AT HOME WITH ENGINEERING EDUCATION

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At Home with Engineering Education

Evaluation: A Teacher Professional Development Program Using Wireless Communications and NGSS to Enhance STEM Teaching & Learning

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NYU TANDON SCHOOL OF ENGINEERING

COLUMBIA ENGINEERING The Fu Foundation School of Engineering and Applied Science

RUTGERS School of Engineering

COSMOS

NSF

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Introduction

- Global economy changing vis-à-vis technological advances
- ***All students*** should have quality access to science, technology, engineering, and math (STEM) precollege coursework
- Higher education is **critical** in preparing the next generation of STEM professionals
- **This work** → Develop a teacher's professional development program and an educational toolkit, using wireless communications and NGSS

How could engineers and educators collaborate to create a wireless communications teacher PD program in order to develop NGSS lessons with STEM teachers?

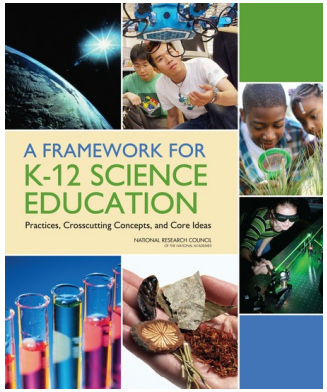
Next Generation Science Standards

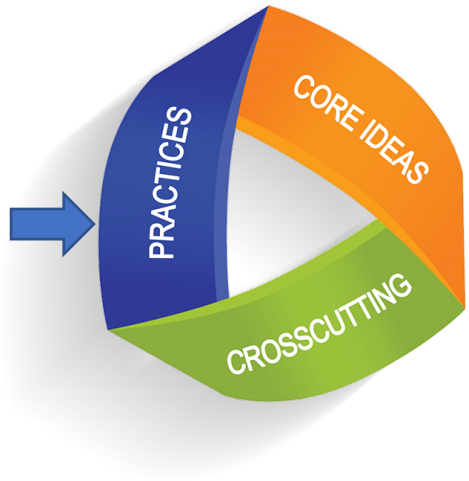
- What is the Next Generation Science Standards?
  - A set of goals that lay the groundwork for K–12 education
  - Based on 'A Framework For K–12 Science Education'
  - Developed at the National Research Council in 2012
  - Prepare *all students* for college, careers and life

8 Science and Engineering Practices

44 Disciplinary Core Ideas

7 Crosscutting Concepts





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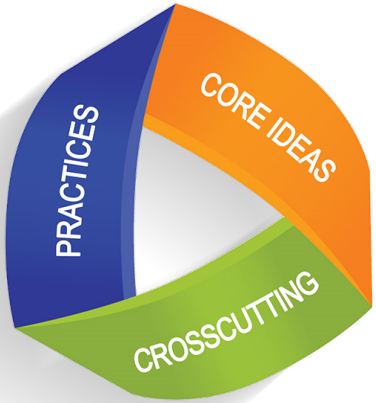
NGSS 3-Dimensional Learning

- NGSS define 'Performance Expectations' as assessable statements of what students should be able to do if they understand the content
- Performance Expectations integrate three dimensions that focus on understanding and application:
  - ***Science and Engineering Practices:*** Behaviors for investigating and building models
  - ***Disciplinary Core Ideas:*** Key concepts specific to the course content
  - ***Crosscutting Concepts:*** Concepts that link various science domains



PD Program Overview (1/2)

The program in divided in five conceptual phases:

a. ***Lecture and lab phase:*** The participants are introduced in fundamental and some advanced concepts in wireless communications and networking

b. ***Design phase:*** The participants conduct research on potential educational NGSS STEM lessons with a hands-on wireless labs using the 'COSMOS Educational Toolkit'

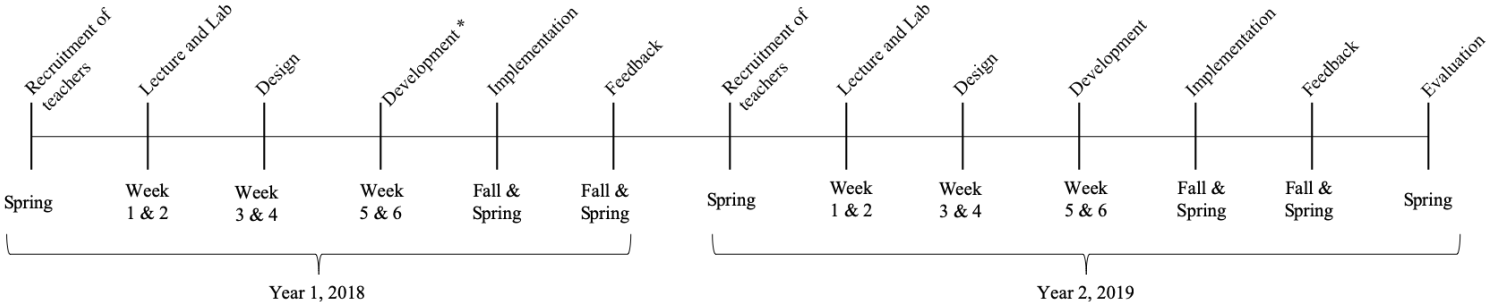


Fig: Teacher PD program phases timeline. *Phase when the 'COSMOS Education Toolkit was created.

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PD Program Overview (2/2)

c. ***Development phase***: the teachers co-develop with the researchers their best ideas on how to use the wireless labs for NGSS-aligned STEM lessons

d. ***Implementation phase***: teachers and students use the developed lessons in the class during the school year

e. ***Feedback phase***: teachers provide feedback in order to improve the NGSS STEM lessons and develop new ones

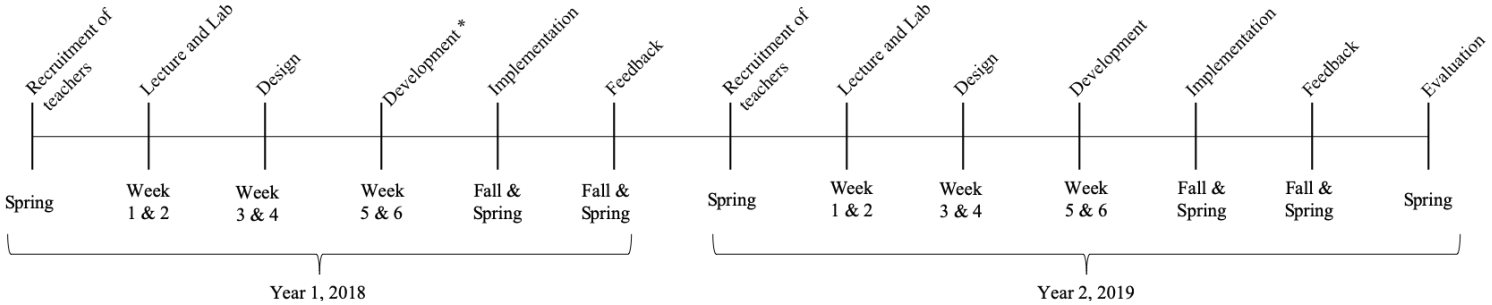

Fig: Teacher PD program phases timeline. *Phase when the 'COSMOS Education Toolkit was created.

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Lecture/Lab and Design Phase

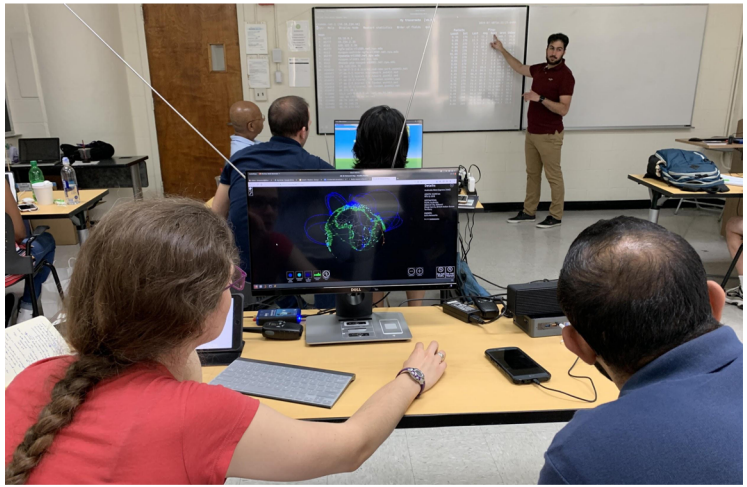


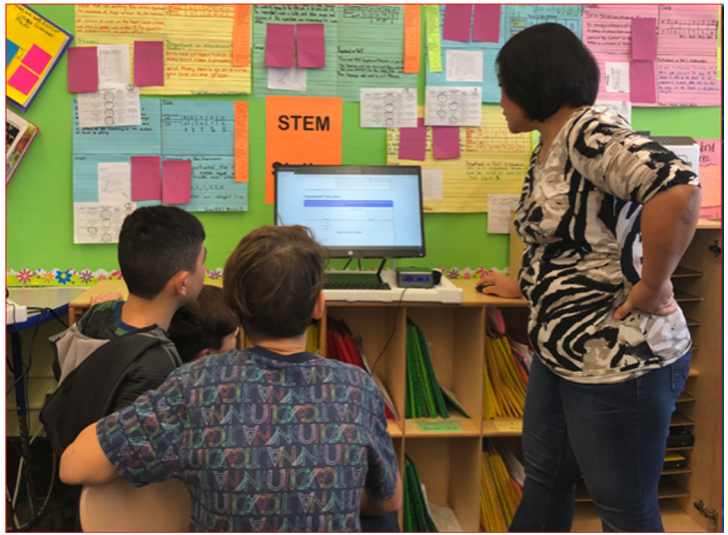
Fig: Participants attend an instructor-led lesson using the 'COSMOS Educational Toolkit'

Fig: Participants conduct research using sensors

Development Phase

Fig: Teachers present their developed NGSS lesson plans at Silicon Harlem

Implementation Phase



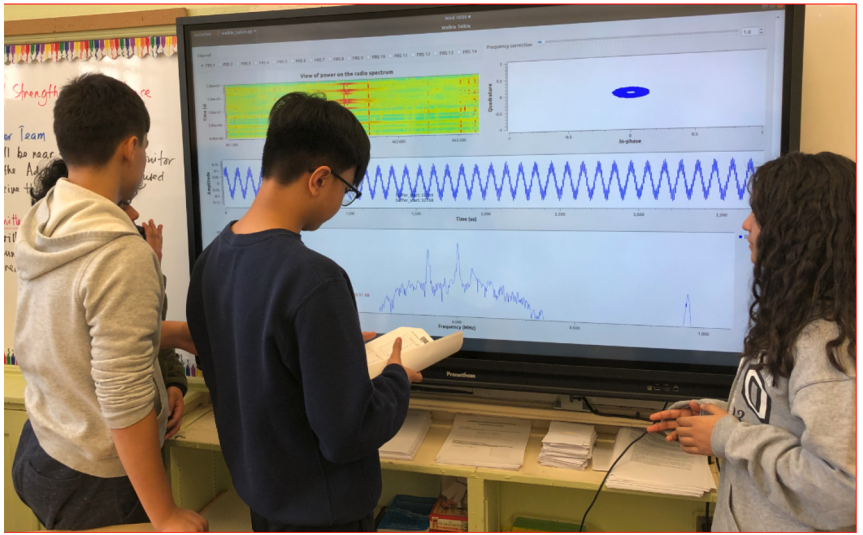


Fig: Middle school students with their Teacher using the 'COSMOS Educational Toolkit'

Feedback Phase

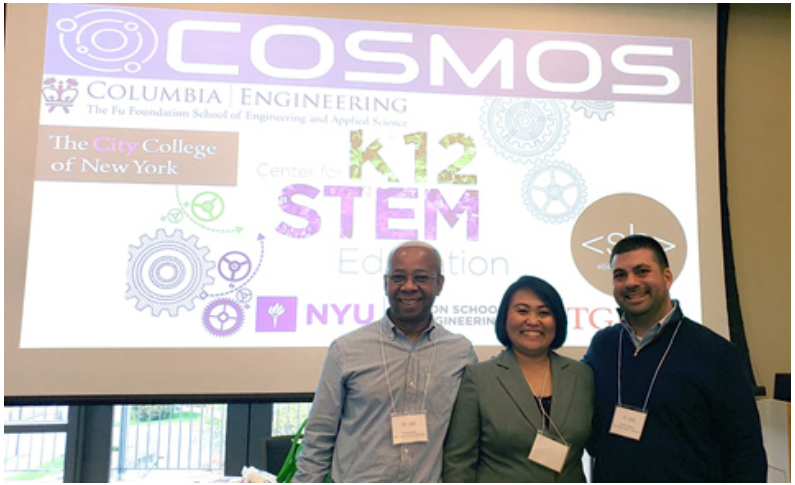


Fig: Teachers present the PD Program and the developed NGSS Lesson Plans at the NE-ASTE Conference 2018

Fig: Teachers present the PD Program and the developed NGSS Lesson Plans at the ERN Conference 2020

COSMOS Research Testbed

- The COSMOS testbed is based on a multi-layered architecture which relies on commodity components, programmable hardware, and open-source software
- An innovative learning platform for K–12 students
  - Bridge the digital divide
  - Educational benefits for the local community
- Allow any public school in NYC to remotely use the testbed for educational experiments

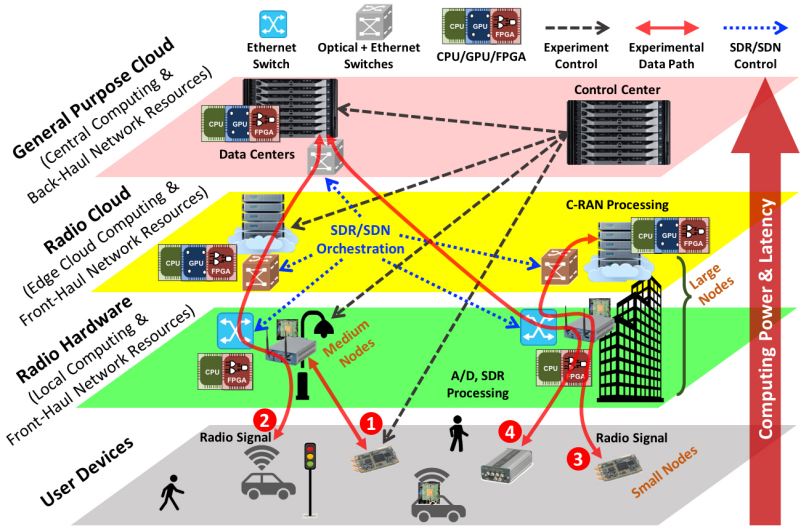


Fig: COSMOS multi-layer architecture

https://www.cosmos-lab.org/

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COSMOS Educational Toolkit

- Hardware components:
  - **Processing Units:** Intel NUC, Raspberry PI
  - **Software Defined Radio:** ADALM Pluto SDR, RTL-SDR
  - **IoT Nodes:** Arduino/Micro:bit, XBEE/BLE, sensors
- Software components:
  - **Web front-end interface:** HTML, CSS and Javascript
  - **Web back-end server:** Python
  - **SDR Software:** GNU Radio
  - **IoT management:** influxdB and Chronograf

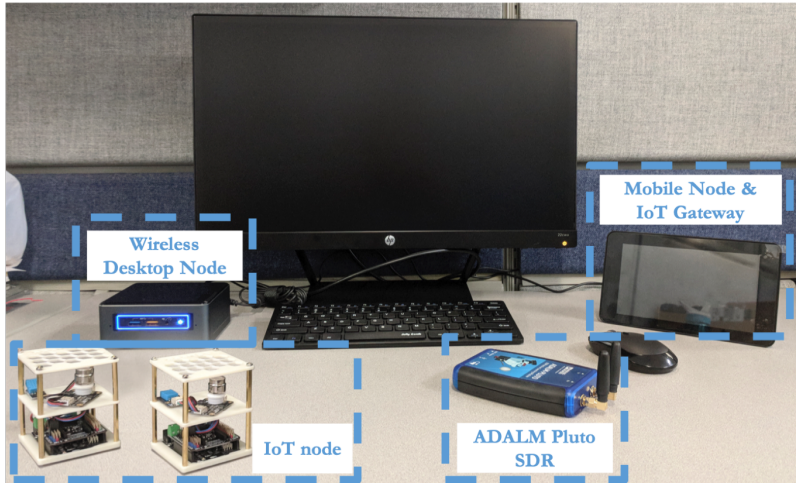

Fig: Hardware components of the 'COSMOS Educational Toolkit'

Web-based interface

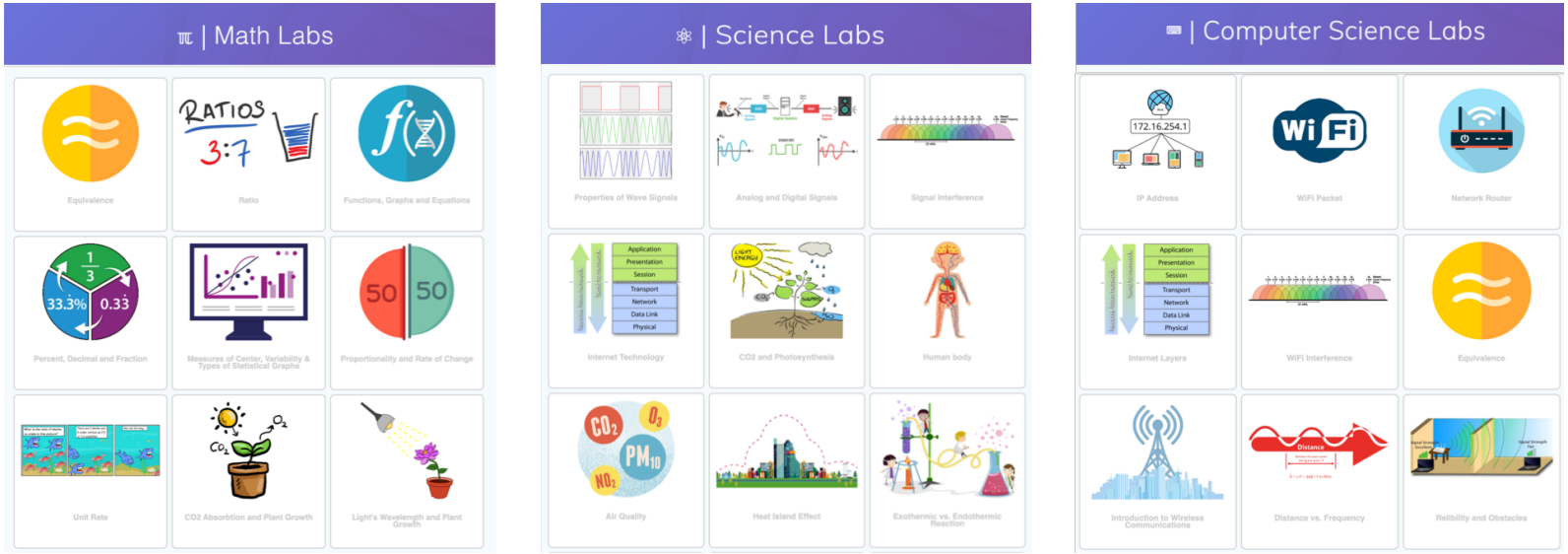

Fig: Examples of Math, Science and Computer Science Labs

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NGSS Lesson Development

- The modules that were created in this PD program follow the NGSS lessons standards → support teachers in their science conceptualization
- We address the STEM K–12 digital and equity divide by using the testbed as an experimental educational platform and engaging underserved students in real-world engineering activities.

Subject Area	2018	2019	Total
Mathematics	8	15	23
Science	11	22	33
Computer Science	6	4	10
Interdisciplinary (Math, Computer Science)	1	5	6
Interdisciplinary (Math, Science)	2	1	3
Interdisciplinary (Science, Computer Science)	4	0	4
Total	32	47	79

Tab: Summary of the developed lessons from the participants over the summers of 2018 and 2019.

https://www.cosmos-lab.org/cosmos-toolkit/

Science: Ambient waves (NGSS-Lesson)

Topic: Waves

Grade/Grade Band: 8th – 12th

Lesson Description: This is an introduction to waves, and their properties (i.e., amplitude, frequency, and phase). Students learn about different types of waves and explore how electromagnetic waves propagate in space. Students use technology to visualize ambient waves, listen to FM radio, AM stations, and capture aircraft messages.

Performance Expectations: MS-PS4-1, MS-PS4-2, MS-PS4-3, HS-PS4-1, HS-PS4-2, HS-PS4-3, HS-PS4-4, HS-PS4-5

Science & Engineering Practices (SEPs)	Disciplinary Core Ideas (DCIs)	Crosscutting Concepts (CCs)
MS-PS4-1 and HS-PS4-1: Using Mathematics and Computational Thinking MS-PS4-2: Developing and Using Models MS-PS4-3: Obtaining, Evaluating, and Communicating Information HS-PS4-2: Asking Questions and Defining Problems HS-PS4-3: Engaging in Argument from Evidence HS-PS4-3: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena HS-PS4-4 and HS-PS4-5: Obtaining, Evaluating, and Communicating Information	PS4.A: Wave Properties PS4.B: Electromagnetic Radiation PS4.C: Information Technologies and Instrumentation PS3.D: Energy in Chemical Processes	MS-PS4-1: Patterns MS-PS4-2: Structure and Function MS-PS4-3: Influence of Science, Engineering, and Technology on Society and the Natural World HS-PS4-1, HS-PS4-4 and HS-PS4-5: Cause and Effect HS-PS4-3: Systems and System Models HS-PS4-2: Stability and Change HS-PS4-5: Interdependence of Science, Engineering, and Technology HS-PS4-2 and HS-PS4-5: Influence of Science, Engineering, and Technology on Society and the Natural World

Common Course State Standards (CCSS)

ELA/Literacy: SL.8.5, RST.6-8.1, RST.6-8.2, RST.6-8.9, WHST.6-8.9, RST.9-10.8, RST.11-12.1, RST.11-12.7, RST.11-12.8, WHST.9-12.2, WHST.11-12.8

Mathematics: MP.2, MP.4, 6.RP.A.1, 6.RP.A.3, 7.RP.A.2, 8.F.A.3, HSA-SSE.A.1, HSA.SSE.B.3, HSA-CED.A.4

Science: Ambient waves (Lab)

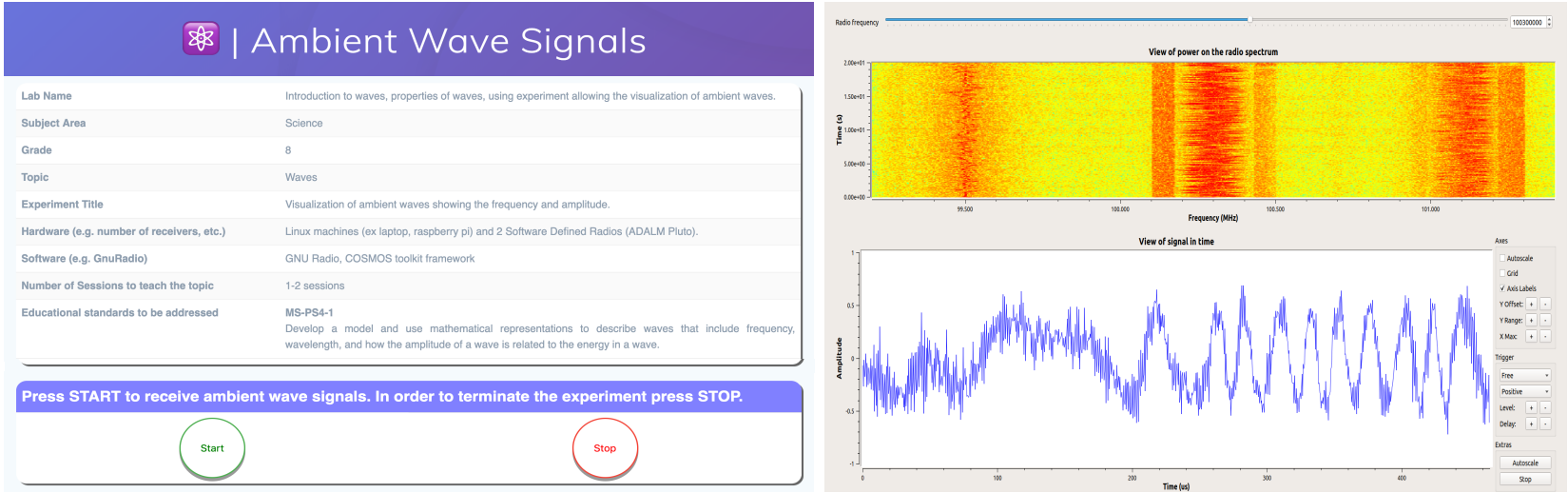

Fig: Example of a science lesson web page with a detailed experiment description (top-left), the easy-to-use interface (bottom-left) with the GNU Radio visualization (right).

PD Program Evaluation

- Evaluating the impact of the COSMOS platform to their students, teachers gave high rates

- When asked what they thought their students would be most excited about, many wrote about the integration of technology with hands-on activities:
  - *Doing something with technology and having a hands-on activity ... literally!*
  - *Working with the toolkit and conducting hands-on experiments related to technology.*
  - *It's really cool to feel like you have access and knowledge about cutting-edge technology (5G)!*
  - *The lessons make my content come alive with a hands-on experiment*

- Regarding the impact of the labs' content, teachers highlighted the following aspects:
  - *The use of sensors and the ability of analyzing the data via the 'COSMOS Educational Toolkit'*
  - *Through the lesson plans students getting to know better how the Internet works*
  - *Students can 'see' waves in reality*
  - *Understand how the math is used behind the technology they are exposed to everyday*

Conclusions

- The PD program has been implemented over the summers of 2018 and 2019, and organized virtually for 2020
- The 'COSMOS Education Toolkit' has been evaluated in 20 middle/high schools in NYC
- 3 Returning Teachers from 2018 program in 2019
- Outcomes of the project:
  - A hardware/software system that provides the necessary infrastructure for the lessons
  - Teachers gained in depth knowledge of wireless communications

Over 50 NGSS-aligned engineering labs!

The COSMOS Educational Toolkit nominated for the 2020 GLOMO Awards in MWC Barcelona 2020, under the YoMo STEAM Activity for Young People category.

Acknowledgements

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We thank the teachers who participated in the program during the summers of 2018 and 2019 for their contributions to the development of the COSMOS Educational Toolkit.

For more information on our K-12 Engineering Education program:

https://www.cosmos-lab.org/category/outreach/

https://youtu.be/len8RijwS54

Thank you!

Any questions?

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