

Quantum Information Science Programs & Research at Historically Black Colleges & Universities

An overview and needs



Acknowledgements

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- Veronica L. Nelson, Advancing Minorities' Interest in Engineering
- Damian Watkins, Aperio Global
- Historically Black Colleges and Universities (HBCU) Schools of Engineering Faculty and Staff

All assessments of QIST curriculum and research capabilities are based on HBCU QIST Capability Study survey results. Websites and articles are cited where relevant.

About QED-C

QED-C is an industry-driven consortium managed by SRI International. With a diverse membership representing industry, academia, government, and other stakeholders, the consortium seeks to enable and grow the quantum industry and associated supply chain. For more about QED-C, visit our website at quantumconsortium.org.

About Advancing Minorities' Interests in Engineering (AMIE)

Advancing Minorities' Interest in Engineering (AMIE) is a non-profit organization whose purpose is to expand corporate and government alliances with the (16) ABET accredited HBCU Schools of Engineering to implement and support programs to attract, educate, graduate and place underrepresented minority students in engineering and computer science careers.

AMIE is the premier organization that develops industry, government and university partnerships to achieve diversity in the engineering workforce. AMIE assures that the STEM talent pipeline has diverse and exceptional talent for industrial and governmental businesses who seek diverse perspectives in their workforce. AMIE provides a coalition with direct access to almost a third of graduating minority engineers annually. Unlike working individually with each partner in three areas (university, industry and government), AMIE's coalition provides a holistic approach to develop partnerships to achieve greater diversity in the engineering workforce.

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Table of Contents

Acknowledgements.....	1
Executive Summary.....	4
Background	5
Introduction	6
Quantum Information Science and Technology Capability Study	6
Next Steps	9
Recommendations	9
Conclusion	10
Appendix 1: Methodology	11
Appendix 2: Quantum Information Science and Technology Capability Survey Results	13

Executive Summary

Advancing Minorities' Interest in Engineering (AMIE) supported the Quantum Economic Development Consortium (QED-C) by performing a HBCU Quantum Information Science Capability Study survey of the ten (10) Accreditation Board for Engineering and Technology (ABET) accredited Historically Black Colleges and Universities (HBCU) Schools of Engineering curriculum and research capabilities to assess how to prepare students for participation in the QIST workforce.

This report details the Quantum Information Science and Technology (QIST) current curriculum and research capabilities; the flow of information for research opportunities to faculty; the flow of information, opportunities and jobs involving QIST to students; materials, curricula and resources needed to equip students for participation in the QIST workforce; strengths, readiness and opportunities of improvement for developing a new workforce ready to participate in the QIST workforce; and recommendations on what is needed to more effectively engage underrepresented students, with a focus on resources to increase engagement at the HBCU Schools of Engineering.

Our assessment revealed that eight (8) of the ten (10) HBCUs surveyed have faculty trained in QIST or offer/plan to offer some form of QIST courses in the areas of Quantum Physics Nuclear Magnetic Resonance, Quantum Mechanics, Nuclear Magnetic Resonance, Semiconductor Devices, Intro to Cryptography, Quantum Computing, Cryptology and Cryptography, Quantum Protocols, Quantum Algorithms, Post Quantum Cryptography, Quantum Communication Systems, Quantum Networking, Quantum Sensing, and Quantum Materials. Six (6) of the HBCU Schools of Engineering surveyed are performing QIST research in the areas of Intrusion Detection via Quantum Variational Autoencoder; Quantum Dots, Semiconductor Processes and Quantum Material Research; Quantum Algorithms; Quantum Cryptography; RSA Exploration Quantum Networking; Quantum Computing - Interaction of Molecules; and Quantum Materials and Quantum Sensing.

The survey identified the strengths, readiness and opportunities for improvement to develop a new workforce ready to participate in Quantum Information Science and Technology (QIST). Several materials and resources were identified to build a quantum workforce, including funding and resources for capacity building, external partnership development, curriculum development, career opportunities, student engagement, faculty engagement, workshops/lecturers and QIST awareness.

The recommendations to effectively engage students, help prepare students for the QIST workforce and increase research partnerships for faculty at the HBCU institutions includes additional funding, QIST resources and additional support in the areas of curriculum development, research projects, student engagement, faculty support and fellowships, QIST equipment and materials, external partner engagement and grant support.

Background

The QED-C Workforce Technical Advisory Committee (TAC) advances workforce development, quantum education and training infrastructure, and quantum literacy in the scientific and technical community. The QED-C Workforce TAC and its members have assessed the workforce needs of the quantum industry. QED-C found that there are many different types of quantum-related jobs with distinct requirements for knowledge and skills and advanced recommendations to universities developing curricula for the quantum industry.¹ Recently QED-C members were investigating and proposing curricula to meet the growing workforce need. For example, QED-C identified that efforts are underway to prepare students at the undergraduate, masters, and PhD level for quantum engineering and scientist roles; however, there are few associate degree and certificate-level programs geared toward training technicians.² QED-C members have also proposed undergraduate curricula.³ The Workforce TAC recognized a critical need to evaluate the Quantum Information Science and Technology (QIST) curriculum and research capabilities at Historically Black Colleges and Universities (HBCU) to increase the pipeline for the Quantum Information Science and Technology (QIST) Workforce.

Historically Black Colleges and Universities (HBCUs) are institutions of higher education in the United States that were established before the Civil Rights Act of 1964 with the intention of primarily serving African Americans.⁴ During the period of racial segregation in the United States, the majority of American institutions of higher education served predominantly white students and disqualified or limited black American enrollment. Later on some universities, either after expanding their inclusion of black people and African Americans into their institutions were classified as a Minority-Serving Institutions (MSI) or Predominantly Black Institutions (PBIs). HBCUs comprise 3% of America's institutions of higher education, yet enroll 10% of all African-American students in higher education and award 24% of all baccalaureate degrees earned by African-Americans nationwide.⁵ There are currently sixteen (16) Accreditation Board for Engineering and Technology (ABET) accredited HBCU

¹ C. Hughes, D. Finke, D. -A. German, C. Merzbacher, P. M. Vora and H. J. Lewandowski, "Assessing the Needs of the Quantum Industry," in IEEE Transactions on Education, vol. 65, no. 4, pp. 592-601, Nov. 2022, doi:10.1109/TE.2022.3153841.

² QED-C, Guide to building a quantum technician workforce: Reskilling and upskilling recommendations to prepare a workforce of quantum technicians, Arlington, VA: Oct. 2023, <https://quantumconsortium.org/workforce23>.

³ See, e.g., A. Asfaw et al., "Building a Quantum Engineering Undergraduate Program," in IEEE Transactions on Education, vol. 65, no. 2, pp. 220-242, May 2022, doi:10.1109/TE.2022.3144943 and Adrian German, Marcelo Pias, and Qiao Xiang, "On the Design and Implementation of a Quantum Architectures Knowledge Unit for a CS Curriculum," in Proceedings of the 54th ACM Technical Symposium on Computer Science Education (SIGCSE 2023), vol. 1, Association for Computing Machinery, New York, NY, pp. 1150–1156, doi:10.1145/3545945.3569845.

⁴ What is an HBCU? | White House Initiative on Advancing Educational Equity, Excellence, and Economic Opportunity through Historically Black Colleges and Universities. (n.d.). <https://sites.ed.gov/whhbcu/one-hundred-and-five-historically-black-colleges-and-universities/>.

⁵ HBCU Statistics: Market Report & Data • GitNux. (2023, December 20). GITNEX. <https://gitnux.org/hbcu-statistics/>.

Schools of Engineering representing 3% of the nation's ABET accredited Engineering Schools/Colleges that currently produce approximately 30% of all baccalaureate degrees in Engineering earned by African American in the United States.

HBCU Schools of Engineering were surveyed to assess their Quantum Information Science and Technology (QIST) curricula and research capabilities and solicited recommendations on what materials and resources are needed to more effectively engage underrepresented students at the HBCU Schools of Engineering to increase the pipeline for the Quantum Information Sciences and Technology (QIST) workforce.

Introduction

Workforce development in QIST is a priority for the United States as part of the National Quantum Initiative and similar national initiatives. To ensure economic and national security, several actions are recommended to evaluate the QIST workforce, prepare more people for jobs with quantum technology, enhance STEM education at all levels, accelerate exploration of quantum frontiers and expand the talent pool for industries of the future.⁶ Beyond the significant technical challenges facing QIST research and development (R&D), there is a shortage of talent. There is not enough trained QIST talent to fill the many job openings related to QIST in academia, industry, national labs, and government.

Building a global QIST workforce will require coordination among government agencies or ministries, academic institutions, professional societies, non-profit or non-governmental organizations, industry, and international partners.⁷ There are also important roles for STEM educators and diversity, equity and inclusion experts to ensure that training in QIST will position more individuals for rewarding careers and spur innovation.

The objective of this project was to assess the QIST capabilities at the ABET accredited HBCU Schools of Engineering and obtain recommendations for additional resources needed to develop and grow the QIST programs at the HBCU Schools of Engineering to increase the talent pipeline for the QIST workforce.

Quantum Information Science and Technology Capability Study

The Quantum Information Science and Technology (QIST) Capability Study survey assessed ten (10) ABET accredited Historically Black Colleges and Universities (HBCU) Schools of Engineering curriculum and research capabilities; the flow of information for research opportunities to faculty; the flow of information, opportunities and jobs involving QIST to students; materials, curricula and resources

⁶ National Quantum Coordination Office. (2023, December 1). National Quantum Strategy - National Quantum Initiative. National Quantum Initiative. <https://www.quantum.gov/strategy/#People>

⁷ Report, Q. C. (2022, February 3). U.S. Government Releases National Strategic Plan for Quantum Workforce Development. News | Communications of the ACM. <https://cacm.acm.org/news/258574-us-government-releases-national-strategic-plan-for-quantum-workforce-development/fulltext>

needed to equip students for participation in the QIST workforce; strengths, readiness and opportunities of improvement for developing a new workforce ready to participate in the QIST workforce; and recommendations on what is needed to more effectively engage underrepresented students, with a focus on resources to increase engagement at the HBCU Schools of Engineering.

Our assessment revealed that eight (8) of the ten (10) HBCUs surveyed have faculty trained in QIST, offer some form of QIST Courses or plan to offer QIST courses in the areas of Quantum Physics Nuclear Magnetic Resonance, Quantum Mechanics, Nuclear Magnetic Resonance, Semiconductor Devices, Intro to Cryptography, Quantum Computing, Cryptology and Cryptography, Quantum Protocols, Quantum Algorithms, Post Quantum Cryptography, Quantum Communication Systems, Quantum Networking, Quantum Sensing, and Quantum Materials in the Physics, Computer Science, Electrical & Computer Engineering, Mathematics and/or Chemistry departments. One (1) institution without a QIST Program is investigating the intersection of Quantum Information Science and Cybersecurity. Five (5) institutions offer Python and eight (8) institutions offer or require programming classes such as JAVA, UNIX, Visual Basic, C++, MATLAB or other programming languages in the College/School of Engineering.

Six (6) of the HBCU Schools of Engineering surveyed are performing QIST research in the areas of Intrusion Detection via Quantum Variational Autoencoder, Quantum Dots, Semiconductor Processes and Quantum Material Research, Quantum Algorithms, Quantum Cryptography, RSA Exploration Quantum Networking, Quantum Computing - Interaction of Molecules, and Quantum Materials and Quantum Sensing.

We assessed the HBCU Schools of Engineering engagement and collaboration with external partners to enhance or develop Quantum awareness, skills, programs or research opportunities. Five (5) of the HBCU Schools of Engineering partnered with corporations, majority institutions, government agencies/labs or organizations such as IBM HBCU Quantum Computer Center, Brookhaven National Laboratory, Lawrence Livermore National Laboratory, Oak Ridge National Laboratory, MICRON, NIST, University of Colorado, Virginia Tech, and National Science Foundation.

The survey revealed that there is limited to no awareness or access to QIST career opportunity information including internships and full-time opportunities for the students. There is also limited exposure to faculty fellowships and research opportunities. One (1) institution has partnered with several organizations, government agencies and labs to obtain grants funding faculty and student research in the area of Quantum Materials and Quantum Sensing from the National Science Foundation (NSF), the Department of Defense (DOD) and Sandia National Laboratory (SNL).

The survey identified the strengths, readiness and opportunities for improvement to develop a new workforce ready to participate in Quantum Information Science and Technology (QIST). Four (4) of the institutions have infrastructures in place to support existing QIST courses, research efforts and/or grants. There is still a need for additional funding, resources and support to continue to develop and grow their QIST courses and research areas. Four (4) of the institutions have or have plans to implement QIST programs and are soliciting funding, resources and support to develop and grow their QIST courses and research. The remaining institutions are ready to start the development of a QIST

program with funding, support and resources. Although there are existing efforts to develop and grow QIST programs at the HBCU Schools of Engineering, there is still an opportunity to support the institutions through the development of infrastructures for QIST courses and research, the development of labs to increase awareness and hands on experience for students, the support to investigate QIST grant funding,

The QIST curriculum and research resources and materials needed to develop and increase capabilities at the HBCU Schools of Engineering to prepare students for the QIST workforce can be classified as follows:

- 1) **Capacity Building:** Resources to support QIST courses/program and lab infrastructure development to support, educate and engage underrepresented students. Institutions dedicated resources to attract and hire faculty with research area in Quantum Science/Engineering.
- 2) **External Partnerships:** Industry engagement is needed as well as employment/internship opportunities for students. Financial and in-kind resources to develop educational modules, exploratory research and grant submission support.
- 3) **Curriculum Development:**
- 4) **Quantum Information Science Awareness:** To increase awareness, Internships, Experimental Experiences, and Resources are required at the HBCU Schools of Engineering.
- 5) **Career Opportunities:** Awareness and exposure to employment/internship opportunities for students at the HBCU Schools of Engineering are required to increase interest in QIST workforce.
- 6) **Student Engagement:** For any emergent areas, early engagement with students is important. Summer programs, badging and micro-credentialling offer a few opportunities.
- 7) **Faculty Engagement:** Faculty trained in quantum science research and education are the primary resources needed for engaging students in QIST. Need to mentor existing faculty and hire new Faculty in the QIST area.
- 8) **Speakers:** Guest lecturers in QIST are required. It is important to bring the industry prospective to the classroom.
- 9) **Research Opportunities:** Research projects are important to expose undergraduate and graduate students to QIST.
- 10) **Seminars and Workshops:** Seminars to help learn the basics. After students learn the basics, they would probably be more engaged. HBCUs should have various workshops and funds should be made available to build infrastructure on HBCU campuses.
- 11) **Equipment/Material:** Quantum Materials and Quantum Dots experimental work, Lab development to support teaching and faculty research/projects, Computing Equipment or access to, Large Scale Solid State Quantum Simulators and Computers for Quantum Information Processing. Experimental Resources, including Quantum Simulators, Computers, Quantum Dot Material and Support for Post-Doctoral Fellows in QIST.

12) **Funding:** QIST Grant Support, Funding to support current faculty initiative in QIST research and New faculty support.

Next Steps

This report has successfully identified the strengths, opportunities, gaps and resources needed at HBCU Schools of Engineering to foster workforce development in QIST. However, this is just the first step. A common goal among these institutions is to position the HBCU Schools of Engineering to support the following National Quantum Information Science Strategic Actions:⁸

1. Develop and maintain an understanding of the workforce needs in the QIST ecosystem, with both short-term and long-term perspectives
2. Introduce broader audiences to QIST through public outreach and educational materials;
3. Address QIST-specific gaps in professional education and training opportunities; and
4. Make careers in QIST and related fields more accessible and equitable.

Recommendations

The survey has identified recommended actions to grow the QIST curriculum and research capabilities to prepare a QIST workforce. The actions listed below will grow the QIST Programs, effectively engage students, help prepare students for the QIST workforce at the HBCU institutions. Partnering with the ABET accredited HBCU Schools of Engineering to provide

1. QIST resources and support in the areas of curriculum development related to Quantum Information Sciences.
2. QIST Subject Matter Experts and workshops
3. Experimental Work and research projects in related areas
4. Resources and support for Lab development to support teaching and faculty research/projects
5. Classroom material to help introduce students to the emerging QIST Field
6. Increased awareness and exposure to student through QIST projects, workshops, internships and full-time opportunities
7. Faculty resources and support in the areas of QIST faculty training and mentoring
8. Increase access to QIST External Partners, Programs and Grant opportunities to support QIST Industrial Partnerships in Research and Educational Modules

⁸ What is an HBCU? A Complete List of Schools. (2023, July 22). CollegeVine Blog. <https://blog.collegevine.com/what-is-an-hbcu-a-complete-list-of-schools/#schools>

Conclusion

The findings discussed in this report should incentivize strategic dialogue to acquire targeted funding, resources and partnerships required for the HBCU Schools of Engineering to ensure success. It is critical that we invest in the HBCU Schools of Engineering to grow the QIST programs and address any gaps in the QIST curricula and research areas, improve the flow of information for career opportunities and increase the awareness of QIST job opportunities for students, increase research opportunities and faculty support, obtain additional materials, curricula and resources needed to equip students for participation in the QIST workforce, partner to improve strengths, readiness and opportunities for developing a new workforce ready to participate in the QIST workforce, and invest in recommended resources needed to more effectively engage underrepresented students to increase the pipeline and diversity in the Quantum Information Science workforce.

Appendix 1: Methodology

Advancing Minorities' Interest in Engineering (AMIE) supported QED-C by developing and conducting a HBCU Quantum Information Science Capability Study survey of the ABET accredited Historically Black Colleges and Universities (HBCU) Schools of Engineering curriculum and research capabilities. Ten (10) of the sixteen (16) ABET accredited Historically Black Colleges and Universities (HBCU) Schools of Engineering responded to the survey. The ten (10) respondents were Alabama A&M University (Normal, AL), Jackson State University (Jackson, MS), Morgan State University (Baltimore, MD), Norfolk State University (Norfolk, VA), Southern University and A&M College (Baton Rouge, LA), Tennessee State University (Nashville, TN), Texas Southern University (Houston, TX), Tuskegee University (Tuskegee, AL), University of Maryland Eastern Shore (Princess Anne, MD) and Virginia State University (Peterburg, VA). The ten (10) HBCUs surveyed represent approximately 55% of the total students enrolled at the sixteen (16) HBCU Schools of Engineering.

The HBCU Quantum Information Science Capability Study survey consisted of a set of questions focused on curricula to prepare students for participation in the QIST workforce; the flow of information for research opportunities to faculty; the flow of information, opportunities and jobs involving QIST to students; materials, curricula and resources needed to equip students for participation in the QIST workforce; strengths, readiness and opportunities of improvement for developing a new workforce ready to participate in the QIST workforce; and recommendations on what is needed to more effectively engage underrepresented students, with a focus on resources to increase engagement at the HBCU Schools of Engineering.

Survey Questions

1. Does your university currently offer class(es) or program(s) in Quantum Information Science (QIS) to include Quantum Computing, Quantum Networking, Quantum Sensing, Quantum Cryptography or others?
2. If so, please list course or program or certification below and supply detailed description in a separate document.
3. Which department does Quantum Information Science (QIS) fall under?
4. Does your university currently participate in research in the area of Quantum Information Science? If so, please describe research focus areas and submit supporting documents.
5. Do you have faculty member(s) leading Quantum Information Science (QIS) course development or research in the School of Engineering or at your university? Please describe and submit supporting documentation.
6. Do you have faculty currently engaged in teaching Quantum Information Science (QIS) curriculum? Please describe. If not, what resources are required?
7. Do you have faculty currently engaged in Quantum Information Science (QIS) research? Please describe. If not, what resources are required? Other (please specify)

8. Do you have a Physics major or minor program in the School of Engineering? Yes or No
9. Is Computer Science part of the School of Engineering? Other (please specify)
10. For Quantum Information Science (QIS), do you offer or require programming classes such as Python or other programming languages in the School of Engineering? Please describe.
11. Are you receiving information related to Quantum Information Science (QIS) career opportunities? If so, please specify.
12. Are you updated and aware of Quantum Information Science (QIS) internships or fulltime opportunities for students? Please specify details.
13. Are you updated and aware of Quantum Information Science (QIS) Research opportunities and fellowships for Faculty? Please specify details.
14. Is the School of Engineering currently engaged in collaboration with external partners to enhance or develop Quantum awareness, skills, programs or research opportunities? Please describe.
15. Do you have any areas in the Quantum Information Science Curricula that you require assistance with to prepare students for participation in the QIST workforce? Please specify.
16. Please describe materials and resources needed to grow or create a Quantum Information Science Program. Please submit supporting documents.
17. Please describe materials and resources needed to grow or create a Quantum Information Science Research Focus Area.
18. Please summarize your current strengths, readiness and opportunities of improvement for developing a new workforce ready to participate in Quantum Information Science (QIS). Please submit additional documentation.
19. Please supply recommendations on what is needed to more effectively engage underrepresented students in the field of Quantum Information Science. Please include resources required to increase engagement. Please submit additional documentation.
20. Please share additional information regarding your current or proposed focus in Quantum Information Science Curriculum and/or Research focus areas.

Appendix 2: Quantum Information Science and Technology Capability Survey Results

A Quantum Information Science and Technology (QIST) Capability Study Survey to access the curriculum and research capabilities at ten (10) ABET accredited HBCU Schools of Engineering was performed in July/August 2023.

Survey Questions and Results:

1. Does your university currently offer class(es) or program(s) in Quantum Information Science (QIS) to include Quantum Computing, Quantum Networking, Quantum Sensing, Quantum Cryptography or others?

Table 1: HBCU QIST Courses

Institution	Quantum Information Science and Technology Courses
Jackson State University	Quantum Information Science is taught within Physics, Chemistry and Electrical & Computer Engineering: Quantum Mechanics [PHY 422], Nuclear Magnetic Resonance [CHEM 429], Semiconductor Devices [ECE 335]
Morgan State University	Quantum Information Science is taught within Computer Science in the College of Science and Computing: COSC 323 Intro to Cryptography, COSC 586 Quantum Computing, COSC 614 Cryptology and Cryptography, COSC 686 Quantum Algorithms, COSC 724 Post Quantum Cryptography.
Alabama A&M University	Dr. Matthew Edwards is performing research in this area in Physics.
Texas Southern University	Quantum Information Science is taught within Physics. They offer Quantum Mechanics -- PHYS 432.
Tennessee State University	There are faculty that are trained and supervise graduate students in Quantum Information Science. Tennessee State University is also a member of the IBM HBCU Quantum Computing Center. A special graduate level course is being taught Fall 2023. There are three students who have completed their Master's thesis in this area.
Norfolk State University	<p>The department of Computer Science offers</p> <ul style="list-style-type: none"> • An advanced computer course (CSC-466-90 Advanced Computer Topics I – Quantum Computing Fundamentals) offered Spring 2023 to undergraduate students. • The grant (funded by IBM-HBCU Quantum Center and led by Dr. Yen-Hung Hu, professor of computer science at NSU) supports 2 undergraduate students and 2 graduate students to participate in learning and research activities administered by Howard University.

	<ul style="list-style-type: none"> • Dr. Hu has offered quantum computing seminars to students. Seven topics from the fundamentals of quantum computing to quantum protocols and quantum algorithms have been included. • In the Spring of 2022, graduate students were offered a course on Quantum Mechanics (PHY 580) and a Solid State Physics course both of which emphasized Quantum Materials.
Tuskegee University	The Department of Computer Science is developing intro courses in this subject matter for undergraduate students. Tuskegee University is currently engaged in teaching Quantum Information Science (QIS) curriculum through a research grant from IBM.
Virginia State University	Virginia State University is planning to launch a couple of courses in the Spring 2024 semester.
Southern University	None. A few faculty members recently participated in a workshop at Brookhaven National Lab on Quantum Information Science. More expertise and mentoring are needed.
University of Maryland Eastern Shore	None.

2. Does your university currently participate in research in the area of Quantum Information Science?

Table 2: QIST Research Areas

Institution	Quantum Information Science and Technology Research
Tuskegee University	Tuskegee University is currently working with the IBM QIST project hosted by Howard University. They received a grant from IBM to initiate QIST research in the area of Intrusion Detection via QVAE (Quantum Variational Autoencoder) approach for deep and machine learning.
Jackson State University	Research Areas: Quantum Dots, Semiconductor Processes and Quantum Material Research
Morgan State University	<p>Morgan State University has a Quantum Computing Group which focuses on</p> <ul style="list-style-type: none"> • Quantum Algorithms - promotes the progress of science in quantum computing algorithms and cryptologic techniques in order to improve security of encrypted information which will have national security and defense applications, • Quantum Cryptography - Integer factorization, Efficient QFT algorithms, automatic quantum circuit generation and • RSA Exploration Quantum Networking - Quantum networking stack and QKD.
Alabama A&M University	Research is being performed by Dr. Edwards in Physics at Alabama A&M University

Tennessee State University	Research Area: One focus is using quantum computing to understand the interaction of molecules.
Texas Southern University	Some research has been performed but Texas Southern University has not applied for the related grants required.
Norfolk State University	<p>At Norfolk State University, several grants are currently funding faculty and student research in Quantum Materials and Quantum Sensing:</p> <ul style="list-style-type: none"> • “Single Crystal Growth and Investigation of Novel Exotic Fermion Materials”, NSF \$999,590 plus supplement \$184,000, 9/1/2018 – 8/31/2024, NSF grant #1832031. • “Partnership for Education and the Advancement of Quantum and nano Systems (PEAQS)”, a partnership between Norfolk State, Fort Lewis College, and the University of Colorado at Boulder, NSF PREM \$3,600,000, 9/1/2018 – 8/31/2024, NSF grant #1827847. • “MRI: Acquisition of a Cryogen-Free Physical Properties Measurement System (PPMS DynaCool) for Quantum Materials Research and Education at NSU,” NSF \$741,571, 10/1/2021 – 9/30/2023, NSF grant #2117588. • “Acquisition of a Real-Time Laue Back Reflection X-Ray System and a Powder Pattern X-Ray System and a Powder Pattern X-Ray Diffraction System for Education and Research in Crystallography,” DOD \$452,043, 5/31/2021 – 5/30/2024, DOD #W911NF2110294. • “Crest Center for Research and Education in Quantum-leap Science and Technology (CREQS),” NSF \$5,000,000, 9/15/2021 – 9/14/2026, NSF grant #2112595. • “Quantum Materials for Next Generation Electronic and Optical Devices Applications,” Sandia National Laboratory (SNL) \$49,999, 11/30/2022 – 9/30/2023, SNL #2175640.

3. Do you have faculty member(s) leading Quantum Information Science (QIS) course development or research in the School of Engineering or at your university?

Table 3: QIST Course/Research Development

Institution	Quantum Information Science and Technology Course/Research Development
Virginia State University	Virginia State University is collaborating with Virginia Tech to develop courses in Basic Quantum Science, Quantum Communications, Quantum Cryptography and Quantum Sensing. In addition, Virginia State University is in the process of developing labs for Quantum Engineering courses.
Tuskegee University	The recent IBM grant initiates the proposed research. The faculty resides in the Department of Computer Science at Tuskegee University .
Jackson State University	Currently, QIST course development is under consideration in the Electrical Engineering and Physics programs at Jackson State University .

Morgan State University	QIST course development is part of the Department of Computer Science at Morgan State University .
Texas Southern University	A few Physics Department faculty have done quantum related research at Texas Southern University .
Norfolk State University	Dr. Yen-Hung Hu, professor of Computer Science at Norfolk State University , is leading an effort to develop courses in information sciences and Dr. Doyle Temple, professor of Physics, is leading an effort to develop courses on quantum materials and quantum sensing .
Tennessee State University	Dr. Lijun Qian is leading work in this area at Tennessee State University .

4. Do you have faculty currently engaged in teaching Quantum Information Science (QIS) curriculum?

Table 4: QIST Curriculum

Institution	Quantum Information Science and Technology Curriculum
Virginia State University	Virginia State University is planning to launch a couple of courses in Spring 2024 semester.
Tuskegee University	Tuskegee University is currently engaged in teaching Quantum Information Science (QIS) curriculum through a research grant from IBM.
Jackson State University	Jackson State University has faculty currently engaged in teaching courses that intersect with QIS, including: Quantum Physics Nuclear Magnetic Resonance, and in the derivative Computational Data Enabled Science and Engineering (CDS&E) PhD program.
Morgan State University	Morgan State University teaches Quantum Information Science (QIS) within Computer Science.
Texas Southern University	Texas Southern University teaches Quantum Information Science (QIS).
Norfolk State University	At Norfolk State University , one course involving Quantum Information has been offered by Dr. Hu. Additional courses are being taught in the department of Computer Science.
Tennessee State University	Tennessee State University has faculty who have received training and supervise graduate students in this area. They are also a member of the IBM HBCU Quantum Computing Center
Southern University	At Southern University , a few faculty recently participated in a workshop at Brookhaven National Lab on QIS. More expertise and mentoring are probably needed.

5. Do you have faculty currently engaged in Quantum Information Science (QIS) Research?

Table 5: QIST Research Areas

Institution	Quantum Information Science and Technology Research
Virginia State University	Virginia State University is seeking lab resources that will support research and project in Quantum Engineering/Science.
Tuskegee University	We are currently working with the IBM QIS project hosted by Howard University.
Jackson State University	Large Scale Solid State Quantum Simulators and Computers for Quantum Information Processing are required
University of Maryland Eastern Shore	N/A
Morgan State University	Morgan has a Quantum Computing Group which focuses on Quantum Algorithms - promotes the progress of science in quantum computing algorithms and cryptologic techniques in order to improve security of encrypted information, which will have national security and defense applications. Quantum Cryptography - Integer factorization, Efficient QFT algorithms, automatic quantum circuit generation and RSA Exploration Quantum Networking - Quantum networking stack and QKD
Alabama A&M University	Dr. Matthew Edwards is performing research in this area in Physics.
Texas Southern University	Yes, but have not applied for the related grants yet.
Norfolk State University	N/A
Southern University	No. A few faculty at our school recently participated in a workshop at Brookhaven National Lab on QIS. More expertise and mentoring are probably needed.
Tennessee State University	We need more training in this space.

6. Are you receiving information related to Quantum Information Science (QIS) career opportunities?

Table 6: QIST Career Opportunities

Institution	Quantum Information Science and Technology Career Opportunities
Virginia State University	Yes. Limited.
Tuskegee University	No
Jackson State University	Periodically, We are aware of some internships in QIS.
University of Maryland Eastern Shore	No
Morgan State University	CS is NIST Security Project and takes part in the various QIS conferences. Some but could use more.
Alabama A&M University	Yes. Sometimes.
Texas Southern University	No
Norfolk State University	Yes, as part of participation in the IBM/HBCU Quantum Center led by Howard University
Southern University	Somewhat from the workshop at Brookhaven
Tennessee State University	No

7. Are you updated and aware of Quantum Information Science (QIS) internships or full-time opportunities for students?

Table 7: QIST Internships or Full-time Opportunities

HBCU School of Engineering	Quantum Information Science and Technology Opportunities
Virginia State University	Yes, but limited. We would like to get more internship and full-time opportunities for our students.
Tuskegee University	No
Jackson State University	We are aware of some internships in QIS.
University of Maryland Eastern Shore	No
Morgan State University	Some but could use more

Alabama A&M University	Yes
Texas Southern University	N/A
Norfolk State University	Yes, as part of participation in the IBM/HBCU Quantum Center led by Howard University
Southern University	Somewhat (from the workshop at Brookhaven)
Tennessee State University	No

8. Are you updated and aware of Quantum Information Science (QIS) Research opportunities and fellowships for Faculty?

Table 8: QIST Research Opportunities and Fellowships

Institution	Quantum Information Science and Technology – Opportunities and Fellowships
Virginia State University	Yes, in a limited way from partner PWI institutions. We would like to get more internship and full-time opportunities for our students
Tuskegee University	No
Jackson State University	N/A
University of Maryland Eastern Shore	No
Morgan State University	Yes
Alabama A&M University	Yes
Texas Southern University	N/A
Norfolk State University	Yes, as part of participation in the IBM/HBCU Quantum Center led by Howard University
Southern University	Somewhat (from the workshop at Brookhaven).
Tennessee State University	No

9. Is the School of Engineering currently engaged in collaboration with external partners to enhance or develop Quantum awareness, skills, programs or research opportunities?

Table 9: HBCU QIST External Partners

Institution	HBCU Schools of Engineering Quantum Information Science and Technology External Partners
Virginia State University	Partnering with Virginia Tech to enhance or develop Quantum awareness, skills, programs or research opportunities.
Tuskegee University	Yes, the grant with IBM.
Jackson State University	Our programs are in the process of identifying possible partners to develop Quantum awareness and skill development in QIS.
University of Maryland Eastern Shore	None
Morgan State University	Not in the School of Engineering. This is an opportunity for growth.
Alabama A&M University	Yes, we are trying to engage research collaboration between faculty and industry/government agencies in this area.
Texas Southern University	Yes
Norfolk State University	Yes. Engineering faculty are part of the NSF CREST Center for Research and Education in Quantum-leap Science and Technology which has quantum related partnerships with government labs and private industries such as: JILA at the University of Colorado, Lawrence Livermore National Laboratory, Oak Ridge National Laboratory and Micron.
Southern University	None
Tennessee State University	We are involved with PRISSEM.

10. Do you have any areas in the Quantum Information Science Curricula that you require assistance with to prepare students for participation in the QIST workforce?

Table 10: QIST Curricula Assistance Required

Institution	Quantum Information Science and Technology Resources Needed
Virginia State University	Quantum Computing, Quantum Sensing and Quantum Cryptography curriculum development
Tuskegee University	Any supporting material to help introduce students to the emerging QIS field
Jackson State University	Quantum Materials and Quantum Dots experimental work
University of Maryland Eastern Shore	The Intersection of Quantum Information Sciences and Cybersecurity
Morgan State University	No specific needs in SOE
Alabama A&M University	We do not have the curricula yet
Texas Southern University	None at this time
Norfolk State University	Assistance is needed for development of programs for Quantum Information, Quantum Materials and Quantum Sensing
Southern University	To prepare students for QIST, I think a new curriculum would be needed...so a concerted effort from the University administration would be required.
Tennessee State University	Yes. We want to build expertise in this area

11. Please describe materials and resources needed to grow or create a Quantum Information Science Program and Research Focus Area.

Table 11: QIST Curriculum and Research Resources

Institution	Quantum Information Science and Technology Curriculum and Research Resources
Virginia State University	<ul style="list-style-type: none"> • Virginia State is in the process of implementing a virtual laboratory course as introduction to hardware implementation of a spectrum of quantum science and engineering topics. These include fundamental science concepts; however, the emphasis is on applied engineering applications including quantum communication systems, quantum cryptography, and quantum sensing. • Virginia State would like to have resources to help develop actual/physical labs to support teaching of Quantum Information Science courses. • Virginia State would also like to have Labs to support faculty research/projects in Quantum Information Science.
Tuskegee University	<p>Any supporting material to help introduce students to the emerging QIST field.</p> <p>Additional Resources:</p> <ul style="list-style-type: none"> • Train the faculty • Classroom material • Computing equipment • Industrial Partnership in Research and Educational Modules
Jackson State University	<ul style="list-style-type: none"> • Quantum Materials and Quantum Dots experimental work. • Large Scale Solid State Quantum Simulators and Computers for Quantum Information Processing are required. • Experimental Resources, including Quantum Simulators, Computers, Quantum Dot Material and Support for Post-Doctoral Fellows in QIST.
University of Maryland Eastern Shore	<ul style="list-style-type: none"> • The Intersection of Quantum Information Sciences and Cybersecurity - Research as it relates to quantum and cybersecurity. • Typical curriculum development related to Quantum Information Sciences.
Morgan State University	<ul style="list-style-type: none"> • Computer Science has existing courses. No specific needs in the School of Engineering. • Morgan has a Quantum Computing Group which focuses on <ul style="list-style-type: none"> ▪ Quantum Algorithms - promotes the progress of science in quantum computing algorithms and cryptologic techniques in order to improve security of encrypted information which will have national security and defense applications. ▪ Quantum Cryptography - Integer factorization, Efficient QFT algorithms, automatic quantum circuit generation and RSA Exploration ▪ Quantum Networking - Quantum networking stack and QKD
Alabama A&M University	<ul style="list-style-type: none"> • Alabama A&M does not have the curricula yet. • Physics program needs lab equipment support. • Need seed money to support current faculty initiative in QIST research.

Texas Southern University	<ul style="list-style-type: none"> • None at this time. Need to apply for related grants.
Norfolk State University	<ul style="list-style-type: none"> • The primary resource needed for advancing quantum science at Norfolk State University is a core group of new faculty engaged in Quantum Science Research. • Assistance is needed for the development of programs for quantum information, quantum materials and quantum sensing.
Southern University	<ul style="list-style-type: none"> • To prepare students for QIST, a new curriculum would be needed. A concerted effort from the University administration would be required. • Southern would need an expert/mentor to determine what courses would be needed in the program curriculum and to provide materials to teach those courses. • A few faculty recently participated in a workshop at Brookhaven National Lab on Quantum Information Science. More expertise and mentoring are needed.
Tennessee State University	<ul style="list-style-type: none"> • Alabama A&M University does not have the curricula yet. • Physics program needs lab equipment support. • Need seed money to support current faculty initiative in Quantum Information Science research.

12. Please summarize your current strengths, readiness and opportunities of improvement for developing a new workforce ready to participate in Quantum Information Science (QIS).

Table 12 – HBCU Schools of Engineering Strengths, Readiness and Opportunities

Institution	HBCU Schools of Engineering Strengths, Readiness and Opportunities
Virginia State University	<ul style="list-style-type: none"> • Virginia State University (VSU) is in the process of developing lab infrastructure for hands-on training in Quantum Information Science. • Virginia State University (VSU) and Virginia Tech (VT) were awarded Sloan Foundation and Genentech Foundation Fund grants to develop a plan of action for systemic changes by identifying best practices that would lead to such a partnership, one that facilitates faculty collaborations and development; fosters student research engagements; leverages VT's industry partnerships; and develops pathways for creating the next generation of a QIST workforce. • In Spring 2024, a Quantum Information Science and Engineering (QISE) experiential learning laboratory will be installed at VSU which focuses on quantum cryptography and quantum sensing. This is applicable because sensing and cyber are the two main applications in QIST. • Two VSU undergraduate students performed research at VT this summer in QISE and were trained on the new laboratory equipment. • The plan is to ultimately create a diverse pipeline of students from "K through graduate school" to ultimately enter the workforce in the critical technology areas. • Faculty will attend a QISE workshop again in Summer 2024 to ready themselves for teaching the experiential learning laboratory and other courses.

	<ul style="list-style-type: none"> In addition, the College of Engineering and Technology at Virginia State University plans to integrate AI/ML and quantum computing into the research expertise and VSU Computer Science and Engineering curriculums. The plan is to implement new educational initiatives that can positively impact students and the wider community.
Tuskegee University	<ul style="list-style-type: none"> Tuskegee is currently starting in this technology for faculty and the curriculum.
Jackson State University	<ul style="list-style-type: none"> Jackson State University will grow the intersection of Quantum Physics, Quantum Mechanics, Supercomputing, Mathematics and Electrical Engineering courses. They can leverage existing courses and the Computational Data-Enabled Science and Engineering program to develop a new minor in QIST. Areas of Interest: Quantum Material including solar cells, Semiconductor Devices, and Cybersecurity.
University of Maryland Eastern Shore	<ul style="list-style-type: none"> UMES has a strong foundation as it relates to Cybersecurity. They desire to extend their ability with Cybersecurity as it relates to Quantum Information Science. Proposed focus would be the intersection of Quantum Information Sciences and Cybersecurity for Curriculum and/or Research focus areas.
Morgan State University	<ul style="list-style-type: none"> Computer Science has several courses, faculty and research activities that can support workforce development. QIST falls under CS which is not housed with the School of Engineering (SOE). As of today, SOE does not have an initiative to launch a QIST program.
Alabama A&M University	<ul style="list-style-type: none"> Alabama A&M University is dedicated to STEM education and experiential learning. Proposed focus area: Physics, quantum computing and plasma physics.
Texas Southern University	<ul style="list-style-type: none"> There is only one class related to Quantum. Texas Southern University has not spent more effort on this area yet.
Norfolk State University	<ul style="list-style-type: none"> There is a small group of approximately 6 faculty directly involved in quantum research. This small group has been able to secure over \$15M in instrumentation and research funding for quantum research. Primarily for quantum materials and sensing. The Departments of Engineering and Physics are working on a proposal to establish Master's and Doctoral programs in Quantum Engineering.
Southern University	<ul style="list-style-type: none"> Southern has a basic understanding of QIST but would like to start participating in a research project to get immersed in the field in order to pass that knowledge on to students.
Tennessee State University	<ul style="list-style-type: none"> Tennessee State University is developing in this area. Recommendation: HBCUs should have various workshops from experts and funds should be made available to build infrastructure on our campuses.

13. Please supply recommendations on what is needed to more effectively engage underrepresented students in the field of Quantum Information Science.

Table 13: QIST Curriculum and Research Recommendations

Institution	Quantum Information Science and Technology Curriculum and Research Recommendations
Virginia State University	Capacity Building: Resources to support QIS courses/program and lab infrastructure development to support educate/engage underrepresented students. Also, institutions need to dedicate resources to attract and hire faculty with research area in Quantum Science/Engineering.
Tuskegee University	IBM is assisting in this area, but more industry engagement is needed as well as employment/internship opportunities for students. financial and in-kind resources to develop educational modules and exploratory research
Jackson State University	Awareness; Internships; Experimental Experiences; Required Resources
University of Maryland Eastern Shore	Guest speakers, internships, and co-ops for students to be exposed to QIS.
Morgan State University	For any emergent areas, early engagement with students is important. Summer programs, badging and micro-credentialling offer a few opportunities.
Alabama A&M University	Internships, research projects are important to our students.
Texas Southern University	New to hire new Faculty in the area.
Norfolk State University	Junior faculty, trained in quantum science research and education, are the primary resource needed for engaging students in QIS.
Southern University	Not sure, but perhaps seminars to help them learn the basics. After they learn the basics, they would probably be more engaged.
Tennessee State University	HBCUs should have various workshops and funds should be made available to build infrastructure on our campuses

14. Please share additional information regarding your current or proposed focus in Quantum Information Science Curriculum and/or Research focus areas.

Table 14: QIST Curriculum and Research Additional Information

Institution	Quantum Information Science and Technology Curriculum and Research Additional Information
Virginia State University	In addition, the College of Engineering and Technology at Virginia State University plans to integrate AI/ML and quantum computing into the research expertise and VSU Computer Science and Engineering curriculums. The plan is to implement new educational initiatives that can positively impact students and the wider community.
Tuskegee University	None
Jackson State University	Quantum Material including solar cells, Semiconductor Devices, and cybersecurity
University of Maryland Eastern Shore	Our proposed focus would be the intersection of Quantum Information Sciences and Cybersecurity for Curriculum and/or Research focus areas.
Morgan State University	QIS falls under CS which is not housed with SOE. As of today, SOE does not have an initiative to launch a QIS program.
Alabama A&M University	Physics, quantum computing, plasma physics
Texas Southern University	None
Norfolk State University	The Departments of Engineering and Physics are working on a proposal to establish Master's and Doctoral programs in Quantum Engineering.
Southern University	None
Tennessee State University	HBCUs should have various workshops from experts and funds should be made available to build infrastructure on our campuses.