factor, but indicated the success was due to multiple components. The screenshot below summarizes the rankings from 2025.



Data Table	Average Rank	1		2		3		4		5	
		Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Camp provided opportunity to teach, observe, and interact with students	2.77	6	23.08%	5	19.23%	7	26.92%	5	19.23%	3	11.54%
Opportunity to discuss content and classroom strategies with colleagues (in preparation for teaching the student camp or during workshop)	2.81	4	15.38%	9	34.62%	5	19.23%	4	15.38%	4	15.38%
Curriculum was available in a usable format appropriate for the classroom.	2.88	2	7.69%	8	30.77%	10	38.46%	3	11.54%	3	11.54%
Multidisciplinary connections and real-world applications were engaging and appropriate for students	3.23	7	26.92%	1	3.85%	2	7.69%	11	42.31%	5	19.23%
Content focused workshop used materials and methods that could be used in the classroom.	3.31	7	26.92%	3	11.54%	2	7.69%	3	11.54%	11	42.31%

When participants were asked why they did not implement the lessons, the highest ranking was that they needed a deeper understanding of the content. Neither understanding the pedagogy nor needing equipment seemed to be a factor, which means the PD was successful in the aspect of trying to keep materials and equipment costs to a minimum. The higher ranking for needing more content background and connection to other STEM areas is understandable and one that can be attained by more opportunities to learn. In fact, those that gave the most feedback regarding lessons implemented were participants attending multiple years. The extra time in learning and collaboration seems to have developed stronger bonds with peers, higher confidence in learning, and greater likelihood of implementation. Our findings showed that those who had implemented lessons, not only increased their confidence for their own classroom, but increased confidence to share with peers back in their school or district. Over 70% of those who had implemented lessons were comfortable enough to share with local teachers and 24% shared with colleagues at state conferences. The pie chart below summarizes the confidence levels attained by the 2025 participants.



2) Does the design cause a change in student understanding, attitudes, and interest in STEM, ICT, or QIS?

Ans: Initial attitude and interest surveys for students proved to be insufficient in determining levels of change. For example, students felt confident of knowing the answers even when they did not, so there was little change in confidence levels. In addition, the survey questioning their interest in STEM/ICT/QIS showed little change from beginning to end which is likely because it was a summer camp so they were obviously interested or they would not have come. It would have been useful to ask similar questions to students in classroom of teachers implementing the lessons, but that was not an option for project period. However, we did have students and parents tell us at the open house (last day of the camp) how much they learned and how excited the students were to share that knowledge with their parents when they got home. Also, many of the students evidently asked their parents if they could still change their class schedules because they wanted to take more STEM courses after the camp. Since there was no IRB for this and it was anticipated, specific numbers were not collected. However, there were over a dozen (over 1/3) in 2024 that followed up on their student's interest by talking to the school principal after the camp about changing schedules, so it is reasonable to assume there were more and that other years had similar impact.

Student Understanding

Student content understandings were often similar to teachers in that unfamiliar content had very low prescores and yet were statistically significant with the post assessments. (Note: The student assessments were given at the beginning and end of each day so if a student was absent, it would not influence the overall content information.) Although the tests for students and teachers were different, some questions were on both the teacher and student assessments as a means to gain insight as to comparisons between teacher content understanding and student understanding.

Student increases in content were statistically significant for most of the assessments, but the overall scores did not increase as much as the teachers. The 2024 lesson on blackbody radiation, photoelectric effect, and Planck's constant provided challenges in their understanding and the p-value was slightly less than significant (i.e. 0.0657). Some of the lesson was reworked for 2025, but we still did not see the expected results (p-value was 0.1292). It seems that the topics of Herschel, UV Catastrophe, photoelectric effect, and Planck are more challenging to the students, especially since they were mostly 9th and 10th graders. However, other topics such as Heisenberg, Golden Rules, and Polarization/Superposition had a p-value of 0.0001with a pre score of 1.41 and post of 2.59 and all the others have statistically significant increases. Post camp discussions with participants and leaders point to a common denominator for the student understandings being the level and time spent on hands-on activities. This is not surprising as research has shown inquiry, phenomena, and engagement is conducive to student learning. Thereby the challenge lies in developing these in an appropriate manner for young students, relying on limited math as the explanations.

Student p-values for 2023, 2024, 2025

Content Topics (Year)	**Content**	**Confidence**	**N**
Maglev, quantum levitation, superconductors, locking (2023)	0.0025***	0.0001***	32
Spectroscopy, energy levels, states, quantum numbers, Bohr (2023)	0.0324**	0.0001***	29
Quantum gates, QKD, polarization, measurements (2023)	0.0001***	0.0001***	27
Momentum, energy, Doppler (2023)	n/a	n/a	
Quarks, Higgs, Atomic model, CERN, antimatter (2024)	0.0075**	0.0001***	35
Radiation/decay, Herschel, Feynman, flame tests (2024)	0.001**	0.0001***	37
Blackbody Radiation, Bohr, Photoelectric, Planck (2024)	0.0657	0.0008***	31

Polarization/Superposition, Golden Rules, Heisenberg, LIGO, double slit (2024)	0.0001***	0.0001***	37
Superposition, Interference, Interferometer, Mach Zehnder, LIGO (2025)	0.8524	0.0273*	21
Malus' Law, Cryptography, Polarization (2025)	0.0005***	0.0001***	24
Blackbody, Herschel, UV Catastrophe Photoelectric, Planck, Quantization (2025)	0.1293	0.0075**	19
Heisenberg, Probability, Bohr, Quantum dots (2025)	0.0013**	0.0001***	

(*=statistically significant, **=statistically highly significant, ***=statistically extremely significant).

Teacher Content

Tables below identify the p-values for the teachers pre, mid, and post assessments for the years 2023-25. Analysis of the data from the assessments (see tables) supports the effectiveness of the professional development in terms of pedagogy and content. All topics had statistically significant increases in content and confidence, either from pre to mid, mid to post, or pre to post.

Note the years are in parenthesis and level of significance is indicated by an asterisk (*=statistically significant, **=statistically highly significant, ***=Statistically extremely significant). Specific pre and post content scores are given in the yearly summary reports.

Quantum For All Teacher Assessments
p-values for 2023, 2024, 2025

Superposition, Interference, Interferometer, Mach Zehnder, LIGO

WPD (25)	**p-values**	**pre/mid**	**mid/post**	**pre/post**
	content	0.0013**	0.3648	0.0002***
	confidence	0.0033**	0.7119	0.0090**

Malus' Law, Cryptography, Polarization

Malus' Law (25)	**p-values**	**pre/mid**	**mid/post**	**pre/post**
	content	0.0027**	0.4795	0.0009***
	confidence	0.0213*	0.1302	0.0007***

Blackbody, Herschel, UV Catastrophe Photoelectric, Planck, Quantization

HUBPPQ (25)	**p-values**	**pre/mid**	**mid/post**	**pre/post**
	content	0.1377	0.2246	0.0059**
	confidence	0.0001***	0.5093	0.0001***

Heisenberg, Probability, Bohr, Quantum dots

Hei., Bohr, Prob. (25)	**p-values**	**pre/mid**	**mid/post**	**pre/post**
	content	0.0409*	0.0468*	0.9976
	confidence	0.0035**	0.3147	0.0006***

Quarks, Higgs, Atomic model, CERN, antimatter

Atomic, Quarks, Higgs (24)	**p-values**	**pre/mid**	**mid/post**	**pre/post**
	content	0.1977	0.0018**	0.0006***
	confidence	0.0001***	0.1702	0.0001***

Radiation/decay, Herschel, Feynman, flame tests

Radioactivity, Feynman (24)	p-values	pre/mid	mid/post	pre/post
	content	0.0020*	0.7927	0.0104*
	confidence	0.0001***	0.2592	0.0001***

Blackbody Radiation, Bohr, Photoelectric, Planck

BBPP (24)	p-values	pre/mid	mid/post	pre/post
	content	0.0582	0.6573	0.0229*
	confidence	0.0001***	0.1658	0.0001***

Polarization/Superposition, Golden Rules, Heisenberg, LIGO, double slit

Heisenberg (24)	p-values	pre/mid	mid/post	pre/post
	content	0.0147*	0.7524	0.0410*
	confidence	0.0001***	0.7436	0.0001***

Maglev, quantum levitation, superconductors, locking

MagLev (23)	p-values	pre/mid	mid/post	pre/post
	content	0.0001***	0.2921	0.0011***
	confidence	0.0001***	0.826	0.0001***

Spectroscopy, energy levels, states, quantum numbers, Bohr

Atomic, Spectrum(23)	p-values	pre/mid	mid/post	pre/post
	content	0.0005***	0.5374	0.0011***
	confidence	0.0008***	0.3073	0.0001***

Quantum gates, QKD, polarization, measurements

Gates, Polar (23)	p-values	pre/mid	mid/post	pre/post
	content	0.0007***	1.00	0.0011***
	confidence	0.0006***	0.1644	0.0001***

Momentum, energy, Doppler

Laser Cooling (23)	p-values	pre/mid	mid/post	pre/post
	content	0.0026***	1	0.0022***
	confidence	0.0001***	0.418	0.0001***

Key Outcomes or other Achievements

All topics for teachers had statistically significant increases in content and confidence, either from pre to mid, mid to post, or pre to post. All topics for students had statistically significant increases in content and confidence from pre to post.

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The level of implementation increased both in the number of topics being incorporated to traditional curriculum and the number of teachers providing these topics to students in their classroom. Teachers increased in both confidence and content understanding. In addition, teachers expressed confidence in using the resources developed during the project and were instrumental in providing both feedback and adjustments to make them more effective for any secondary classroom.

Publications

Matsler K, Lopez R. (2025) The Quantum for All Project: Student Outcomes and Connection to Teacher Professional Development, WCPE2025 WCPE matsler, lopez

Lopez, R. & Matsler, K. (2025) The Quantum for All Project: Professional Development Model and Teacher **Outcomes**, WCPE2025. WCPE lopez, matsler

Lopez, R., & Matsler, K. (2025). The Quantum for All Project Professional Development Model and the Effect on Classroom Implementation, INTED2025 Proceedings, pp. 6983-6987. ISBN: 978-84-09-70107-0. ISSN: 2340-1079 March 2025 https://doi.org/10.21125/inted.2025.1797

Lopez, R. E., & Matsler, K. J. (2025). The Quantum for All Students and Teachers Project: Sample Activities and the Historical Storyline Linking Them. The Physics Teacher, 63(1), 26-28, https://doi.org/10.1119/5.0226389 .

K. J. Matsler and R. E. Lopez, (2024). The Quantum for All Project: Student Learning in the summer camps, Proceedings of the 16th International Conference on Education and New Learning Technologies, 5961-5965, IATED, 10.21125/edulearn.2024.1425. doi: https://doi.org/10.21125/edulearn.2024.1425

Lopez, R. and Matsler, K. (2024). THE QUANTUM FOR ALL PROJECT: TEACHER CONTENT KNOWLEDGE AND CONFIDENCE. 5955-5960. ISBN: 978-84-09-62938-1 ISSN: 2340-1117 doi: https://doi.org/10.21125/edulearn.2024.1424

Lopez, R. and Matsler, K. (2024). IMPACT OF PROFESSIONAL DEVELOPMENT ON TEACHER UNDERSTANDING OF QUANTUM INFORMATION SCIENCE. 5523-5529, INTED2024 Proceedings, IATED, 10.21125/inted.2024.1429 doi: https://doi.org/10.21125/inted.2024.1429

Singh, C., Matsler, K. J., and Lopez, R (2024). Applying Classroom Practices Learned from Virtual Professional Development During a Pandemic. The Physics Teacher, 62(1), 41-46, https://doi.org/10.1119/5.0107084 .

R. E. Lopez and K. J. Matsler, (2024). The Quantum for All Project: Teacher Content Knowledge and Confidence, Proceedings of the 16th International Conference on Education and New Learning Technologies, 5955-5960, IATED, ISBN: 978-84-09-62938-1 ISSN: 2340-1117 doi: 10.21125/edulearn.2024.1424

Lopez, R. & Matsler, K. (2023). THE QUANTUM FOR ALL PROJECT: RATIONALE AND OVERVIEW. EDULEARN23 Proceedings, 3311-3316. IATED, 10.21125/edulearn.2023.0913. ISBN:978-84-09-52151-7 LOPEZ2023QUA

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Matsler, K., & Lopez, R. (2023). The Quantum for All Project: Teacher Professional Development Model. EDULEARN23 Conference Proceedings, 3337-3345. IATED, 10.21125/edulearn.2023.0919. ISBN:978-84-09-52151-7 MATSLER2023QUA

Newsworthy
Aug 2025 K-12 Dive https://www.k12dive.com/news/how-a-texas-project-is-breaking-down-quantum-education-to-expand-access/756964/

UTA June 26, 2025 https://www.uta.edu/news/news-releases/2025/06/26/taking-the-fear-out-of-quantum-physics.

Quantum Camp: https://vimeo.com/1097588465/cc05cc19c0

Quantum Camp with Captions: https://vimeo.com/1097587793/e30ee4c59c

Quantum Camp Social: https://vimeo.com/1097586757/68882b8409

Quantum Camp Social with Captions: https://vimeo.com/1097586707/0d58235838

News Release from AAPT https://www.uta.edu/news/news-releases/2024/10/03/uta-professor-honored-for-science-education-leadership

The **Quantum for All** project is focused on integrating STEM lessons. Background expertise comes from multiple sources including the PI who is one of 3 people highlighted in this article on STEM from UTA. UTA STEM

NSF Discovery Files Podcast (8.26.24) https://www.youtube.com/watch?v=apL0uE_dt84

UTA Shorthorn 7/25/24 https://www.theshorthorn.com/news/uta-spearheads-quantum-for-all-science-initiative/article_a7904858-4ab9-11ef-80de-cfabba58ed1b.html

UTA spearheads Quantum For All science initiative _ News _ theshorthorn.com

UTA website (7.24) https://www.uta.edu/news/news-releases/2024/07/10/bringing-quantum-tools-to-high-school-classrooms

UTA website (9.22.23) https://www.uta.edu/news/news-releases/2023/09/22/quantum-information-science

The Conversation (9.11.23) https://theconversation.com/quantum-information-science-is-rarely-taught-in-high-school-heres-why-that-matters-210112

University of Texas Arlington (7.21.23) https://www.uta.edu/news/news-releases/2023/07/20/on-a-mission-to-bring-quantum-physics-to-high-school-classrooms

Dallas Morning News (7.10.23) https://www.dallasnews.com/news/education/2023/07/10/its-your-future-high-schoolers-and-teachers-learn-quantum-at-ut-arlington-camp/

PDF QuantumLearningprint_DallasMornNews QuantumLearningprint_7.10.23 p. 2

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Arlington Independent School District (7.4.23) https://www.aisd.net/district-news/quantum-is-for-all/?fbclid=IwAR3L1Zbx3F-u9rMitAIZZHPjADUD6uKXd7fmB3PmxTw-pZwmUGUSxHxgFng_aem_AQijAA0zELxkMLXUBJanAHAgZSUZILJ7k2Umzu0a3LtmjfmlhjJc0D66POrpNvZI3eU&mibextid=Zxz2cZ

PDF ‘It’s your future’_ High schoolers and teachers learn quantum at UT Arlington camp

University of Texas Arlington (8.4.22) https://www.uta.edu/news/news-releases/2022/08/03/uta-physics-professor-leads-national-quantum-initiative-for-high-school-teachers
Quantum trailblazer - News Center - The University of Texas at Arlington

Arlington Independent School District https://www.aisd.net/district-news/quantum-physics-camp/?fbclid=IwAR3fgdRXnrfjIwibmxJbhPt_14gfQoeIY5v6bsG5PCjI4WuTjxV0L45HQ_s

Dallas Morning News https://www.dallasnews.com/news/education/2021/06/17/ut-arlington-researchers-aim-to-help-teachers-bring-quantum-physics-into-the-classroom/

An article published by APS details background information on the "quantum trek" of Karen Matsler https://aps.org/publications/apsnews/202102/quantum.cfm

Quantum Insider https://thequantuminsider.com/2021/06/13/university-of-texas-arlington-to-build-quantum-physics-training-for-high-school-teachers/#:~:text=The%20$998%2C448%20grant%20from%20the%20National%20Science,to%20offer%20one%20of%20the%20country's%20first

Q2Work is hosting a workshop Feb. 24 aimed at people working on designing, implementing, and/or scaling quantum education programs. The list of speakers is attached Q2Workshop Speakers