Program Book

The 3rd Quantum Science and Engineering Education Conference (QSEEC) 2024

Palais des Congrès

Montréal, Québec, Canada

September 15-16, 2024

Co-located with

IEEE QUANTUM WEEK

IEEE International Conference on Quantum Computing and Engineering — QCE24

The ***Quantum Science and Engineering Education Conference (QSEEC)*** is an annual conference where education researchers, practitioners, and students come together to discuss methodologies for curriculum and tool development for instruction and teaching. QSEEC emphasizes the need for quantum science and engineering education at all levels, translating from teachable skills to real-world applications, and sharing perspectives from students, educators, and professionals alike.

IEEE Quantum Week — the **IEEE International Conference on Quantum Computing and Engineering (QCE)** — is bridging the gap between the science of quantum computing and the development of an industry surrounding it. As such, this event brings a perspective to the quantum industry different from academic or business conferences. IEEE Quantum Week is a multidisciplinary quantum computing and engineering venue that gives attendees the unique opportunity to discuss challenges and opportunities with quantum researchers, scientists, engineers, entrepreneurs, developers, students, practitioners, educators, programmers, and newcomers.

Sunday, September 15

	Room 523AB		**Room 524A**
9:30 – 10:00	Break	9:30 – 10:00	Break
10:00 – 11:30	QSEEC01: Welcome to QSEEC 2024		
11:30 – 13:00	Lunch	11:30 – 13:00	Lunch
13:00 – 14:30	QSEEC03: Quantum in K-12	13:00 – 14:30	QSEEC04: Quantum Outreach & Engagement
14:30 – 15:00	Break	14:30 – 15:00	Break
15:00 – 16:00	QSEEC05: Quantum Pedagogy	15:00 – 17:00	QSEEC06: Tutorial Session
16:00 – 17:00	Poster Session		

Monday, September 16

	Room 523AB		**Room 524A**
9:30 – 10:00	Break	9:30 – 10:00	Break
10:00 – 11:30	QSEEC07: Quantum Education Resources	10:30 – 11:30	QSEEC08: Tutorial Session
11:30 – 13:00	Lunch	11:30 – 13:00	Lunch
13:00 – 14:30	QSEEC09: Quantum Understanding	13:00 – 14:30	QSEEC10: Workforce Development & Tutorial Session
14:30 – 15:00	Break	14:30 – 15:00	Break
15:00 – 16:30	QSEEC11: Forging New Horizons	15:00 – 16:30	QSEEC12: Quantum Education Tools
16:30 – 17:00	Break	16:30 – 17:00	Break

Room 1 of 2 **Palais des Congres — Room 523AB**

QSEEC01	**Welcome to QSEEC 2024** Session Chair: Marek Osinski (University of New Mexico, United States)
10:00 - 10:15	**Opening Remarks from QSEEC24 Chair: Marek Osinski** (University of New Mexico, United States)
10:15 - 11:00	**Keynote: Building a Quantum Workforce – Starting in High School and Creating Pathways into College -** Megan Ivory (Sandia National Laboratories, United States)
11:00 - 11:30	**Best Paper: Forging Pathways: Quantum Computing Initiatives in Mexico** - Alberto Maldonado-Romo (Instituto Politécnico Nacional, Mexico), Claudia Zendejas-Morales (Universidad Nacional Autónoma de México, Mexico), Boris Escalante-Ramirez (Universidad Nacional Autónoma de México, Mexico), Jimena Olveres (Universidad Nacional Autónoma de México, Mexico), Isabel Pedraza (Benemérita Universidad Autónoma de Puebla, Mexico), Javier Maldonado-Romo (Tecnologico de Monterrey, Mexico), and Jesús Yaljá Montiel-Pérez (Instituto Politécnico Nacional, Mexico)
11:30 - 13:00	**LUNCH**
QSEEC03	**Quantum in K-12** Session Chair: Mariana Filipova (University of Library Studies and Information Technologies, Bulgaria)
13:00 - 13:15	**Review of Literature on Quantum Information Science and Technology Programs for High School Students** - Michele Darienzo and Angela Kelly (Stony Brook University, United States)
13:15 - 13:30	**High schoolers excel at Oxford post-graduate quantum exam: experimental evidence in support of quantum picturalism** - Bob Coecke (Quantinuum, United Kingdom), Aleks Kissinger (University of Oxford, United Kingdom), Stefano Gogioso (University of Oxford, United Kingdom), Selma Dündar-Coecke (Quantinuum, United Kingdom), Caterina Puca (Quantinuum, United Kingdom), Lia Yeh (University of Oxford, United Kingdom), Muhammad Hamza Waseem (University of Oxford, United Kingdom), Vincent Wang (Quantinuum, United Kingdom), Sieglinde M.-L. Pfaendler (IBM, Switzerland), Emmanuel Pothos (City University of London, United Kingdom), Thomas Cervoni (Quantinuum, United Kingdom), Ferdi Tomassini (Quantinuum, United Kingdom), Vincent Anandra (Quantinuum, United Kingdom), Peter Sigrist, and Ilyas Khan (Quantinuum, United Kingdom)
13:30 - 13:45	**Exploring quantum physics in (junior) high schools: Introduction and evaluation of an innovative teaching concept for grade 9 students** - Carsten Albert (IFW Dresden, Germany)
13:45 - 14:00	**Why Teach Quantum: Elementary Teachers Initial Beliefs about Quantum** - Xiaolu Zhang, Nancy Holincheck, Jessica Rosenberg, Stephanie Dodman, Ben Dreyfus and Jennifer Simons (George Mason University, United States)
14:00 - 14:15	**Teaching Quantum Information Science in K-12: Challenges and Successes** - Karen Matsler (The University of Texas at Arlington, United States)
14:15 - 14:30	**Qubit by Qubit: Evaluating the Impact of Professional Development Modalities on High School Educators** - Kiera Peltz (The Coding School, United States)

14:30 - 15:00	**BREAK**

QSEEC05	**Quantum Pedagogy** Session Chair: Lia Yeh (University of Oxford, United Kingdom)
15:00 - 15:15	**From Theory to Practice: Qubit by Qubit's Key Findings from Teaching Quantum Computing At-Scale to Early Learners** - Lori Gatmaitan (The Coding School, United States)
15:15 - 15:30	**Quantum Computing Education for Computer Science Students: Bridging the Gap with Layered Learning and Intuitive Analogies** - Anila Mjeda and Hazel Murray (Munster Technological University, Ireland)
15:30 - 15:45	**Quantum Awareness for Post-Secondary Students** - Jessica Rosenberg and Nancy Holincheck (George Mason University, United States)
15:45 - 16:00	Poster Setup
16:00 - 17:00	**Poster Session**

Posters

States of QCamp: Demystifying quantum physics for pre-university students and teachers in Singapore - Xin Yi Puah, Jenny Hogan, Clara Yun Fontaine, Clive Aw, Lin Htoo Zaw, Elizaveta Maksimova, Celine Trieu, Jinyan Chen, Shuin Jian Wu, Fernando Valadares, and Chong Hian Chee (Centre for Quantum Technologies, Singapore)

Curiosity Meets Quantum: Accessible Quantum Education for the Inquisitive - Whei Yeap Suen and Jibo Dai (Centre for Quantum Technologies, Singapore)

An Interactive Tool of Spin Qubit for Quantum Science and Engineering Education - Qimao Yang, Raiden Williams, Yukyeong Song, Wanli Xing, and Jing Guo (University of Florida, United States)

Introducing Quantum Computing with a Novel Integrated Quantum Robotics Curriculum - Saarah Nazar (Purdue University, United States)

Landscape of Quantum Information Science and Engineering Education in the United States - Andi Pina, Mike Verostek, Brett Boyle, Mateo Cacheiro, Matt Lawler, Namitha Pradeep, Ella Watts (Rochester Institute of Technology, United States), Colin G. West, Heather Lewandowski (University of Colorado Boulder, United States), and Benjamin M. Zwickl (Rochester Institute of Technology, United States)

Teaching Quantum Science and Technology in Elementary and Lower Secondary School - Mariana Filipova (University of Library Studies and Information Technologies, Bulgaria)

Room 2 of 2 **Palais des Congres — Room 524A**

9:30 - 10:00	**BREAK**
11:30 - 13:00	**LUNCH**

QSEEC04	**Quantum Outreach & Engagement** Session Chair: Marek Osinski (University of New Mexico, United States)
13:00 - 13:15	**Why Teach Quantum At Your Own Time: The Values of Grassroots Organisations Involved in Quantum Technologies Education and Outreach** - Ulrike Genenz (RWTH Aachen University, Germany), Neelanjana Anne (University of California, Irvine, United States), Zeynep Kılıç (Middle East Technical University, Turkey), Daniel Mathews (B.M.S. Institute of Technology and Management, India), Oya Ok (Terakki Foundation Schools, Turkey), Adrian Schmidt (Karlsruhe Institute of Technology, Germany), and Zeki Can Seskir (Karlsruhe Institute of Technology, Germany)
13:15 - 13:30	**Building Quantum Information Science Capabilities at HBCUs: Insights and Recommendations** - Kayla Lee (IBM, United States), Michelai Lowe (IBM HBCU Quantum Center, United States), and Thomas A. Searles (University of Illinois Chicago, United States)
13:30 - 13:45	**Quantum Computing Society of the Philippines: An NGO Perspective on Promoting Quantum Information, Science, and Technology in the Philippines** - Dylan Josh Lopez (De La Salle University, Philippines), Bobby Corpus (Quantum Computing Society of the Philippines, Philippines), Elmer Peramo (Advanced Science and Technology Institute, Philippines), Jabez Ayson (Don Honorio Ventura State University, Philippines), Angela Nicole Masongsong (De La Salle University Integrated School, Philippines), and Lance Dominic Raquel (University of San Carlos, Philippines)
13:45 - 14:00	**Quantum Game Club: Engaging with Quantum Computing Through Interactive Learning** - Dongyang Li (Purdue University, United States), Zirui Zhang (Purdue University, United States), Xinzhe Xu (Purdue University, United States), and Mahdi Hosseini (Northwestern University, United States)
14:00 - 14:15	**Using Quantum Network Explorer for Outreach and Knowledge Sharing** - Ravisankar A V and Mark Önder Karpat (Delft University of Technology, Netherlands)
14:15 - 14:30	**Towards an inclusive and interdisciplinary quantum workforce through Quantum Education** - Nithyasri Srivathsan (SheQuantum, Singapore)

14:30 - 15:00	**BREAK**

QSEEC06	**Tutorial Session** Session Chair: Zeki Can Seskir (Karlsruhe Institute of Technology, Germany)
15:00 - 16:00	**Tutorial 1: Student-centered activities on basic principles of quantum computing: a guide for instructors** - Gina Passante (California State University, Fullerton, United States), Steven Pollock (University of Colorado Boulder, United States), and Bethany Wilcox (University of Colorado Boulder, United States)
16:00 - 17:00	**Tutorial 2: Using Programming Exercises with Immediate Feedback for Learning and Teaching Quantum Computing** - Mariia Mykhailova (Microsoft, United States)

Room 1 of 2 **Palais des Congres — Room 523AB**

9:30 - 10:00	**BREAK**
QSEEC07	**Quantum Education Resources** Session Chair: Marek Osinski (University of New Mexico, United States)
10:00 - 10:30	**Invited Talk: Hands-On Labs for High-School Quantum Education** - John Donohue (University of Waterloo, Canada)
10:30 - 10:45	**Entangling Disciplines: Causality, Entropy and Time-Travel Paradoxes on a Quantum Computer** - Maria Violaris (University of Oxford, United Kingdom)
10:45 - 11:00	**Bridging the Quantum Education Gap: Hands-on Visualization Projects for Quantum Search Algorithm** - Yao-Hsin Chou (National Chi Nan University, Taiwan), Yu-Chi Jiang (Princeton University, Taiwan), Shu-Yu Kuo (National Taiwan University, Taiwan), and Sun-Yuan Kung (Princeton University, United States)
11:00 - 11:15	**Adaptable curricular exercises to support teaching undergraduate quantum information** - Steven Pollock (University of Colorado, Boulder, United States), Gina Passante (California State University, Fullerton, United States), Bethany Wilcox (University of Colorado, Boulder, United States), and Giaco Corsiglia (University of Colorado, Boulder, United States)
11:15 - 11:30	**Dancing quantum computing and other Curieux quantiques' educational tools and projects** - Dominique Wolfshagen and Mélissa Greene (Université de Sherbrooke, Canada)
11:30 - 13:00	**LUNCH**
QSEEC09	**Quantum Understanding** Session Chair: Lia Yeh (University of Oxford, United Kingdom)
13:00 - 13:15	**Sharing of Preliminary PreCollege QIS Research** - Karen Matsler (The University of Texas at Arlington, United States)
13:15 - 13:30	**Quantum Computing Conceptual Survey: Results from 2 semesters of pilot data collection** - Josephine C. Meyer (University of Colorado Boulder, United States), Gina Passante (California State University, Fullerton, United States), Steven J. Pollock (University of Colorado Boulder, United States), and Bethany R. Wilcox (University of Colorado Boulder, United States)
13:30 - 13:45	**The Quantum Computing Conceptual Survey – an assessment instrument for the growing educational ecosystem of quantum computing** - Bethany Wilcox (University of Colorado Boulder, United States), Josephine Meyer (University of Colorado Boulder, United States), Gina Passante (California State University, Fullerton, United States), and Steven Pollock (University of Colorado Boulder, United States)
13:45 - 14:00	**Student ideas and difficulties when reasoning around the CNOT gate** - Gina Passante (California State University, Fullerton, United States), Jonan-Rohi Plueger (University of Colorado, Boulder, United States), Steven Pollock (University of Colorado, Boulder, United States), and Bethany Wilcox (University of Colorado, Boulder, United States)
14:00 - 14:15	**Quantum Error Correction for kids** - Richard A. Wolf (University of Galway, Ireland)
14:15 - 14:30	**Towards Personalized Quantum Information Learning for Dynamic Class Environment and Student Engagement** - Nikos Chrisochoides (Old Dominion University, United States), Norou Diawara (Old Dominion University, United States), and Michail Giannakos (Norwegian University of Science and Technology, Norway)

Room 1 of 2 **Palais des Congres — Room 523AB**

14:30 - 15:00	**BREAK**

QSEEC11	**Forging New Horizons** Session Chair: Zeki Can Seskir (Karlsruhe Institute of Technology, Germany)
15:00 - 15:15	**The Power of Student-Led and Grassroots Organizations in the Quantum Education & Workforce Pipeline** - Sanskriti Deva (North Carolina State University, United States)
15:15 - 15:30	**Quantum Horizons: Examining the Scope of Quantum Computing in Latin American Universities** - Laura Gatti, Rafael Sotelo, and Agustin Panizza (Universidad de Montevideo, Uruguay)
15:30 - 15:45	**Quantum Education in Latin America for Younger People: The Experience of Quantum Computing Seedbeds and their Results** - Alcides Montoya Cañola and Cristian E. Bello (Universidad Nacional de Colombia, Colombia)
15:45 - 16:00	**Driving Quantum Literacy: Multi-Stakeholder Collaborative Efforts in Philippine Education** - Jul Jon General, Ross Romuel Mariano, and Jeffrey Aborot (Advanced Science and Technology Institute, Philippines)
16:00 - 16:15	**Towards a Faculty Learning Community in Quantum Education for HS Teachers in the state of Indiana** - Dan-Adrian German (Indiana University Bloomington, United States), Christian Scott (Indiana University, United States), Christina Snyder (The Westminster Schools, United States), Carla Gehlhausen (Hoosier College and Career Academy, United States), Matt Mindach (Wabash High School, United States), Blake Clevenger (Randolph Eastern School Corporation, United States), Ahmad Faiz (Indiana University Bloomington, United States), Elmar Bucher (Indiana University Bloomington, United States), Scott Winchester (Indiana University, United States), and Rebekah Randall (Canterbury High School, United States)
16:15 - 16:30	**Quantum Computing Education in the Humanities: Project-Based Learning Development** - Jose Hernandez (Florida State University, United States)

16:30 - 17:00	**BREAK**

Room 2 of 2 **Palais des Congres — Room 524A**

9:30 - 10:00	**BREAK**
QSEEC08	**Tutorial Session** Session Chair: Ghislain Lefebvre (Université de Sherbrooke, Canada)
10:30 - 11:30	**Tutorial 3: Exploring The Quantum Enigmas in the classroom** - Ghislain Lefebvre (Université de Sherbrooke, Canada)
11:30 - 13:00	**LUNCH**
QSEEC10	**Workforce Development & Tutorial Session** Session Chair: Marek Osinski (University of New Mexico, United States)
13:00 - 13:15	**Developing an Undergraduate Quantum Workforce** - Dongyang Li, Priyam Gupta, Yi Lin Yang, Eric Christopher Broyles, Lakshay Goel, and C. Robert Kenley (Purdue University, United States)
13:15 - 13:30	**The Design and Implementation of a Quantum Information Science Undergraduate Program** - Sarah Blanchette, Danièle Normandin, Michel Pioro-Ladrière, Lyne St-Hilaire, Armand Soldera, Karl Thibault, and Dave Touchette (Université de Sherbrooke, Canada)
13:30 - 14:30	**Tutorial 4: Exploring Virtual and Customised Laboratory for Quantum Computing Software** - Alberto Maldonado-Romo (Instituto Politécnico Nacional, Mexico), and Ricky Young (qBraid, United States)
14:30 - 15:00	**BREAK**
QSEEC12	**Quantum Education Tools** Session Chair: Mariana Filipova (University of Library Studies and Information Technologies, Bulgaria)
15:00 - 15:15	**QuantumCrypto: A Web Framework for Quantum Cryptography Education** - José Ossorio (University of Victoria, Canada), Jean Frédéric Laprade (Université de Sherbrooke, Canada), Ulrike Stege (University of Victoria, Canada), and Hausi Müller (University of Victoria, Canada)
15:15 - 15:30	**QUINTET: An Experiential Learning Platform for Quantum Education** - Abhishek Parakh (Kennesaw State University, United States), and Mahadevan Subramaniam (University of Nebraska at Omaha, United States)
15:30 - 15:45	**Niel's Chess: A Quantum Game for Schools and the General Public** - Tamás Varga (Constructor Institute Schaffhausen, Switzerland)
15:45 - 16:00	**qBook: A hands-on cloud-based course platform to learn quantum computing and its applications** - Ricky Young, Ryan Hill, Akash Kant, James Brown, Kenneth Heitritter, Tarini Shekhar Hardikar, and Kanav Setia (qBraid, United States)
16:00 - 16:15	**QGrover: Teaching Grover's Algorithm Through Visual Exploration** - Samantha Norrie, Anthony Estey, Hausi Müller, and Ulrike Stege (University of Victoria, United States)
16:15 - 16:30	**QNotation: A Visual Browser-Based Notation Translator for Learning Quantum Computing** - Samantha Norrie, Anthony Estey, Hausi Müller, and Ulrike Stege (University of Victoria, United States)
16:30 - 17:00	**BREAK**

Keynote Talk

Building a Quantum Workforce – Starting in High School and Creating Pathways into College

Megan Ivory, Sandia National Laboratories, United States

We continue to see demand for quantum-ready workers and exciting new training programs across many different disciplines and education levels. This talk will highlight some of our efforts to create programs starting at the high school level and to build out pathways into community colleges and four-year colleges. 2024 brought about an expansion of QCaMP for Teachers to reach high school educators across 5 different states, an expansion of QCaMP for Students from a week-long engagement to a 4-week-long engagement with high schoolers, and funding for the Quantum Learning Lab through the newly announced Elevate Quantum TechHub which aims to launch a first of its kind Quantum Bootcamp to provide students with the hands-on training needed to succeed in technician roles in the growing quantum ecosystem.

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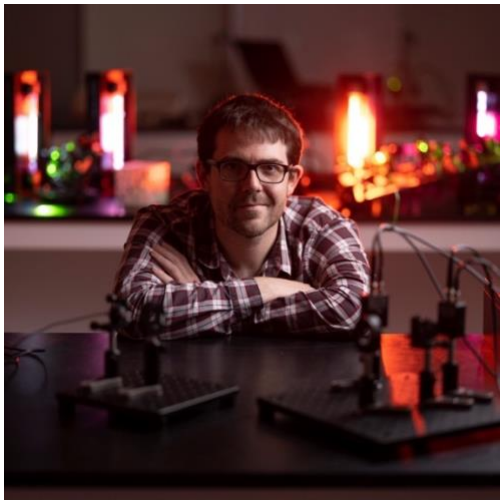
Dr. Megan K. Ivory is a Senior Member of the Technical Staff at Sandia National Laboratories splitting her time between the Quantum Scientific Computing Open User Testbed (QSCOUT) where she builds trapped-ion quantum computers and various efforts to build a diverse, inclusive, quantum-ready workforce. Her workforce development projects focus on introducing quantum science and technology at earlier education levels to underrepresented communities, for which she was awarded the 2023 APS Forum for Early Career Scientists' Diversity and Inclusion Award and the 2023 New Mexico Excellence in STEM Mentor Award. She is the Co-Director of QCaMP, a summer camp aimed at introducing quantum concepts to high school students and teachers, co-lead of the Quantum Learning Lab, an effort to establish hands-on technician training opportunities, and co-PI of QIST in the CSU, a project aiming to build capacity for QIST across the California State University's predominantly undergraduate and minority serving institutions.

Invited Talk

Hands-On Labs for High-School Quantum Education

John Donohue, Institute for Quantum Computing, University of Waterloo, Canada

To allow high-school students to engage with quantum information science on a broad scale, it is essential to provide educators with the resources needed to understand and effectively communicate the topic to students. We have run the Quantum for Educators (QEd) workshop for ten years to address this need and, from a variety of surveys, have found that hands-on activities for students remain the resource that teachers desire most. The ensure broad and equitable access to introductory QIS education, such activities should be low-cost, easy to replicate, and intuitive. In this talk, we will outline our quantum education efforts with a special focus on hands-on activities, which cover topics such as quantum key distribution, the uncertainty principle, ion trapping, and quantum gates. These activities form the backbone for the long-running QEd and Quantum School for Young Students (QSYS) workshops, from which we will share participant feedback to highlight which labs, lessons, and activities most strongly resonate with different audiences.

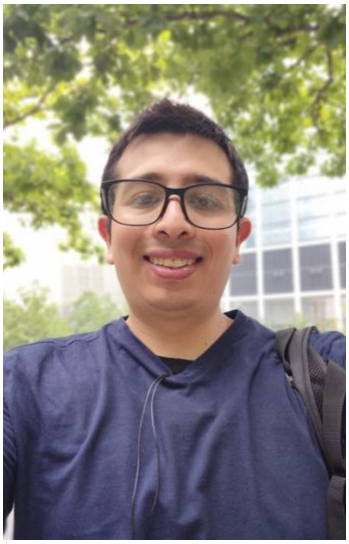


John Donohue is the Senior Manager of Scientific Outreach at the Institute for Quantum Computing (IQC), a research institute at the University of Waterloo. At IQC, he directs a variety of activities and events to help people engage with quantum technologies, including Quantum: The Pop-Up Exhibition, the Undergraduate School on Experimental Quantum Information Processing, the Quantum School for Young Students, and the Quantum for Educators workshop. His research background is in experimental quantum optics.

Best Paper

Forging Pathways: Quantum Computing Initiatives in Mexico

Alberto Maldonado-Romo, Instituto Politécnico Nacional, Mexico
Claudia Zendejas-Morales, Universidad Nacional Autónoma de México, Mexico
Boris Escalante-Ramirez, Universidad Nacional Autónoma de México, Mexico
Jimena Olveres, Universidad Nacional Autónoma de México, Mexico
Isabel Pedraza, Benemérita Universidad Autónoma de Puebla, Mexico
Javier Maldonado-Romo, Tecnologico de Monterrey, Mexico
Jesús Yaljá Montiel-Pérez, Instituto Politécnico Nacional, Mexico



Alberto Maldonado-Romo

This work presents establishing a nationwide university network to address the relevance of quantum computing, where challenges and opportunities for industry and academia focus from undergraduate to doctoral levels. The network comprises a series of talks on opportunities in the quantum computing ecosystem and potential collaborations and development opportunities aimed at Latin American countries. A total of 242 Spanish speakers registered, with 30% identifying as introductory level and 4% as experts in quantum computing. The remarks underscore the importance of creating opportunities across various domains of the quantum computing ecosystem for a country showing initial interest in this field. Additionally, we present the educational levels of the participants, including their proficiency levels in quantum computing, their areas of interest within this field, and the topics and trends they consider relevant when engaging in quantum computing.

The Center for Computing Research of the National Polytechnic Institute (CIC-IPN) hosted this event, organized by CIC-IPN, the National Autonomous University of Mexico (UNAM), the Superior School of Computing (ESCOM), the Interdisciplinary Professional Unit in Engineering and Advanced Technologies (UPIITA), the Center of Studies in Advanced Computing of UNAM (CECAv), Institute of Advanced Materials for Sustainable Manufacturing of the Technological Institute of Monterrey, Benemérita Autonomous University of Puebla (BUAP), Tecmilenio University, Superior School of Mechanical and Electrical Engineering Unit (ESIME) Zacatenco, and Quantum Universal Education in collaboration with IBM Quantum, Xanadu, Haiqu, Unitary Fund, qBraid, Oak Ridge National Laboratory, Kipu Quantum, Pasqal, Quantinuum, Womanium, and BQB.

Alberto Maldonado-Romo is a PhD student in Computer Science at Instituto Politécnico Nacional, Mexico. He leads the Quantum Open Source Foundation (QOSF) and organized its 2022 mentorship program. As an ambassador for the Unitary Fund and a Qiskit advocate, Alberto has won QCHack 2021 and QHack 2022. His research focuses on Quantum Machine Learning, algorithms, error mitigation, software, and education. He has reviewed technical content for Packt, organized hackathons and colloquiums, and volunteered at Quantum Universal Education. Alberto has interned at Entropica Labs, qBraid, and IBM Quantum, and is committed to advancing Quantum education for Latin American and Spanish-speaking communities.

Abstracts

Paper

Review of Literature on Quantum Information Science and Technology Programs for High School Students

Michele Darienzo, Stony Brook University, United States
Angela Kelly, Stony Brook University, United States

This review of literature critiques recent research (2019-2023) on quantum information science and technology (QIST) programs designed specifically for high school students. Since QIST research and applications are advancing rapidly with an accompanying global demand for QIST workforce development, it is important to understand how high school students may be introduced to QIST concepts and skills early in the academic pipeline. The review identifies best practices for QIST teaching and learning, how prerequisite mathematical skills are addressed, methodological approaches and limitations, as well as QIST practices in high school outreach programs that have not published empirical findings. Implications for practice and future empirical work are discussed.

Talk

High schoolers excel at Oxford post-graduate quantum exam: experimental evidence in support of quantum picturalism

Bob Coecke, Quantinuum, United Kingdom
Aleks Kissinger, University of Oxford, United Kingdom
Stefano Gogioso, University of Oxford, United Kingdom
Selma Dündar-Coecke, Quantinuum, United Kingdom
Caterina Puca, Quantinuum, United Kingdom
Lia Yeh, University of Oxford, United Kingdom
Muhammad Hamza Waseem, University of Oxford, United Kingdom
Vincent Wang, Quantinuum, United Kingdom
Sieglinde M.-L. Pfaendler, IBM, Switzerland
Emmanuel Pothos, City University of London, United Kingdom
Thomas Cervoni, Quantinuum, United Kingdom
Ferdi Tomassini, Quantinuum, United Kingdom
Vincent Anandraj, Quantinuum, United Kingdom
Peter Sigrist, Quantinuum, United Kingdom
Ilyas Khan, Quantinuum, United Kingdom

We demonstrate that a group of ‘fairly randomly selected’ UK high school students can outperform Oxford postgrad students on an Oxford postgrad quantum exam when using quantum picturalism instead of Hilbert spaces. We followed the format of an Oxford postcard course, and only used questions of Oxford postgrad quantum exams. Almost 50% of the students got distinctions, and 80% passed. The result was already reported in The Guardian/Observer just before Xmas:
https://www.theguardian.com/science/2023/dec/16/physicist-bob-coecke-its-easier-to-convince-kids-than-adults-about-quantum-mechanics

We are currently talking to a number of governments who are interested in using quantum picturalism for country-wide education of quantum at high school level.

Abstracts

Talk

Exploring quantum physics in (junior) high schools: Introduction and evaluation of an innovative teaching concept for grade 9 students

Carsten Albert, IFW Dresden, Germany

The significance of quantum physics in secondary school curricula is increasing, raising the question of modern approaches to the topic for younger target groups. For this purpose, a state-of-the-art teaching concept on quantum physics in the context of the quantum computers for grade 9 students (approx. 14 years old) has been developed within a Design-Based-Research-project.

The teaching concept is based on a 'Spin-First' approach – meaning that concepts and phenomena of quantum physics are introduced using an exemplary two-state quantum system. In this case, electron spin is used for introducing quantum concepts while the concept of waves is fully omitted in order to avoid known learning difficulties and to reduce required prior knowledge as well.

The course includes in total seven chapters and numerous teaching materials have been developed, including a textbook, a workbook, a simulation, and guidelines for teachers. Summative evaluation is conducted as a field study that runs until summer 2024 and involves several hundred grade 9 students from Germany.

The talk provides insights into the teaching concept and reports first promising findings from summative evaluation of the concept regarding learning achievement, affective variables as well as practitioner feedback.

Paper

Why Teach Quantum: Elementary Teachers Initial Beliefs about Quantum

Xiaolu Zhang, George Mason University, United States
Nancy Holincheck, George Mason University, United States
Jessica Rosenberg, George Mason University, United States
Stephanie Dodman, George Mason University, United States
Ben Dreyfus, George Mason University, United States
Jennifer Simons, George Mason University, United States

This paper examines the initial beliefs held by elementary educators (n=11) and their students about teaching and learning quantum concepts at the elementary level. All teachers were participants in a grant-funded project focused on developing teachers' quantum content knowledge for teaching quantum and creating curricular resources to use in elementary classrooms. Although elementary teachers had limited knowledge of quantum at the beginning of the project, they expressed excitement and a belief that learning quantum would create future possibilities for their students.

Abstracts

Talk

Teaching Quantum Information Science in K-12: Challenges and Successes

Karen Matsler, The University of Texas at Arlington, United States

Quantum Information Science and Engineering (QISE) undergirds a set of critical technologies that will affect information security, smart phones, computers, and other widely used technology. There is a broad need to develop a "quantum smart" workforce in addition to traditional STEM fields, and this development needs to occur in precollege education. The US National Science Foundation has tasked the Quantum for All (#2048691) project to provide professional development opportunities for high school STEM educators so they can learn about QISE and how to implement it in their high school classrooms.

The teacher professional development is tied to a summer camp experience for students during which the teachers can test their delivery of the material with students in the summer camp. The camp was designed for high school students, but a large majority were in grades 9 and 10. Students in these grades did not typically have strong math or STEM content background which led to curriculum being redesigned. However, the assessments show the concepts as presented in the project were accessible. Data indicates teachers also had significant gains in learning concepts relating QISE and their increase in content correlates to their confidence increase. However, in spite of content gains, implementation is still a challenge. Interviews with teachers revealed collaborating with each other was important, especially in this unfamiliar area of content.

In addition, conversations with peers was critical to understanding the content and having confidence in their understanding. This talk will discuss research collected regarding how quantum information science is being taught in the teacher PD as well as the camp and highlight some of the successes and challenges.

Abstracts

Talk

Qubit by Qubit: Evaluating the Impact of Professional Development Modalities on High School Educators

Lori Gatmaitan, The Coding School, United States

As interest in quantum computing education expands, understanding the most effective methods for training our educators – who are integral to nurturing student engagement – becomes increasingly important. One critical question in the discourse regarding quantum professional development (PD) methodologies is whether the modality through which educators enroll and participate in a quantum computing professional development affects their material comprehension and confidence in teaching quantum concepts thereafter. In this talk, Qubit by Qubit will explore answers to this question through a comparative analysis of learning outcomes from two of our PD programs for high school educators that employ different recruitment methods and learning environments.

The first modality is a 1-week in-person program funded by Ohio's state legislature and organized in collaboration with Cleveland State University for a cohort of their high school computer science educators in Ohio. Participants from Cleveland and "inner-ring" suburbs will be eligible for stipends. Given that participants for this PD are recruited by our community partners, attend sessions locally, and are offered stipends, this PD generally targets educators who would otherwise not necessarily be inclined to learn about quantum and are instead looking for supplementary education in computer science. The second modality is our virtual quantum PD: this PD is open to high school educators worldwide and does not currently provide stipends, in turn attracting participants that are inherently interested in adapting quantum to various subjects. Neither program assumes prior quantum knowledge.

In this talk, we will first outline the structure of both our PD sessions, highlighting the common elements of all of our quantum PDs as well as adaptations made for virtual delivery versus in-person interaction. Thereafter, we will discuss our findings from pre and post-course survey results, focusing on learning outcomes relating to educators' performance on technical assessments and their confidence and likeliness to implement quantum concepts in their classrooms following the PD. We will also assess, for both programs, barriers to the implementation of quantum in classroom curricula and opportunities for broader adoption recommendations. Finally, we will share best practices for teaching quantum computing to high school educators, tailored specifically for the differing needs and dynamics of virtual versus in-person settings.

Abstracts

Talk

From Theory to Practice: Qubit by Qubit's Key Findings from Teaching Quantum Computing At-Scale to Early Learners

Lori Gatmaitan, The Coding School, United States

As interest in quantum education has expanded beyond later-career academics to attract early learners, there is a dearth of research to suggest optimal teaching practices for these students, with even less of an understanding of how to attract, retain, and support early quantum learners of various STEM, educational, and demographic backgrounds.

This past year, the world's largest quantum education initiative for early learners, Qubit by Qubit (QxQ) partnered with Google Quantum AI on QxQ's 2023-2024 Introduction to Quantum Computing course in an effort to bridge this data gap. Unlike many STEM courses that involve many prerequisites, this course only required participants - mostly high school and undergraduate students - to have taken high school geometry. Through live instruction delivered virtually, over 2,000 students worldwide learned topics in quantum mechanics, information, computation, and algorithms, in addition to developing coding ability in Cirq (one of Google's open-source programming languages).

A previous analysis taken at the course's midway point sought to understand patterns in student learning behavior and knowledge gains across the material covered. Since the course ended in April, QxQ will now assess overarching findings based on pre-course and post-course assessment, reflecting the program's ultimate impact on students who completed both semesters of the program. Specifically, the talk will explore the patterns in students' knowledge gains and socio-emotional responses based on their educational level as well as their STEM backgrounds and demographic factors. Based on these findings, the talk will also provide suggestions for how teachers can best present complex topics in fields like quantum education to meet various educational needs and minimize potential obstacles to learning.

Paper

Quantum Computing Education for Computer Science Students: Bridging the Gap with Layered Learning and Intuitive Analogies

Anila Mjeda, Munster Technological University, Ireland
Hazel Murray, Munster Technological University, Ireland

Quantum computing presents a transformative potential for the world of computing. However, integrating this technology into the curriculum for computer science students who lack prior exposure to quantum mechanics and advanced mathematics remains a challenging task. This paper proposes a scaffolded learning approach aimed at equipping computer science students with essential quantum principles. By introducing foundational quantum concepts through relatable analogies and a layered learning approach based on classical computation, this approach seeks to bridge the gap between classical and quantum computing. This differs from previous approaches which build quantum computing fundamentals from the prerequisite of linear algebra and mathematics. The paper offers a considered set of intuitive analogies for foundation quantum concepts including entanglement, superposition, quantum data structures and quantum algorithms. These analogies coupled with a computing-based layered learning approach, lay the groundwork for a comprehensive teaching methodology tailored for undergraduate third level computer science students.

Abstracts

Paper — Quantum Awareness for Post-Secondary Students

Jessica Rosenberg, George Mason University, United States
Nancy Holincheck, George Mason University, United States

Quantum Information Science is a new and growing field. Significant growth in the quantum workforce has been called for by some in the quantum industry. Supporting this growth will require engaging the best and brightest. However, most students do not know what quantum information science entails or what jobs are available. We present a workshop model that we have developed to build quantum awareness among post-secondary students. These workshops have been effective in raising awareness and increasing interest in the field among students at a range of educational levels including community college, undergraduate, and graduate students. All of the students who attended these workshops attended minority serving institutions and most attended historically black colleges and universities. These workshops are only a first step towards building the quantum workforce. We still need to define pathways that allow students to take the next steps towards entering the workforce if they are interested in pursuing the field after one of these workshops.

Poster — States of QCamp: Demystifying quantum physics for pre-university students and teachers in Singapore

Xin Yi Puah, Centre for Quantum Technologies, Singapore
Jenny Hogan, Centre for Quantum Technologies, Singapore
Clara Yun Fontaine, Centre for Quantum Technologies, Singapore
Clive Aw, Centre for Quantum Technologies, Singapore
Lin Htoo Zaw, Centre for Quantum Technologies, Singapore
Elizaveta Maksimova, Centre for Quantum Technologies, Singapore
Celine Trieu, Centre for Quantum Technologies, Singapore
Jinyan Chen, Centre for Quantum Technologies, Singapore
Shuin Jian Wu, Centre for Quantum Technologies, Singapore
Fernando Valadares, Centre for Quantum Technologies, Singapore
Chong Hian Chee, Centre for Quantum Technologies, Singapore

We present our pedagogical approach for QCamp, a five-day camp on quantum technologies at the Centre for Quantum Technologies in Singapore for pre-university students. QCamp aims to help students develop intuition for quantum science, build a technical foundation, explore diverse motivations and questions, and believe that they can thrive in the field. Students indicate in post-camp surveys that they found QCamp fun, enlightening and enriching, and will consider quantum as a future education and career pathway. QCamp has also evolved into different states, including a one-day version for students and teachers respectively. We introduce these new states of QCamp and the successes and challenges adapting the original programme into a single day programme for different audiences.

Abstracts

Poster

Curiosity Meets Quantum: Accessible Quantum Education for the Inquisitive

Whei Yeap Suen, Centre for Quantum Technologies, Singapore
Jibo Dai, Centre for Quantum Technologies, Singapore

We present our online quantum education platform that provides high-quality educational resources tailored to curiosity-driven individuals. We will showcase our carefully designed curriculum, which includes interactive modules, video lectures from renowned experts, and hands-on tutorials that teaches quantum mechanics and its applications. The platform's user-centric design ensures that learners from diverse backgrounds can easily navigate and benefit from the content, fostering an inclusive learning environment.

Our community-driven approach also encourages collaboration with industry experts to provide content on the current-state-of-the-art quantum technologies. Discover how we are making quantum education not only accessible but also engaging and effective for all.

Poster

An Interactive Tool of Spin Qubit for Quantum Science and Engineering Education

Qimao Yang, University of Florida, United States
Raiden Williams, University of Florida, United States
Yukyeong Song, University of Florida, United States
Wanli Xing, University of Florida, United States
Jing Guo, University of Florida, United States

Silicon-based spin qubits represent a promising technology for scalable quantum computing. However, the complex nature of this field, which requires a deep understanding of quantum mechanics, materials science, and nanoelectronics, poses a significant challenge in making it accessible to future engineers and scientists. Spin Quantum Gate Lab, a spin qubit simulation tool, is proposed in this paper to address this obstacle. This tool is designed to introduce key concepts of spin qubit to undergraduate students, enabling the simulation of single-qubit rotational gates and two-qubit controlled-phase gates. By providing hands-on experience with quantum gate operations, it effectively links theoretical quantum concepts to practical experience, fostering a deeper understanding of silicon-based quantum computing.

Poster

Introducing Quantum Computing with a Novel Integrated Quantum Robotics Curriculum

Saarah Nazar, Purdue University, United States

Robotics is often learners' first introduction to computer science concepts due to its hands-on nature. Quantum robotics is a quickly evolving field which holds similar promise. This poster introduces a novel curriculum for teaching about the core concepts of quantum computing through quantum agent models implemented for managing robots' decision processes. Specifically, it delves into the use of a variety of quantum algorithms, such as quantum random walks, to be used in tandem with classical reinforcement learning algorithms in order to enable robots to improve their performance on specified design goals. Such an approach allows learners to visually understand the impacts that quantum algorithms can have, a skill directly correlated to higher learner retention rates.

Abstracts

Poster

Landscape of Quantum Information Science and Engineering Education in the United States

Andi Pina, Rochester Institute of Technology, United States
Mike Verostek, Rochester Institute of Technology, United States
Brett Boyle, Rochester Institute of Technology, United States
Mateo Cacheiro, Rochester Institute of Technology, United States
Matt Lawler, Rochester Institute of Technology, United States
Namitha Pradeep, Rochester Institute of Technology, United States
Ella Watts, Rochester Institute of Technology, United States
Colin G. West, University of Colorado Boulder, United States
Heather Lewandowski, University of Colorado Boulder, United States
Benjamin M. Zwickl, Rochester Institute of Technology, United States

This work is part of an ongoing effort to characterize the current landscape of Quantum Information Science and Engineering (QISE) education. The primary goal of this project being addressed here is to characterize the landscape of QISE courses, degree programs, and other QISE educational activities in higher education. Here we present preliminary findings on QISE programs and courses at a wide variety of institutions. Courses were identified via publicly available course catalogs; any course whose name or description contained the word "quantum" was recorded. Data collection is an ongoing effort with an of an overall goal of 1601 institutions comprised of all R1 and R2 institutions, all institutions with an ABET accreditation, all minority serving institutions, and the institutions that award the largest number of STEM bachelors (top 10) and associates degrees (top 5) in every state. The sample encompasses all levels of post-secondary institutions and ensures a level of geographic diversity. Over 5000 courses and 54 programs have been identified. Preliminary results have shown that QISE programs are very rare outside of R1 and R2 institutions. Due to our inclusion criteria for recording courses, we find that there is a significant difference between the distribution of courses recorded among academic departments/disciplines and those that teach QISE topics. In both groups however, the majority of courses are being taught in physics departments. While our results suggest that QISE courses are becoming more common, most institutions are unlikely to have more than one or two courses covering QISE topics.

Poster

Teaching Quantum Science and Technology in Elementary and Lower Secondary School

Mariana Filipova, University of Library Studies and Information Technologies, Bulgaria

The quantum science and technology sector is a rapidly developing field. This is a prerequisite for quantum knowledge to be targeted at wider masses of people who are in different professional fields and at different levels. The changes that will occur in the scientific and business sectors are expected to create additional and even new requirements for knowledge and skills in different types of professions. This turns the popularization of quantum sciences and their training into a necessity, the age limit of which should be lowered, and the level of knowledge offered should become more and more accessible and attractive. In preparation for the quantum era, the only emphasis should not be on additional qualifications for specialists and retraining and lifelong learning for non-specialists, but on building the quantum mindset from childhood and motivation in developing a quantum workforce for various industries in the qualitative sense for both specialists and users. The formation of a positive attitude and basic knowledge at an early age is key to achieving future readiness. The application of appropriate pedagogical methods and the creation of age-relevant motivational activities are of particular importance in achieving this goal. This paper aims to show different types of activities and proven working approaches and methodologies for popularizing quantum science and technology and laying the quantum knowledge foundation for primary and lower secondary school students.

Abstracts

Paper

Why Teach Quantum At Your Own Time: The Values of Grassroots Organisations Involved in Quantum Technologies Education and Outreach

Ulrike Genenz, RWTH Aachen University, Germany
Neelanjana Anne, University of California, Irvine, United States
Zeynep Kılıç, Middle East Technical University, Turkey
Daniel Mathews, B.M.S. Institute of Technology and Management, India
Oya Ok, Terakki Foundation Schools, Turkey
Adrian Schmidt, Karlsruhe Institute of Technology, Germany
Zeki Can Seskir, Karlsruhe Institute of Technology, Germany

This paper examines the intersection of goals and values within grassroots organizations operating in the realm of quantum technologies (QT) education. It delineates a fundamental distinction between the objective to provide education and the drive to democratize learning through principles of inclusivity, accessibility, and diversity. The analysis reveals how these organizations navigate their nascent stages, grappling with the dual challenge of adhering to their foundational values while aspiring for sustainable growth and development in the highly specialized field of QT. The study uncovers the strategic approaches adopted by these entities, including efforts to create educational ecosystems and foster community engagement. The research underscores the potential vulnerabilities of these grassroots organizations, particularly in relation to the longevity and evolution of their initiatives as members transition into professional roles within the quantum sector. Through this investigation, the paper contributes to a nuanced understanding of how emerging educational organizations in the QT field balance their ideological commitments with practical growth considerations, highlighting the critical factors that influence their trajectory and impact.

Talk

Building Quantum Information Science Capabilities at HBCUs: Insights and Recommendations

Kayla Lee, IBM, United States
Michelai Lowe, IBM HBCU Quantum Center, United States
Thomas A. Searles, University of Illinois Chicago, United States

The IBM HBCU Quantum Center is at the forefront of revolutionizing Quantum Information Science and Engineering (QISE) education and research through a one-of-a-kind industry academic partnership. In this presentation, we delve into various strategies for building Quantum Information Science and Engineering (QISE) capabilities at Historically Black Colleges and Universities (HBCUs), drawing insights from initiatives such as the IBM HBCU Quantum Center while considering the broader context. Our discussion encompasses the current status of QISE initiatives at HBCUs, including curriculum development, research capabilities, and faculty demographics across physics, computer science, and engineering departments.

We explore the interdisciplinary nature of quantum education and research, emphasizing collaborative efforts aimed at equipping students with the skills necessary for success in advanced computing technologies of the future.Drawing upon the experiences and achievements of HBCUs involved in quantum initiatives, we offer actionable recommendations for enhancing capacity-building efforts. These recommendations encompass curriculum enhancement, faculty recruitment and retention strategies, research collaboration frameworks, and initiatives to promote diversity and inclusion across disciplines.

In conclusion, this presentation provides a comprehensive overview of the ongoing efforts to build QISE capabilities at HBCUs, informed by both specific initiatives such as the IBM HBCU Quantum Center and broader trends within the HBCU community. Through collaboration and strategic investment, we can further advance quantum education and research, ensuring that HBCUs play a pivotal role in shaping the future of quantum information science.

Abstracts

Paper

Quantum Computing Society of the Philippines: An NGO Perspective on Promoting Quantum Information, Science, and Technology in the Philippines

Dylan Josh Lopez, De La Salle University, Philippines
Bobby Corpus, Quantum Computing Society of the Philippines, Philippines
Elmer Peramo, Advanced Science and Technology Institute, Philippines
Jabez Ayson, Don Honorio Ventura State University, Philippines
Angela Nicole Masongsong, De La Salle University Integrated School, Philippines
Lance Dominic Raquel, University of San Carlos, Philippines

The development of Quantum Information Science and Technology (QIST) as an emerging technology among developed and developing countries has caught the attention of governments, industries, and educational institutions. However, not all countries have equal starting points in promoting QIST amongst different sectors. Several players in various countries promote QIST as a discipline and education. Although significant developments in quantum technology are focused in Western countries, great innovation can also be seen in Eastern countries, specifically Asia. The Philippines is one of several developing countries in Asia that is in the process of adopting QIST in multiple sectors. In this paper, the Quantum Computing Society of the Philippines (QCSP) is introduced as one of the arms of the country for promoting QIST to the public. Further in this paper, the initial impact of QIST promotion on various communities across the Philippines through multiple activities and educational efforts is explained. Several critical success stories for different audiences were described, wherein initial acceptance of QIST was evident through hackathons and lecture series. Events held show improvement in interest and proficiency in the foundations of QIST.

Paper

Quantum Game Club: Engaging with Quantum Computing Through Interactive Learning

Dongyang Li, Purdue University, United States
Zirui Zhang, Purdue University, United States
Xinzhe Xu, Purdue University, United States
Mahdi Hosseini, Northwestern University, United States

With the rapid evolution of quantum computing, education in quantum technology should encompass both theoretical knowledge and practical applications relevant to industry and research. We aim to create an educational model that integrates learning, application, and research in quantum computing for students of all levels. Bridging the gap between coursework and active research, a club led by students provides comprehensive learning modules, followed by mini-challenges, which aim to engage students in active research in the field. These challenges have led to the development of web and standalone applications, contributing to both community and academic knowledge. Throughout its operation, the club has introduced a series of learning materials covering fundamental to advanced quantum computing topics, combined with hands-on challenges and projects that transitioned students from theoretical understanding to practical applications. This paper discusses the structure and outcome of the club activities, highlighting specific educational strategies taken and their educational and research achievements. Results indicate the practicality of the club's structure, evidenced by the members' contributions to the field through application development and publications. By detailing the club's methodology, achievements, and challenges, this paper aims to provide insight for educators looking to cultivate similar programs that encourage active learning and research in quantum computing.

Abstracts

Talk

Using Quantum Network Explorer for Outreach and Knowledge Sharing

Ravisankar A V, Delft University of Technology, Netherlands
Mark Önder Karpat, Delft University of Technology, Netherlands

Quantum Network Explorer (QNE) is an open-source platform to learn, explore, and build quantum network applications. As part of the European Union initiative EuroQCI, QNE is responsible for engaging with wider audience to raise awareness of quantum networks (for example, through educational and coding workshops), and function as a demonstrator platform for running quantum network applications. Thus, QNE has a unique standpoint of being the "front-end" of EuroQCI initiatives, a platform for running quantum network applications (with both simulator and hardware integration) and act as a prominent European hub for expertise in quantum networks. In this talk, we give a short overview of the features provided by QNE that helps it in disseminating quantum network topics to audience of varying proficiencies, and its efficacy so far. These features include, but not limited to, designing a community application library for users to share their network applications, live animations for explaining quantum network protocols, and using abstraction to explain complex networking simulator through our Knowledge Base (KB). Expected target audience for this talk would include people interested in community building, those who would like to know about the lessons we learned by organizing workshops and technical tutorials, and those who are curious about the European efforts in building a quantum network ecosystem.

Talk

Towards an inclusive and interdisciplinary quantum workforce through Quantum Education

Nithyasri Srivathsan, SheQuantum, Singapore

Quantum Computing is the future and Quantum Education is the Present. Quantum Computing is poised to become an important scientific advancement to solve complex problems. Quantum being a young field, lacks diverse interdisciplinary talent, posing a barrier in making quantum computers useful. As Quantum Computing emerges as the future, education in this realm assumes critical importance today. SheQuantum, the world's first quantum computing eLearning platform whose inspiring approaches have created a global footprint spanning 300+ research institutions across 70+ countries, supported by collaborators from industry and academia, strongly believes that quantum computing education must be accessible for people diverse in gender, geography, and discipline. This talk by the Founder, SheQuantum will emphasize on their approaches that are shaping the democratization of quantum computing education through inclusivity and interdisciplinarity using their core principles: "Q-Inspiring", "Q-Educating", and "Q-Creating a talented quantum workforce", collectively referred to as the Quantum IEC, driving significant global impact. The speaker invites industry leaders, academia, and standardization bodies to rally behind SheQuantum's mission, extending their support to empower more women globally and cultivate a skilled quantum workforce essential for the future, which she will highlight in her talk using these three important pillars of Quantum IEC to achieve tangibly in this important mission.

Abstracts

Tutorial

Student-centered activities on basic principles of quantum computing: a guide for instructors

Gina Passante, California State University, Fullerton, United States
Steven Pollock, University of Colorado Boulder, United States
Bethany Wilcox, University of Colorado Boulder, United States

Quantum information science and engineering is a field that attracts students from a wide range of backgrounds. In an introductory quantum computing course at the undergraduate or graduate level, there will often be students from physics, engineering, computer science, and mathematics (among others) in the course. These students will have very different experiences with the material introduced, especially at the beginning. For instance, a physics student with some quantum background may be comfortable with the idea that a qubit can exist in a superposition state, while this may be a foreign concept to a computer science student. We have developed a set of worksheets backed by research into student thinking that are designed to support student understanding of the basic topics of quantum gates and circuit diagrams, tensor products, entanglement, and quantum cryptography. These worksheets are available in paper versions (for in-class use) or as interactive online activities (for homework) that students can complete individually or with small groups. In this tutorial, attendees will first work in small groups on the paper version of this activity as students would in a lecture. Attendees will later interact with the online version of the same activity, which has hints and targeted feedback to help guide students through the most difficult ideas so that it can effectively be given to students as homework. We will collectively discuss ways to effectively facilitate these activities with students.

Tutorial

Using Programming Exercises with Immediate Feedback for Learning and Teaching Quantum Computing

Mariia Mykhailova, Microsoft, United States

In this tutorial we invite the attendees to try out a quantum computing curriculum based on programming exercises with immediate feedback.

This tutorial will consist of two parts, first offering the attendees the learner experience, and then - the curriculum developer experience.

In the first part of the tutorial, we introduce the Quantum Katas - an open-source collection of tutorials and programming exercises that can be used online, by self-paced learners or as a part of a quantum computing curriculum. The participants will solve several simple tasks and see how getting immediate feedback on their work and being able to ask the built-in Copilot for assistance enhances their learning experience.

In the second part of the tutorial, we will show the attendees how to create similar programming exercises and testing harnesses for them themselves, using the tools provided in Azure Quantum Development Kit.

The attendees will leave the tutorial empowered to adopt this programming-focused approach in their studies or educational work, either by using the Quantum Katas and Azure Quantum Development Kit or by developing similar assignments using other quantum programming toolkits. Additionally, they will gain basic understanding of testing their quantum programs outside of educational context.

Abstracts

Paper

Entangling Disciplines: Causality, Entropy and Time-Travel Paradoxes on a Quantum Computer

Maria Violaris, University of Oxford, United Kingdom

Merging disciplines has led to incredible learnings and breakthroughs throughout history, including the discovery of quantum computing: a cross between computation and quantum physics. In this paper, I will discuss how we can cross quantum computing with topics in fundamental physics. This leads to fruitful, interactive learning opportunities that fuse deep open physics problems with key insights about quantum information science. By outlining quantum circuit experiments that can be run on current and near-term quantum computers, I demonstrate how to help learners engage with principles in special relativity, general relativity and thermodynamics. In turn, these connections can advance their understanding of quantum computing. Learners can further explore the quantum computing activities in this paper via the Quantum Paradoxes content series of videos, blogs and code tutorials that I created with IBM Quantum.

Paper

Bridging the Quantum Education Gap: Hands-on Visualization Projects for Quantum Search Algorithm

Yao-Hsin Chou, National Chi Nan University, Taiwan
Yu-Chi Jiang, Princeton University, Taiwan
Shu-Yu Kuo, National Taiwan University, Taiwan
Sun-Yuan Kung, Princeton University, United States

Quantum education has been increasingly emphasized at both the post-secondary and secondary education stages, in line with the advent of the quantum computing paradigm. Traditional quantum computing education, however, necessitates an extensive background in physics, mathematics, and information science, which can be challenging for beginners. This study presents the experience of implementing a college curriculum at National Chi Nan University in Taiwan, designed to enable learners at all levels to grasp the concept of a quantum algorithm using accessible math yet rigorous enough for verification. The study succinctly conveys the concept of the quantum Grover algorithm, provides necessary background knowledge, and elucidates the ideas using three distinct visualization methods. Furthermore, this study offers a novel presentation for aligning the results of geometrical representation with the corresponding quantum circuit layout. The hands-on project demonstration motivates learners to explore solutions using their visualization tool, enhancing their engagement and sense of achievement. Developing these tools deepens learners' understanding and promotes active peer education, thereby improving their participation and retention of quantum knowledge. The visualization tools developed through this process serve as a valuable contribution to quantum education, offering an effective quantum tool and a user-friendly interface for learning, teaching, researching, and providing fresh insights and perspectives. By making quantum computing concepts more understandable through accessible math and visualization, we aim to lower the entry-level barrier to learning quantum computing, encouraging more talents to engage in quantum computing for their research studies.

Abstracts

Talk

Adaptable curricular exercises to support teaching undergraduate quantum information

Steven Pollock, University of Colorado, Boulder, United States
Gina Passante, California State University, Fullerton, United States
Bethany Wilcox, University of Colorado, Boulder, United States
Giaco Corsiglia, University of Colorado, Boulder, United States

Introductory Quantum Information (QIS) topics are taught in a rapidly increasing number of courses and settings, ranging from standalone intermediate or advanced level undergraduate topical courses (often with students from diverse academic backgrounds), to introductory survey courses, and as relatively brief subtopics within a well-established course. We have been developing curricular materials following a research-based approach, resulting in a compilation of adaptable, flexible materials for faculty teaching in varied environments. Our materials include the introductory areas of qubits, quantum gates, entanglement, and quantum cryptography. We have developed a collection of different types of materials, from in-class interactive-engagement questions, conceptually focused activities (available both in paper for small-group activities, and an interactive online format for more individual work), notes for faculty, related homework and exam questions, to a broader conceptual assessment instrument. In this talk, we will share samples of these freely available materials and discuss instructional approaches and implementations.

Talk

Dancing quantum computing and other Curieux quantiques' educational tools and projects

Dominique Wolfshagen, Université de Sherbrooke, Canada
Mélissa Greene, Université de Sherbrooke, Canada

Curieux quantiques is the quantum educational outreach initiative of the Institut quantique de l'Université de Sherbrooke. Its mission is to spread quantum science in an accessible way outside of university walls, mainly, but not exclusively, in French. This talk will provide an overview of Curieux quantiques' diverse activities and their target audiences, which are mainly high school and college students as well as their teachers, but also businesses, science communicators and the general public.

The emphasis will be put on the latest project : the 2-qubit dance, a game that introduces the quantum logic gates. In the game, you get to incarnate the Bloch spheres representing the qubits of a quantum computer by moving your arms in the same way that quantum logic gates rotate the states of qubits.

Anyone who is curious about our educational tools is welcome to the talk. Let's make learning quantum computing fun!

Talk

Sharing of Preliminary PreCollege QIS Research

Karen Matsler, The University of Texas at Arlington, United States

There has been considerable research in the physics education community concerning best practices, but little has been shared regarding instructional sequences for "non required" or challenging courses such as quantum information science (QIS), especially at the pre college level. The Quantum for All project has been working with high school students and teachers to integrate QISE in the pre college classroom. The project uses current or traditional curricula as a means to introduce quantum concepts and then extends student knowledge by using phenomena, technology, and engaging activities. One example is using a traditional physics topic (Malus's law and polarization) to demonstrate superposition and provide applications such as cybersecurity. Results of pre and post assessments indicate the sequence is effective in increasing understandings basic principles of QISE. We will discuss data gathered from the Quantum for All project (NSF #2048691) regarding effective practices and provide suggestions for instructional sequences appropriate for integrating QISE in high school classrooms.

Abstracts

Talk

Quantum Computing Conceptual Survey: Results from 2 semesters of pilot data collection

Josephine C. Meyer, University of Colorado Boulder, United States
Gina Passante, California State University, Fullerton, United States
Steven J. Pollock, University of Colorado Boulder, United States
Bethany R. Wilcox, University of Colorado Boulder, United States

The Quantum Computing Conceptual Survey (QCCS) is a research-based assessment in the pilot and validation phase that aims to reliably benchmark student learning in quantum computing fundamentals at the introductory undergraduate-to-graduate level. We present preliminary results from the first two semesters of pilot data collection and statistical analysis, including findings pertaining to equity and to better understanding student challenges and reasoning patterns in quantum computing.

We anticipate this presentation will be of particular interest to educators, education researchers, and curriculum developers in quantum computing and quantum information at the postsecondary level.

Talk

The Quantum Computing Conceptual Survey – an assessment instrument for the growing educational ecosystem of quantum computing

Bethany Wilcox, University of Colorado Boulder, United States
Josephine Meyer, University of Colorado Boulder, United States
Gina Passante, California State University, Fullerton, United States
Steven Pollock, University of Colorado Boulder, United States

The recent growth of quantum information science, and specifically quantum computation, has led to a surge of new courses and programs designed to teach quantum computation to STEM students. As a relatively new and deeply interdisciplinary field, it is important to ensure that these new courses and programs are achieving their educational goals and serving the needs of all their interdisciplinary stakeholders. Moreover, it is important that these efforts are grounded in reliable information on student learning. Historically, research-based assessments designed to measure student learning in a particular field have provided an important tool to ensuring educational innovation has been informed by data on student learning. As quantum computation is a relatively new field, no such research validated instrument targeting core content in this area has been developed. We attempt to fill this gap with the newly developed Quantum Computing Conceptual Survey (QCCS). In this talk, we will present the QCCS, its development and scope, and preliminary evidence of its validity and reliability.

Abstracts

Talk

Student ideas and difficulties when reasoning around the CNOT gate

Gina Passante, California State University, Fullerton, United States
Jonan-Rohi Plueger, University of Colorado, Boulder, United States
Steven Pollock, University of Colorado, Boulder, United States
Bethany Wilcox, University of Colorado, Boulder, United States

Introductory courses targeting quantum computation aim to provide an accessible introduction to the ideas and applications of quantum information for students from a variety of disciplines, including engineering, physics, and computer science. Early in a quantum computing course, students are introduced to the CNOT gate as one of the most important two-qubit quantum gates, in part due to its ability to entangle two qubits. In order to design effective instruction that meets the specific needs of learners, discipline-based education researchers investigate student learning of specific topics to identify both productive resources and notable difficulties with the content. To better understand student learning of the CNOT gate, we conducted think-aloud interviews with ~20 students from physics, computer science, and engineering, in which they worked through a series of questions targeting their understanding and use of the CNOT gate in the context of quantum computation. We are particularly interested in how students from different disciplinary backgrounds interact with questions about the CNOT gate. In this talk, we will discuss findings from this set of interviews and emphasize implications for instructors teaching quantum computation at the undergraduate level.

Paper

Quantum Error Correction for kids

Richard A. Wolf, University of Galway, Ireland

This extended abstract presents an intuitive gamified approach to one of the core concepts in quantum error correction: the stabiliser formalism. The game gradually builds up complexity and takes the players from classical repetition codes to Calderbank-Shor-Steane (CSS) codes. Through its lightweight mechanics, the game offers a glimpse into the notions of communication channel, noise and encoding as well as decoding. It is designed to be inclusive of a wide range of ages and abilities.

Abstracts

Paper

Towards Personalized Quantum Information Learning for Dynamic Class Environment and Student Engagement

Nikos Chrisochoides, Old Dominion University, United States
Norou Diawara, Old Dominion University, United States
Michail Giannakos, Norwegian University of Science and Technology, Norway

This is a white paper on Workforce Development for Quantum Information Sciences (QIS) led by the Center for Real-Time Computing at Old Dominion University (ODU). We plan to investigate the potential of video lectures in supporting QIS. Specifically, we focus on following four objectives: (a) design a two-course series for both Master-level and PhD students; b) an upgrade of Experimental Lecture System (ELeSy) to test new, innovative, and transformative approaches for inclusive QIS education; c) design and implementation of a mixed-method systematic empirical study on the effects of video learning styles (in-person flipped classroom and voluntary video use) on graduate students' QIS studies, and d) integration of the empirical results and requirements and development of a framework with practical (e.g., best practices) and technical (e.g., systems' design guidelines) knowledge, addressing how instructors and developers can increase video lecture benefits by incorporating AI-based learning tools. The contributions of our white paper are a) methodology for evaluating a novel experimental video analytics system, b) the systematic empirical evaluation of video lectures as a learning technology for QIS, and c) motivating the discussion on how instructors and developers can increase video lecture benefits. The project results (over the next three to five years) will be shared with the broader community and participants.

Talk

The Power of Student-Led and Grassroots Organizations in the Quantum Education & Workforce Pipeline

Sanskriti Deva, North Carolina State University, United States

Student-led organizations are powerful catalysts for advancing quantum education and enhancing the quantum workforce pipeline. In this talk, Sanskriti Deva will explore the significant impact that grassroots student initiatives can have on the field of quantum computing. Drawing from her experience as the founder of the Quantum Computing Club at North Carolina State University, which grew from a handful of members to over 500 in just one year, she will share insights on how these organizations can make quantum computing more accessible, inclusive, and diverse.

Sanskriti will discuss best practices for fostering and sustaining student-led organizations on campuses and in local areas, providing valuable strategies for researchers, faculty members, quantum enthusiasts, and students to build strong communities for quantum computing. She will highlight the domino effect these organizations can have on student motivation and engagement across all levels of quantum learners, from beginners to advanced.

Attendees will learn about high-impact programming that Sanskriti's club implemented, including hackathons, international conference trips, corporate collaborations with leading quantum computing companies, research talks, outreach teaching quantum computing at local schools and museums, and even a movie premiere in partnership with Paramount Pictures. These initiatives not only enhanced learning but also cultivated a vibrant and diverse community passionate about quantum computing.

By sharing her journey and the transformative effects of student-led efforts, Sanskriti aims to inspire and equip others to create and support similar organizations and communities that contribute to the growth and diversification of the quantum education and workforce pipeline.

Abstracts

Paper

Quantum Horizons: Examining the Scope of Quantum Computing in Latin American Universities

Laura Gatti, Universidad de Montevideo, Uruguay
Rafael Sotelo, Universidad de Montevideo, Uruguay
Agustin Panizza, Universidad de Montevideo, Uruguay

This paper systematically investigates the educational contributions of Latin American institutions in the field of quantum computing. Utilizing the Scopus database, we refined a dataset of 1,245 articles to ensure accurate affiliation with Latin American entities from 2021 to the present. Our study reveals that 1,099 of these papers are affiliated with universities ranked in the QS Latin America & Caribbean rankings, highlighting significant engagement in quantum education and research. We emphasize the role of universities in the early adoption and dissemination of quantum technologies, focusing on how they train new generations of scientists and engineers. Additionally, we explore contributions from non-ranked institutions, including 46 publicly funded research centers and corporate entities. By mapping who is publishing in this area and identifying regions with a higher geographic concentration of production, we aim to uncover the "installed capacities" in terms of researchers and educational initiatives. The analysis includes economic indicators such as GDP and R&D expenditure, offering insights into how educational and research efforts align with national capacities. This synthesis is visually represented through a comprehensive map, illustrating the geographic and institutional distribution of quantum computing education and research across Latin America. Keywords— Quantum computing, Latin America, education, research contributions, Scopus database, QS rankings.

Talk

Quantum Education in Latin America for Younger People: The Experience of Quantum Computing Seedbeds and their Results

Alcides Montoya Cañola, Universidad Nacional de Colombia, Colombia
Cristian E. Bello, Universidad Nacional de Colombia, Colombia

In 2021, we started a seedbed of quantum computing and artificial intelligence aimed at young people from all over the country and Latin America. Our proposal began as a large-scale training process, aimed at low-income communities, vulnerable students and women in science. For more than three years we worked in training these young people in quantum computing and artificial intelligence, we created a virtual community based on the Twitch platform, all our content open and available to anyone who wanted to learn about these topics. Our material was used in real time and then on a YouTube channel, where every week we dictated a one-hour class on these topics. Today we have more than 4 courses available, a center of excellence in the subject, and a vibrant community of students from all over the country, working at different stages of their training. The scheme we use is open science for all, we look for inclusion mechanisms and create new possibilities for these young people to develop high-level work, and we connect this talent already formed with research groups in Europe and the United States. We even write articles and make important contributions to both topics. Our virtual research group connects talent from all over the country and Latin America, we stay alive in social networks, in events, we take these young people to master's and doctoral levels.

Abstracts

Paper

Driving Quantum Literacy: Multi-Stakeholder Collaborative Efforts in Philippine Education

Jul Jon General, Advanced Science and Technology Institute, Philippines
Ross Romuel Mariano, Advanced Science and Technology Institute, Philippines
Jeffrey Aborot, Advanced Science and Technology Institute, Philippines

Recent advancements in quantum computing have sparked tremendous interest among students, professors, and enthusiasts, driving a surge in exploration and inquiry. To harness this momentum effectively, collaboration between research institutions, universities, and enthusiast communities is imperative. Furthermore, there's a pressing need to enhance quantum literacy among students and experts from allied fields such as engineering and computer science, which necessitates the development of educational programs specifically tailored to their needs.

This paper delves into the collaborative initiatives orchestrated between the Department of Science and Technology-Advanced Science and Technology Institute (DOST-ASTI), universities, and enthusiast communities to bolster quantum education and awareness in the Philippines. Through presentations delivered to five universities, a hackathon co-hosted with OneQuantum Philippines, and a lecture series in alliance with the Polytechnic University of the Philippines (PUP) engineering faculty, these initiatives aim to ignite interest, offer hands-on experience, and foster a sustainable ecosystem for quantum education and research. By emphasizing the pivotal role of multi-stakeholder engagement, this paper underscores the transformative potential of collective efforts in propelling quantum science and engineering education not only within the Philippine context but also on a broader global scale.

Talk

Towards a Faculty Learning Community in Quantum Education for HS Teachers in the state of Indiana

Dan-Adrian German, Indiana University Bloomington, United States
Christian Scott, Indiana University, United States
Christina Snyder, The Westminster Schools, United States
Carla Gehlhausen, Hoosier College and Career Academy, United States
Matt Mindach, Wabash High School, United States
Blake Clevenger, Randolph Eastern School Corporation, United States
Ahmad Faiz, Indiana University Bloomington, United States
Elmar Bucher, Indiana University Bloomington, United States
Scott Winchester, Indiana University, United States
Rebekah Randall, Canterbury High School, United States

In the US quantum topics appear on the high-school (HS) curriculum standards in just two states: OH (Computing) and TX (Physics). Reaching out to HS and even middle school students (and their teachers) presents obvious long-term benefits in terms of workforce development for the quantum industrial ecosystem. Challenges associated with outreach to HS and middle school teachers are modulated by the short-term imperatives of upskilling and reskilling. While HS teachers are very resourceful and dedicated individuals they are also notoriously overworked and underpaid. Standing in the way of successful and widespread introduction of quantum computing (QC) and quantum information science and engineering (QISe) topics in HS and middle schools are three obstacles: (a) lack of materials at the right level for both students and instructors, (b) funding and opportunities (or, support) for professional development for teachers, and (c) lack of state standards. With help from the QED-C we have had success in proposing a quantum architectures knowledge unit for the new ACM/IEEE-CS/AAAI curricular guidelines CS2023 [1, 2].

Abstracts

Talk

Towards a Faculty Learning Community in Quantum Education for HS Teachers in the state of Indiana (abstract continued)

In 2021 with assistance from Indiana University's Quantum Science and Engineering Center (IU QSEc, [12]) we established a boot camp for incoming students in our accelerated Master's in QIS program (an interdisciplinary program aimed at STEM graduates not majors of Physics.) This year with support from the Center for Quantum Technologies [5, 6] and with assistance from the Indiana Computer Science Teachers Association (IN CSTA) we have successfully repurposed the Boot Camp for the dual target of establishing a Faculty Learning Community (FLC) for HS and middle school teachers in the state of Indiana. A boot camp designed to engage, educate and support can bootstrap itself into a community. We report on this year's [11] cohort experience that included 9 HS teachers (one middle school) from the state of IN and one HS teacher from the state of GA (along with 13 other IU graduate and undergraduate students). The class was six weeks long, met daily, the delivery was hybrid (teachers/students were spread all over IN and the US). Lectures and office hours were held in person for those in Bloomington and via Zoom for everybody else. There was one guest lecture by John McNally (Wolfram Academic Innovation Group) and three guest lectures from Maria Violaris (Oxford University, UK). Support for the course included materials freely available online from Thomas Wong [7] and Martin LaForest [8] as well as a set of materials developed expressly for this class [3, 4] based on (and extending) the remarkable rewriting system introduced by Terry Rudolph in "Q is for Quantum" [9, 10].

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Talk

Quantum Computing Education in the Humanities: Project-Based Learning Development

Jose Hernandez, Florida State University, United States

With the emergence of quantum computing applications in digital humanities research, particularly in areas such as natural language processing, computer vision, and network analysis, there is a growing need to address the education of practitioners in the humanities, social sciences, and the arts (HSSA). This presentation aims to explore the essential knowledge required for these groups to understand and implement quantum computing. To do this, we will draw upon the past work of digital humanities educators in emerging technologies, such as high-performance computing, to inform our future steps in the development of quantum education materials for HSSA learners. As an example of concrete initiatives, we will discuss the benefits of discipline-specific educational materials and how to build upon existing curriculums such as QWorld for project-based learning experiences in quantum humanities education. The expected audience for this talk are educators/researchers who are exploring quantum computing education in non-traditional disciplines and/or those who are interested in employing project-based learning in quantum education materials.

Abstracts

Tutorial

Exploring The Quantum Enigmas in the classroom

Ghislain Lefebvre, Université de Sherbrooke, Canada

The Quantum Enigmas are a series of 12 animated videos that introduces high school, college, and university students to quantum computing in an intriguing and engaging way. Each video, ranging from 7 to 10 minutes, presents classic enigmas solved on the quantum composer through the application of quantum computing principles, devoid of complex mathematical equations or Python programming. The pedagogical approach will be explained in detail.

Following an initial introduction to fundamental concepts such as qubits, quantum logic gates, and measurement, The Quantum Enigmas (free access on Youtube) provide students with tangible problems to solve using a quantum computer. By doing so, it minimizes entry barriers and emphasizes comprehension of the novel paradigms inherent to quantum computing.

The tutorial will commence with an explanation of the video series' concept, followed by a practical example, using the first Enigma, suitable for classroom implementation (IBM Quantum or equivalent). Interactive segments will enable participants to gauge their understanding of enigmas and tackle exercises tailored to presented scenarios, including the making and simplification of quantum circuits on the board. This way of using the Quantum Enigmas has been used several times in the classroom and will provide the attendees all necessary information to do so themselves.

While the videos strictly adhere to quantum logic gates for solving the scenarios, supplementary Python notebooks have been developed for those seeking a deeper understanding of The Quantum Enigmas. These additional exercises will be showcased during the tutorial, inviting participants to explore further the challenges.

Geared towards educators interested in integrating The Quantum Enigmas into their curriculum and students eager to delve into quantum computing in an enjoyable manner, the tutorial will provide participants with access to video links and advanced-level notebooks.

Attendees are encouraged to bring their own computers to partake in the advanced exercises. All tools presented in the tutorial are free though some may require an account (IBM Quantum, Skillsbuild, notebooks).

Abstracts

Paper — Developing an Undergraduate Quantum Workforce

Dongyang Li, Purdue University, United States
Priyam Gupta, Purdue University, United States
Yi Lin Yang, Purdue University, United States
Eric Christopher Broyles, Purdue University, United States
Lakshay Goel, Purdue University, United States
C. Robert Kenley, Purdue University, United States

To fulfill the growing demand for the future workforce in quantum, we need to come up with workforce development programs at the undergraduate level. This paper reflects on discussions with industry professionals and academics that have indicated the need for a future quantum workforce, including all levels of post-secondary education, and it presents an exploration of an experiential learning pedagogy aimed at teaching quantum concepts to undergraduate students. The challenge is the intricate and often abstract domain of quantum mechanics. Due to their complexity, quantum concepts pose a unique challenge in educational settings, making hands-on demonstration and accessible understanding a formidable task. We review the pedagogical approach of project-based learning in The Quantum Game Club at Purdue, a student-led organization that is a community from diverse academic backgrounds, such as Computer Science, Physics, and Engineering, who work on fun and creative quantum computing projects. The club aims to introduce students to quantum and provide the necessary resources to work on projects by utilizing curated assignments that help students understand basic information about quantum circuits and algorithms. After the introductory learning phase, the students are assigned to different teams working on projects related to their interests. Club students successfully completed projects resulting in publications and web apps and went on to win quantum hackathons. To further enhance the learning experience, the VIP (Vertically Integrated Projects) team QuantAlgo was established to provide students with a more immersive industrial experience by facilitating collaboration with companies on more research-heavy projects.

Talk — The Design and Implementation of a Quantum Information Science Undergraduate Program

Sarah Blanchette, Université de Sherbrooke, Canada
Danièle Normandin, Université de Sherbrooke, Canada
Michel Pioro-Ladrière, Université de Sherbrooke, Canada
Lyne StHilaire, Université de Sherbrooke, Canada
Armand Soldera, Université de Sherbrooke, Canada
Karl Thibault, Université de Sherbrooke, Canada
Dave Touchette, Université de Sherbrooke, Canada

Quantum information science is a burgeoning research field attracting vast public and private investment in the last decade. This quick rise has led to a talent gap, where there are more open positions than new graduates who can fill these roles. To meet this critical need, highly skilled individuals must be trained quickly. We thus present a new undergraduate degree in quantum information science at Université de Sherbrooke, aiming to address this gap by training quantum software developers in three and a half years. At the end of this training, they will be ready to join the quantum workforce. The creative process leading to a coherent curriculum, as well as why the local ecosystem led to these choices, is detailed. To support this initiative, we make use of innovative pedagogy, internships and strong links with the quantum industry ensuring the degree fulfills its role in preparing the students for their future careers. To help interested parties in creating such a relevant training program, challenges faced during the creation of this new interdepartmental degree are discussed.

Abstracts

Tutorial — Exploring Virtual and Customised Laboratory for Quantum Computing Software

Alberto Maldonado-Romo, Instituto Politécnico Nacional, Mexico
Ricky Young, qBraid, United States

The aim of this tutorial is to provide attendees with the necessary skills to use platforms such as qBraid, allowing them to create a quantum computing curriculum that is rich in programming exercises without being restricted to specific software or architectures. The tutorial is split in two parts. The first part is an introductory user experience on the qBraid platform. This is followed by a series of exercises in which the participants act as developers of quantum algorithms. This part will give an overview of the qBraid platform, its functionalities and exercises such as the creation of environments and shortcuts. Participants will also learn about the benefits of the platform, including saving code snippets and accessing educational resources. Participants will delve deeper into using the qBraid SDK in the second part of the tutorial. Intermediate level exercises and demonstrations will be performed using various frameworks including Qiskit, Pennylane, Braket, Cirq and OpenQASM, as well as exploring different hardware architectures. On completion of this tutorial, students will have the necessary skills to navigate with ease across a range of software and hardware technologies, encouraging a flexible and versatile approach to teaching without the constraints of a single technology.

Paper — QuantumCrypto: A Web Framework for Quantum Cryptography Education

José Ossorio, University of Victoria, Canada
Jean Frédéric Laprade, Université de Sherbrooke, Canada
Ulrike Stege, University of Victoria, Canada
Hausi Müller, University of Victoria, Canada

Quantum cryptography protocols leverage fundamental quantum computing principles such as superposition and entanglement, making them valuable tools for quantum computing education. While existing web platforms offer interactive interfaces to experiment with these protocols, none of them exploits the context in which cryptographic tasks are conducted: real-time communication between parties. We introduce QuantumCrypto—an innovative framework designed to present quantum cryptography protocols as interactive experiences connecting multiple players. QuantumCrypto aims to bridge the gap between theoretical quantum concepts and practical understanding by enabling users to engage in real-time simulations of quantum cryptography protocols. Our solution is extensible, allowing for the integration of new protocols. We demonstrate the versatility of our framework by showcasing the implementation of the BB84 protocol. Through detailed descriptions of the framework's backend and frontend components, we provide insights into its design and implementation. We also elucidate the learning experience of learners who used QuantumCrypto to simulate the BB84 protocol, and provide suggestions for utilizing our tool in a learning environment. To conclude, we summarize our work and present ideas for integrating more quantum cryptography protocols in the future.

Abstracts

Paper QUINTET: An Experiential Learning Platform for Quantum Education

Abhishek Parakh, Kennesaw State University, United States
Mahadevan Subramaniam, University of Nebraska at Omaha, United States

This paper describes the conceptual framework behind QUINTET, an experiential learning platform, for education and workforce development in secure quantum communication, quantum networks and quantum computation. The platform enables users to generate lessons using QUINTET engine while specifying learning objectives and constraints. The engine composes the required learning objects using fractional knapsack problem to generate best possible lesson(s) that satisfy the given constraints. This paper primarily describes the working of QUINTET and generation of lessons.

Paper Niel's Chess: A Quantum Game for Schools and the General Public

Tamás Varga, Constructor Institute Schaffhausen, Switzerland

In this paper, a quantum variant of chess is introduced, which can be played on a traditional board, without using computers or other electronic devices. The rules of the game arise naturally by combining the rules of conventional chess with key quantum-physical effects such as superposition and entanglement. Niel's Chess is recommended for ages 10 and above, to everyone who wishes to play a creative game with historical roots and at the same time gain intuition about the foundational quantum effects that power cutting-edge technologies like quantum computing and quantum communication, which are poised to revolutionize our society in the coming decades. Takeaways from a pilot educational session that was carried out with 10-to-12-year-old children are also presented.

Abstracts

Talk

qBook: A hands-on cloud-based course platform to learn quantum computing and its applications

Ricky Young, qBraid, United States
Ryan Hill, qBraid, United States
Akash Kant, qBraid, United States
James Brown, qBraid, United States
Kenneth Heitritter, qBraid, United States
Tarini Shekhar Hardikar, qBraid, United States
Kanav Setia, qBraid, United States

Quantum computing, as an industry, is expanding its application base and gaining momentum. According to a McKinsey report, by 2040, there will be a concerning talent gap in the quantum industry, with roughly 3x higher demand for skilled quantum scientists, versus masters' graduates in quantum technology.

To address this talent gap, it is important to bring in quantum technology coursework in an accessible manner. To aid this mission, quantum engineers and scientists at qBraid Co have developed qBook, an interactive platform that hosts quantum courses, provides access to qBraid Lab (a cloud-based research platform), and provides access to 20+ quantum devices and simulators. This allows students to learn about quantum computing through hands-on experimentation, first-hand skill building, and continuous testing of the algorithms they are learning about. The combination of qBook and qBraid Lab provide instructors access to internal modules for quantum applications, such as chemistry, life sciences, and finance, that could be included in the curriculum directly, or used to create their own independent courses. The platform allows users to utilize the best resources in various different quantum software programs, such as Qiskit, Pennylane, Braket, and OpenFermion, each with great educational resources that can be easily used and adapted. Together, the two tools make for a complete learning environment: qBraid Lab offers students a playground where they can experiment and run programs on various quantum devices, and qBook offers instructors a platform to publish and host content in an interactive fashion. Furthermore, qBook also offers access to Qubes, an introductory course designed to teach quantum computing visually, with no prerequisites. Qubes is a full course, with video lectures, notes, periodic quizzes, games, and direct ability to run codes on qBraid-Lab. Students can also take a secondary course after the initial visual course.

These hands-on lab designs and code tutorials will be discussed, along with the effectiveness of the tools and their accessibility for a broad audience. Early insights with trial courses at a few universities, alongside a few corporate partnerships, have demonstrated how useful this platform is. In this work, we will share the importance of bridging the quantum talent gap, provide a demonstration of this platform, and share initial results from early adopters of qBook.

Abstracts

Paper

QGrover: Teaching Grover's Algorithm Through Visual Exploration

Samantha Norrie, University of Victoria, United States
Anthony Estey, University of Victoria, United States
Hausi Müller, University of Victoria, United States
Ulrike Stege, University of Victoria, United States

Quantum Computing is a rapidly growing field that requires a multidisciplinary workforce. In order to successfully educate this up-and-coming workforce, it is crucial that Quantum Computing Education is filled with a variety of tools that support different backgrounds and learning styles. Incorporating visual exploration into learning allows for the use of multiple learning channels and can promote collaborative learning.

We present QGrover, an interactive visualization tool that supports the learning of Grover's algorithm, an important quantum search algorithm. QGrover is a browser-based tool that allows users to examine the different components of Grover's algorithm while exploring experimentally how different parameters affect it.

We also present sample questions for using QGrover in a classroom setting. Sample answers for the questions are included with the questions.

Paper

QNotation: A Visual Browser-Based Notation Translator for Learning Quantum Computing

Samantha Norrie, University of Victoria, United States
Anthony Estey, University of Victoria, United States
Hausi Müller, University of Victoria, United States
Ulrike Stege, University of Victoria, United States

One of the initial challenges of learning Quantum Computing is understanding the different notations used in the field. It is crucial that learners understand the different notations used in Quantum Computing in order to ensure that they can develop a robust comprehension of the field by being able to make use of variety of resources. Depending on their technical background, some learners may struggle with certain notations more than others.

We present QNotation, a browser-based tool that helps learners explore notations in Quantum Computing by translating between a quantum circuit of the learner's choice to circuit, Dirac, and matrix notation. This allows the learner to be able to identify the differences and similarities between the different notations.

QNotation was built to be used throughout one's foundational Quantum Computing learning journey. While users may start using the tool to learn the aforementioned notations, they can continue to use QNotation later on to help them learn how other core Quantum Computing concepts work. In addition to being able to load one's own quantum circuits, multiple pre-composed examples, including Quantum Fourier Transform and Grover's search algorithm, can be loaded into the tool to be explored and modified by the learner. QNotation can be used independently by learners as well as in the classroom.

We also present sample questions for using QNotation in the classroom. These questions focus around using QNotation to teach the aforementioned notations as well as foundational Quantum Computing concepts.

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