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DIRECTORATE FOR
EDUCATION & HUMAN RESOURCES

NSF Dear Colleague Letter 21-033: Advancing Quantum Education and Workforce Development

Webinar #1
April 27, 2021

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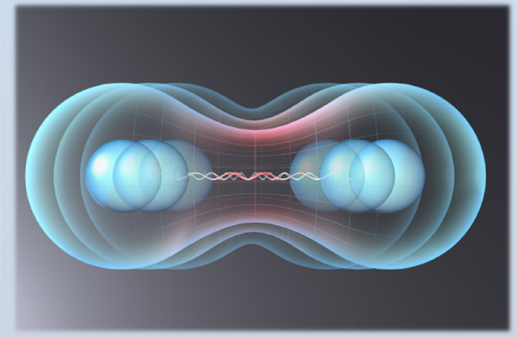
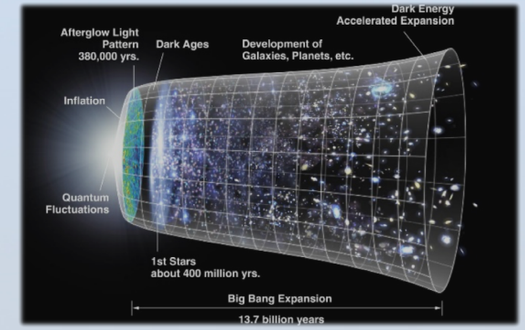
Outline

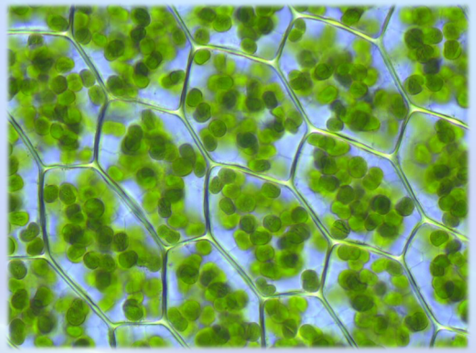
- **NSF Approach to QISE** (Dr. Tomasz Durakiewicz)
- **Three DUE Programs** (Dr. Abiodun Ilumoka and Dr. Corby Hovis)
  1. Scholarships in STEM Program (S-STEM)
  2. Advanced Technological Education Program (ATE)
  3. Improving Undergraduate STEM Education Program (IUSE)
- **The Louis Stokes Alliances for Minority Participation (LSAMP)** (Dr. Martha L. James)
- **Innovative Technology Experiences for Students and Teachers (ITEST)** (Dr. Bob Russell and Dr. Wu He)
- **Q & A**

Quantum Leap : Asking Ambitious Questions

Q1: Are there fundamental limits to how far we can push the **entanglement and coherence** frontiers for quantum states? Are there limits in time, distance, or scale?

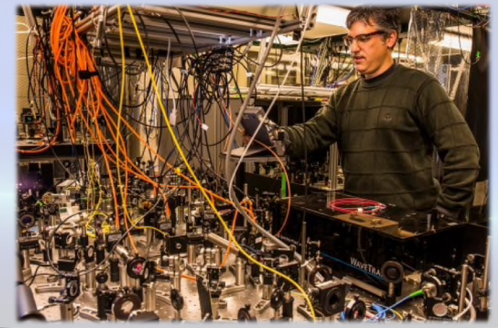






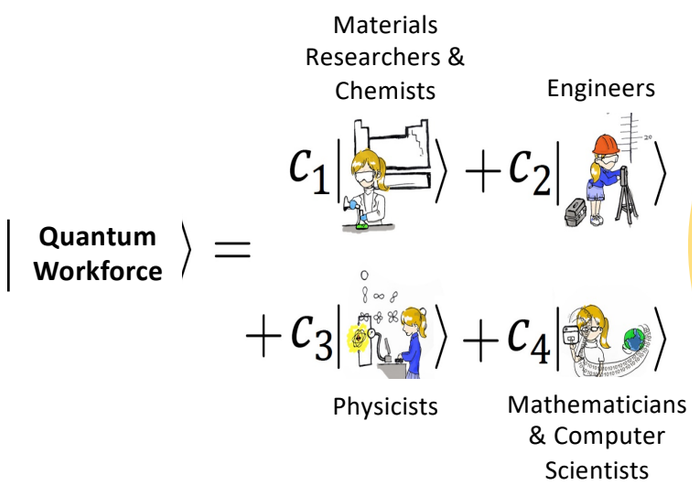
Q2: What can we learn from quantum phenomena in **naturally-occurring and engineered quantum systems**, including emergent behavior, complexity, quantum-classical boundaries, and their theoretical foundations?

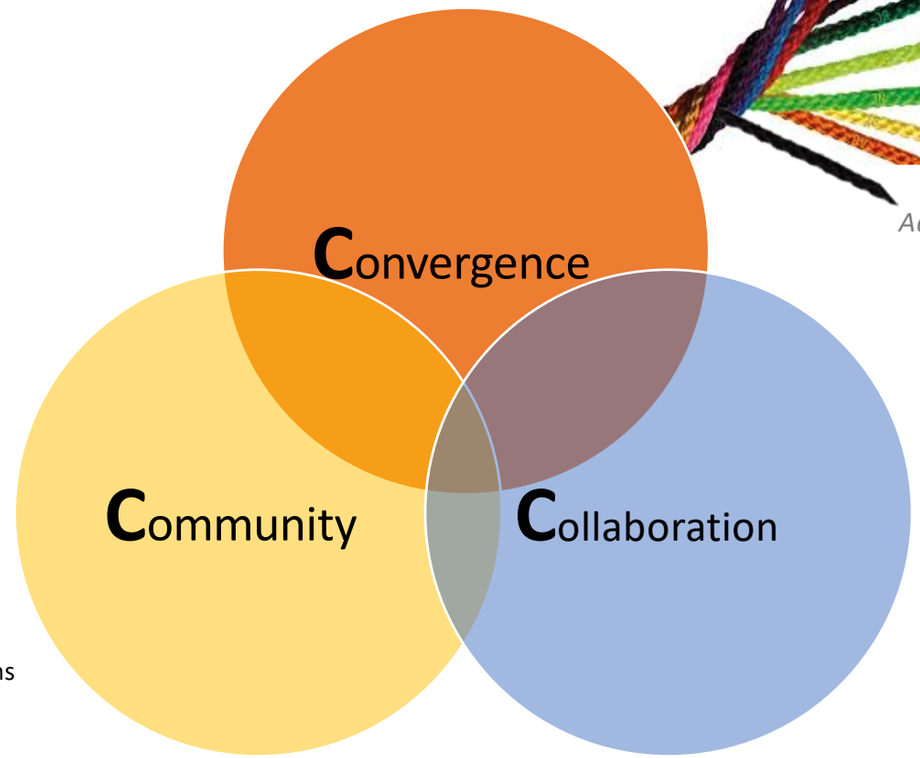
Q3: How do we galvanize the science and engineering **community** to enable quantum devices, systems, and technologies that **surpass classical** capabilities?

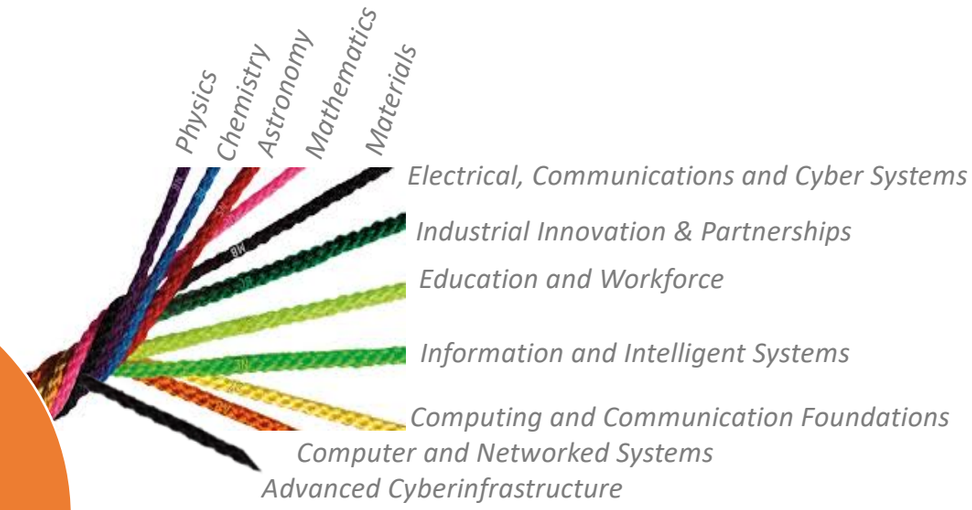


Our NSF Approach

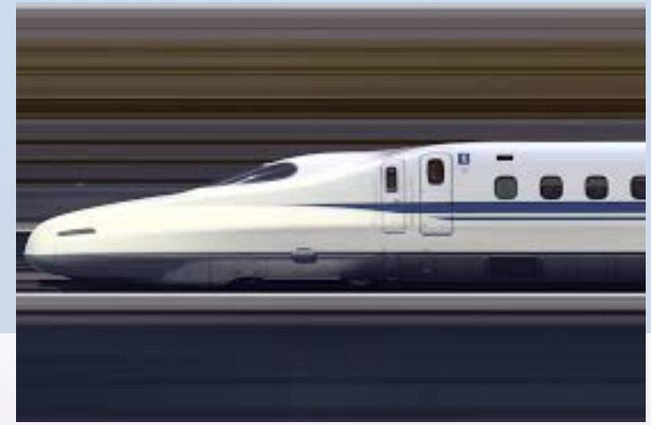
The 3 C's







All-of-Government Approach: WORKFORCE, EDUCATION AND BROADENING PARTICIPATION



Creating a quantum-smart workforce for tomorrow

Building Quantum Intuition: Quantum intuition is the ability to intuitively differentiate between quantum and classical worlds at the very basic level. LOWERING THE BARRIERS

Industry - academia partnerships: recognize required skills and nature of the content specific training that is needed for a diverse workforce. EFFICIENCY

Enhancing curricula in all levels of education: early and continued engagement in STEM fields, particularly for underrepresented groups in STEM such as underrepresented minorities and women, is a key factor in retaining and mitigating attrition as students advance to higher grade levels. INCLUSION AS OPPORTUNITY

Interdisciplinary programs: mathematical algorithms need to be devised, circuit implementations need to be designed, device function needs to be well understood, devices need to be implemented in functional materials, the local environment needs to be controlled, and structural materials are needed to hold everything together. CONVERGENCE

Estimating and tracking future workforce needs: continuing assessment of specific requirements for workforce is vital, especially in a rapidly evolving landscape of workforce needs. ASSESSMENT

Government Programs to enhance QIS-ready workforce: supportive of workforce generation goals, with focused efforts undertaken in collaborative mode LEVERAGE

EHR and NSF-wide programs: https://www.nsf.gov/pubs/2021/nsf21033/nsf21033.jsp

Funding Opportunities for K-12 Education

- Computer Science for All (CSforAll: Research and RPPs) $20M
- Discovery Research PreK-12 (DRK-12) $64M
- Innovative Technology Experiences for Students and Teachers (ITEST) $30M
- Robert Noyce Teacher Scholarship Program (NOYCE) $58M

Funding Opportunities for Undergraduate Programs

- Advanced Technological Education Program (ATE) $66M
- Hispanic Serving Institutions Program (HSI) $11M
- Historically Black Colleges and Universities - Undergraduate Program (HBCU-UP) $55M
- Improving Undergraduate STEM Education Program (IUSE) $63M
- Scholarships in STEM Program (S-STEM) $95M
- The Louis Stokes Alliances for Minority Participation (LSAMP) $10M
- The Centers of Research Excellence in Science and Technology (CREST) $20M
- Tribal Colleges and Universities Program (TCUP) $12M

Funding Opportunities for Graduate Programs

- Alliances for Graduate Education and the Professoriate (AGEP) program
- Innovations in Graduate Education (IGE) Program $4M
- NSF Research Traineeship (NRT) Program $55M

Funding Opportunities for All Educational Levels

- Advancing Informal STEM Learning (AISL) $39M
- EHR Core Research (ECR) $35M
- NSF INCLUDES $3M
- Research on Emerging Technologies for Teaching and Learning (RETTL) $19M
- Secure and Trustworthy Cyberspace (SaTC) $69M

Dear Colleague Letter: Advancing Quantum Education and Workforce Development, NSF 21-033

Three DUE Programs

- NSF Scholarships in Science, Technology, Engineering, and Mathematics Program (S-STEM)
  - Focus on recruiting, retaining, and graduating academically talented, low income students
- Advanced Technological Education (ATE)
  - Focus on training technicians to meet industry needs
- Improving Undergraduate STEM Education: Education and Human Resources (IUSE: EHR)
  - Focus on improving student learning

NSF Scholarships in Science, Technology, Engineering, and Mathematics Program (S-STEM) NSF 20-526

- Purpose of the program:
  - Provide scholarships to encourage and enable **low-income academically talented** students with demonstrated financial need to enter the workforce or graduate study following completion of associate, baccalaureate, or graduate degrees in **S-STEM eligible disciplines**.
- Open to all Institutions of Higher Education that grant associate, baccalaureate, or graduate degrees in S-STEM eligible degree programs

S-STEM Program Goals

increase the number of low-income academically talented students with demonstrated financial need obtaining degrees in S-STEM eligible disciplines and entering the workforce or graduate programs in STEM

improve the education of future scientists, engineers, and technicians, with a focus on low-income academically talented students with demonstrated financial need

generate knowledge to advance understanding of how interventions or evidence-based curricular and co-curricular activities affect the success, retention, transfer, academic/career pathways, and graduation of low-income students in STEM

S-STEM Program Tracks

Institutional Capacity Building (Track 1)

Image courtesy of 7Crafts at FreeDigitalPhotos.net

Up to $650K
Up to 5 yrs

For institutions with li
experience in
effecti

Design and Development (Track 2)

(Track 3)

ional

Budget, Scope, #Students,
Complexity of Support Structures,
Complexity of Research Questions

Seeks to leverage S-STEM funds with institutional efforts and infrastructure to increase and understand impacts

Deadline (All Proposals):
Last Wednesday in March, annually

Advanced Technological Education (ATE) NSF 18-571

- Purpose of the program:
  - Promote improvements in the education of science and engineering **technicians** at the undergraduate and the secondary school levels.
- Effective technological education programs should involve partnerships in which **two-year IHE**s work with four-year IHEs, secondary schools, business, industry, economic development agencies, and government

ATE Program Goals

Produce more qualified science and engineering technicians to meet workforce demands

Improve the technical skills and the general science, technology, engineering, and mathematics (STEM) preparation of these technicians and the educators who prepare them

ATE Program Tracks

- ATE Projects
  - Program Development and Improvement
  - Curriculum and Educational Materials Development
  - Professional Development for Educators
  - Adaptation and Implementation
  - Instrumentation Acquisition
  - …
- New to the ATE Program
- ATE Centers
- Targeted Research on Technician Education

ATE Resources
ATE Central (http://www.atecentral.net)
ATE Centers (http://www.atecenters.org/)
EvaluATE Center (http://www.evalu-ate.org/)

Deadline (All Proposals):
October, annually

Improving Undergraduate STEM Education (IUSE) NSF 19-601

- Purpose of the program:
  - Promote novel, creative, and transformative approaches to generating and using new knowledge about STEM teaching and learning to improve undergraduate STEM education
  - Support development, implementation, and research efforts
- Open to all proposers as described in the NSF PAPPG document

IUSE Program Goals

- Introduce recent advances in STEM disciplinary and interdisciplinary knowledge into undergraduate education
- Add to the body of knowledge about what works in undergraduate STEM education
- Adapt, improve, and incorporate evidence-based practices into STEM teaching and learning
- Lay the groundwork for institutional improvement

IUSE Program Structure

Two Tracks

Engaged Student Learning

Focus on designing, developing, and implementing research on STEM learning models, approaches & tools

3 levels

Level 1	Level 2	Level 3
Up to $300,000 Up to 3 yrs	$300,001 to $600,000 Up to 3 yrs	$600,001 to $2M Up to 5 yrs
Deadlines: 1st Tuesday in Feb & Aug	Deadline: 1st Tuesday in Dec	Deadline: 1st Tuesday in Dec

Institutional and Community Transformation

Focus on increasing the propagation of highly effective methods of STEM teaching and learning

3 levels

Capacity Building	Level 1	Level 2
Up to $150k/$300k 1/2+ institutions Up to 2 yrs	Up to $300,000 Up to 3 yrs	$300,001 to $3M Up to 5 yrs
Deadlines: 1st Tuesday in Feb & Aug	Deadlines: 1st Tuesday in Feb & Aug	Deadline: 1st Tuesday in Dec

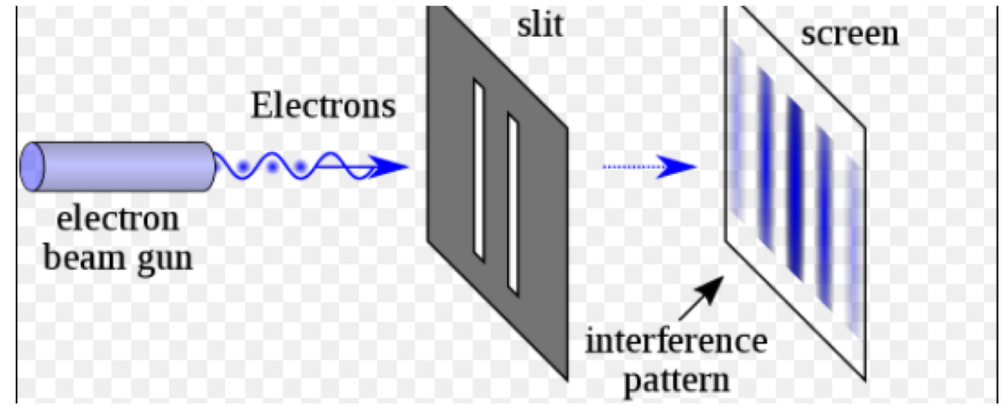
IUSE Program

Example : QISE Education & Workforce Development Award 2011958/2012147 (48 months)

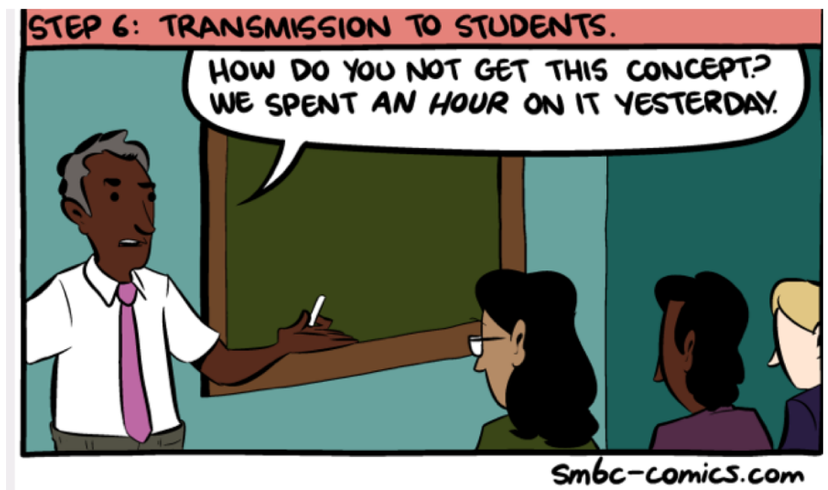
Collaborative Research: Connecting Spins-First Quantum Mechanics Instruction to Quantum Information Science, Cal State Fullerton, Univ of Colorado, Boulder

Project Goals

- support students without prior quantum mechanics (QM) instruction in learning QM concepts necessary for QIS courses
- increase number of students who can learn about QIS by development and distribution of new and innovative curricular materials that can serve instructors' needs
- establish effectiveness of materials by direct assessment as an integrated part of development and pilot implementation



https://selfawarepatterns.com/2021/01/11/ars-technica-has-a-new-series-on-quantum-mechanics-no-math/

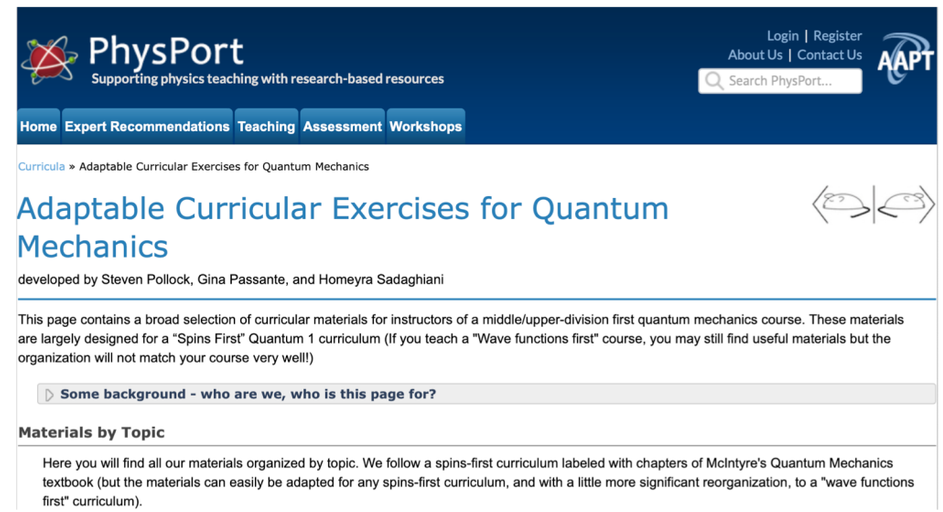


https://www.smbc-comics.com/comic/how-math-works

IUSE Program

Example : QISE Education & Workforce Development Award 2011958/2012147 (contd.)

- Curricula materials developed will facilitate incorporation of QIS into existing courses
- Materials will be produced at multiple institutions with a diverse population of students who reflect broader population
- Advisory board for award brings expertise in collaborative dissemination, content, industrial needs, pedagogy, and curriculum development
- Knowledge will be used to ensure that the materials developed are effectively designed and disseminated to ensure maximum impact on undergraduate and graduate physics and QIS programs



IUSE Program Example : QISE Education & Workforce Development Award 1626280 (Colorado State, Cal Poly Pomona and Cal State Fullerton)

Goals

- developing a set of learning goals for quantum mechanics instruction in collaboration with a broad spectrum of faculty
- improving understanding of student learning and student difficulties in QM in different instructional paradigms
- developing materials and assessments suitable for use in several different instructional paradigms, that are easy for faculty to modify and use in a diverse range of institutions
- widely disseminating materials, supporting new users, and evaluating the effectiveness of curriculum

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DIVISION OF HUMAN RESOURCE DEVELOPMENT

National Science Foundation • Alexandria, VA

Louis Stokes Alliances for Minority Participation

Louis Stokes Alliances for Minority Participation

- Authorized by Congress in 1991
- Significantly increase the quality and quantity of underrepresented minority (URM) students successfully completing STEM BS degree programs to diversify workforce
- Implement strategies that focus on critical transition points
- Alliances are composed of universities and colleges, government labs, industry and not for profit partners

Targeted Groups & Disciplines

- ✓ Blacks
- ✓ Hispanics
- ✓ American Indians
- ✓ Alaska Natives
- ✓ Pacific Islanders

- ✓ Agricultural Sciences
- ✓ Chemistry
- ✓ Computer Science
- ✓ Engineering
- ✓ Environmental Science
- ✓ Geosciences
- ✓ Life/Biological Sciences
- ✓ Mathematics
- ✓ Physics/Astronomy

LOUIS STOKES ALLIANCES FOR MINORITY PARTICIPATION

TYPES OF PROJECTS SUPPORTED in FY2022

Solicitation NSF 20-590

Alliances

- **Bridge to the Baccalaureate (B2B) Alliances**
- **STEM Pathways Implementation-Only Alliances (SPIO)**
- **STEM Pathways and Research Alliances (SPRA)**

Other

- **Bridge to the Doctorate (BD)**

(Eligibility is limited to alliances supported consecutively for ten or more years)

- **Conferences (Limited)**

The solicitation encourages alliances to submit proposals addressing disciplinary areas included in NSF's Ten Big Ideas. Quantum is one of those areas.

LSAMP Team

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Program Director

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Program Director

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Program Director

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Program Specialist

Al Wilson: awilson@nsf.gov
Division Analyst

Frances Carter-Johnson: frajohns@nsf.gov
Data Scientist

Alliance
Private/Public
Partnership

Innovative Technology Experiences for Students and Teachers (ITEST): Solicitation 19-583

Bob Russell and Wu He
Program Officers, Division of Research on Learning

Link to solicitation: https://www.nsf.gov/pubs/2019/nsf19583/nsf19583.htm

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ITEST Program

ITEST is an applied research and development program designed to broaden participation in STEM/ICT careers and career pathways through providing pre-K through 12th grade youth with technology-rich learning experiences in formal or informal settings.

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Project Types

Exploring Theory and Design Principles (ETD)	Designing and Testing Innovations (DTI)	Scaling, Expanding, and Iterating Innovations (SEI)
Up to 3 years	Up to 4 years	Up to 5 years
Up to $400,000	Up to $1,500,000	Up to $3,000,000
• Investigate conditions in the field • Explore factors intended to increase knowledge and interest • Research should build and advance theory, produce design principles or frameworks for innovations	• Design and test or implement the innovation • Analyze outcomes • Research should attend to how the design principles influence knowledge and interest in STEM careers or pathways	• Broaden an innovation at a significant scale (5-10x original) • Extend innovation to new student populations, regions, ages, contexts • Research should attend to transferability and generalizability and factors related to scale

Additional types: Conference, 1 year, $100,000; Synthesis, 2 years, $300,000

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Thoughts on Developing Projects

- Consider the balance between research and development
- Consult the IES/NSF Common Guidelines
  - ETD: Type 2; DTI: Type 3; SEI: Types 4, 5, and 6
- Projects must have high-quality research design, project evaluation, and dissemination of findings

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Five Key Components

ITEST proposals should include design elements that address five components:

- Innovative Use of Technologies
- Innovative Learning Experiences
- STEM Workforce Development
- Strategies for Broadening Participation
- Strategic Partnerships

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Innovative Use of Technologies

- Using new or leading-edge technologies
- Using existing technologies in innovative ways

On the student side, this should include:

- Details about how learners will be directly interacting with the technology
- Measurement of the ways in which the technology experience influences cognitive and socio-emotional learning outcomes

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Innovative Learning Experiences

Describe the innovation and the key aspects of the design.

Make connections to the research literature, and explain how it advances this literature.

Demonstrate how the design builds *knowledge and interest* in preparation for STEM careers.

Be clear about the roles for all stakeholders and how they relate to the overall timeline.

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STEM Workforce Development

- Connecting workforce learning environments to PK-12 learning opportunities
- Making the connection to knowledge of and interest in workforce pathways – not just building STEM knowledge, but explicitly connecting to workforce
- Engaging students in awareness of or participation in entrepreneurship, apprenticeships, internships, or mentoring

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Solicitation-Specific Review Criteria

To what extent does the proposal

- include explicit and adequate strategies for recruiting and selecting participants
- describe approaches to address diversity, access, equity, and inclusion
- describe research-informed instructional approaches to build on strengths and challenges
- explain how innovations with technology are developmentally and age-appropriate

National Q-12 Education Partnership and Q2Work Program

The National Q-12 Education Partnership includes tech companies, scientific professional societies, academics, and the NSF-funded Q2Work Program. Together, we aim to support and grow a quantum workforce that is diverse and equitable, such that the QIS innovators of tomorrow can make discoveries, invent new technologies and drive societal change. We want to increase opportunities, access, and quality of age-appropriate QIS educational experiences for students from all backgrounds.

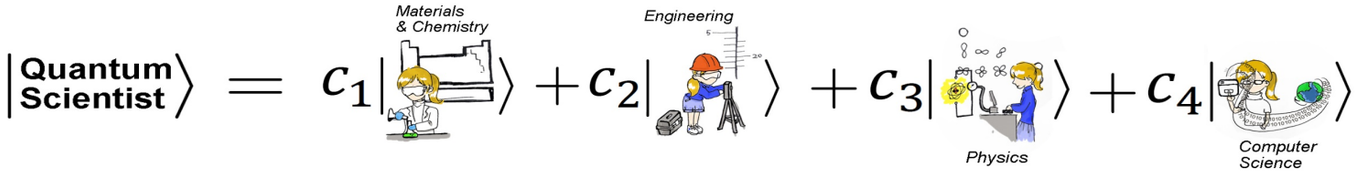
NSF public announcement:
https://www.nsf.gov/news/special_reports/announcements/080520.jsp

Program Homepage:
https://q12education.org/

Examples of QISE Projects

K-12

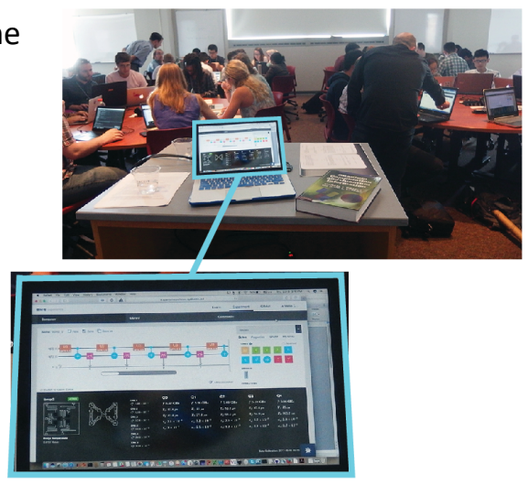
- **#2015205 (PI:** Mark Hannum from American Association of Physics Teachers**)** Cross-Discipline Approach to Quantum Computing in High Schools: Building towards a Quantum Computing Workforce, which focuses on three activities: summer workshops for teachers, building the community of educators involved in deployment of quantum content at schools and organizing a meeting of stakeholders.
- **#2009351 (PI:** Karen Matsler from University of Texas at Arlington**)** Preparing Secondary Teachers to Teach Quantum Information Science built around providing content and support for teachers to develop a sense of how quantum information science and technology affects their students, and how to support understanding of quantum concepts.
- **#2048691** (**PI:** Karen Matsler from University of Texas at Arlington) Preparing Secondary Teachers and Students for Quantum Information Science will provide summer camps for students to learn about quantum, regardless of whether they take a physics class. This project will also provide opportunities for secondary educators to learn about QIS and practice teaching it.



NSF/DOE/AFOSR Quantum Science Summer School

- Convergence QL: NSF/DOE Quantum Science Summer School" DMR-1743059 (Funded by: NSF; DOE/BES, DOE/ASCR, and AFOSR)
  - First school held: Johns Hopkins University, 5-16 June 2017
  - Second school: Cornell Univ., 10-22 June 2018,
  - Third: Penn State, 3-14 June 2019
  - Fourth: TBD (2020)

QS3, June 2017



IBM Quantum Experience: programming a quantum computer

Design and visualization of quantum materials using VR technology

QS3, June 2018

Questions and Discussion