Workshop

Engineering Workshop
for
Gifted and High Achieving
Middle and High School Students
and
Teachers and Parents

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Purpose:

The purpose of this document is to describe the Engineering Minds science and engineering workshops and lectures for gifted and high achieving middle and high school students. This document is also intended to prepare teachers for teaching this curriculum using proven principles and methods.

Overview:

Engineering Minds workshops are designed to inspire, enlighten, and empower students, parents and teachers learning engineering theory, application, and career skills. Students are engaged through discussions, student presentations, projects, and videos and treated as scientists and innovators with no restrictions or constraints imposed on them. Students are free to engage with mentors and each other and are encouraged to think freely and creatively at all levels, on all topics, and in all activities. Even the simplest activities are designed to be fun, innovative, and creative, often at the design and initiative of the students. We cover a broad range of scientific and technical topics and provide supporting content and preparation to registered users through our website.

Rules and Expectations for Students:

There are minimal rules and we want everything about the workshop to be unconventional compared with a typical classroom. Students are free to come up with ideas and innovative solutions to everything they do in the classroom. They are encouraged to make presentations, suggest science and technology topics for discussion, including videos and lectures, and are challenged intellectually by the mentors and each other. This promotes a truly unconstrained free thinking environment that students are allowed to embrace and become comfortable with.

We provide constant encouragement and feedback and constantly reinforce the focus on theory, application, and career skills through examples, challenging students, and asking questions or inviting students to ask questions. We also provide incentives to unique challenges that force students to think across multiple intellectual levels simultaneously.

Students receive a Microelectronics Timeline, an exit briefing, and a customized Engineering Minds certificate, designed to encourage and inspire them far into the future, on the final day of the workshop.

History of Science and Technology:

We discuss the valuable rich history of science and technology through the eyes of the scientists, physicists, chemists, mathematicians, entrepreneurs, visionaries, and risk takers who changed the world and ask students to "Find Your Place" among them. This allows students to begin thinking about their intellectual contributions and role in society and becoming a genuine part of something much bigger than themselves. This is highlighted in the class room with the "*Microelectronics Timeline – The Electron's Perspective*" and the FREE iPhone and iPad mobile app version at the app store. See the Timeline at www.engineeringminds.org/timeline.html.

Engineering Principles:

We use conventional engineering lab equipment and tools such as oscilloscopes, waveform generators, soldering irons, power supplies, multimeters, wiring, and other lab equipment to demonstrate engineering principles. We also demonstrate equipment and components taken from consumer and commercial products such as DC magnetrons and magnets used in microwave ovens, induction motors from ceiling fans, drones, transformers, silicon wafers, vacuum tubes, and microchips. We coordinate visits to local engineering firms allowing students to further develop their understanding of the theory, application, and career skills associated with real world engineers.

Every workshop is provided a RAD Climber, the only portable interactive climbing toy in the world. It is used to teach engineering principles such as geometry, trigonometry, distributed architectures, failure modes, truss design, and strength of materials. The RAD Climber is also used to develop coordination, maintain health, and promote cooperation, creativity, and innovation among students. Students are challenged to come up with new accessories for, and ways to interact with, the RAD Climber and take full responsibility for assembly, configuration, disassemble, and safety. See the RAD Climber at www.engineeringminds.org/rad.html.

Workshop schedule and calendar-

The Engineering Minds workshops will be offered year round beginning in 2016, in Florida. Primary venues are targeted in Pensacola, Jacksonville, Orlando, West Palm Beach, Ft. Lauderdale, Naples, and Tampa. Workshops will be conducted daily for one week each, 8am – 2pm, during which both students and teachers will attend. Teachers will receive supplemental training outside the normal workshop hours. All materials used and referenced in the workshops are available to registered users at the Engineering Minds website. Table 1 shows a typical weekly syllabus template used during the summer workshops in Tampa. Workshops in Tampa are two weeks, Monday – Thursday, 8am – 2pm.

Time	Monday	Tuesday	Wednesday	Thursday
8:00	Q&A Ideas Inventions	Q&A Ideas Inventions	Q&A Ideas Inventions	Q&A Ideas Inventions
9:00	Lecture YouTube Discussions	Lecture YouTube Discussions	Lecture YouTube Discussions	Lecture YouTube Discussions
10:00	Project	Project	Project	Project
11:00	Project	Project	Project	Project
12:00	Lunch- Project	Lunch- Project	Lunch- Project	Lunch- Project
1:00	Student Presentations	Student Presentations	Student Presentations	Student Presentations
2:00	Wrap up	Wrap up	Wrap up	Wrap up

TABLE 1: Typical Weekly Curriculum Template

The template in Table 1 shows place holders for a broad range of content that will be delivered including discussions, videos, projects, and student lectures. The project technology that was focused on in 2015 was the Field Programmable Gate Array (FPGA). In addition, mentors and students proposed interesting topics such as AI, drones, time travel, etc., which turned into engaging lectures lasting anywhere from a few hours to a few days. The objective is to allow students to become deeply engaged in topics of interest while mentors provide in-depth explanations of scientific principles governing the behavior and existence of our physical and quantum universe. For example, artificial intelligence (AI) is always a topic of strong interest since it encompasses many related topics including the fundamental question "what is life" along with topics in biology, androids, automatons, intelligence, emotion, the three laws of robotics, neural networks, etc. Discussions are always complemented with Internet videos of related content, available to students 24/7. Videos and video content are available on YouTube, Udemy, Coursera, EdX, Ted, Tedx, and Engineering Minds. Students eat lunch whenever they get hungry.

Methodology:

There are two key parts to the Engineering Minds teaching methodology. The first part is to describe and show that all science and technology topics are connected and differ only in analogy, just as in the real world. The second part is to teach or discuss the information in a non-sequential random order. This methodology is illustrated in Figure 1.

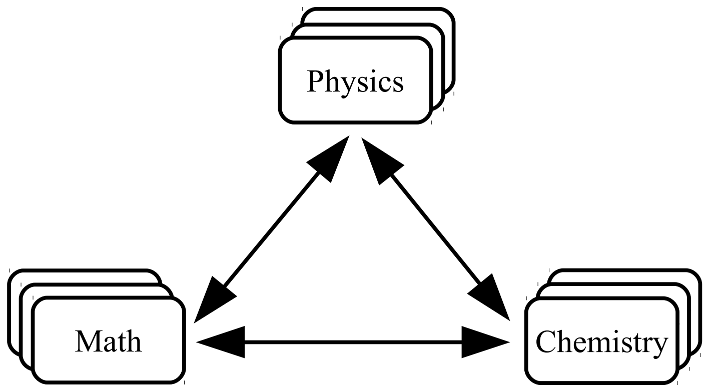

FIGURE 1: Connected and Non-Sequential Teaching Methodology

Methodology
Part 1: All science and technology topics are connected.

A fast, effective, and fun way of learning, comprehend, retain, and build a solid scientific foundation is through the premise that all science and technology is connected. Thus, all scientific topics are connected for the purpose of creating a manageable intellectual foundation designed to reduce the complexity of otherwise unrelated complex topics. This is contrasted to the types of techniques engineers typically use for problem-solving, which involve breaking down complex problems to smaller subsets that are more easily solved, and then reconstruct a solution set through superposition. Proposing connections between all science and technology topics prepares students for real-world engineering, makes students better prepared by developing a positive mindset, and breaks down inhibitions and anxiety students often experience when confronted with a continuous barrage of seemingly unrelated material.

Methodology
Part 2: Teach the information in a non-sequential random order.

Every student learns and comprehends information differently. We present a factual foundation of information to students to stimulate their minds allowing them to learn and comprehend information in their own unique way. This eliminates the often-heard comment from students of "Why am I learning this?". Teaching topics out of order forces students to be innovative and use their imagination to create their own journeys and threads to destination topics.

Example exercise demonstrating the above methodology-

The following example is an actual exercise used in the Engineering Minds workshops. This example demonstrates numerous techniques of applying the above methodologies in a fun and interactive way and shows just how much students can learn and comprehend. This is one of many exercises used in the workshops, which demonstrate the above methodology.

Exercise Topic: Waves-
Equipment needed: Oscilloscope, scope probe, wall outlet or power strip.

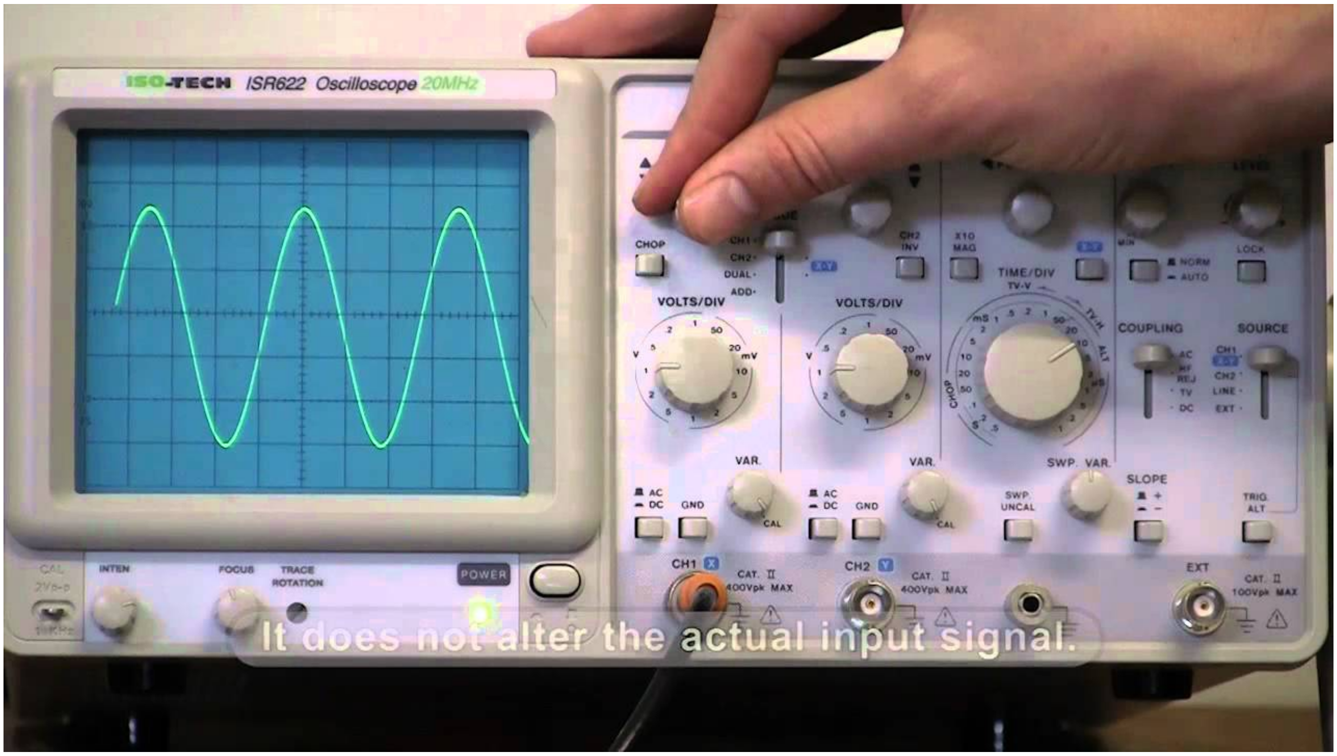

FIGURE 2: 110VAC 60Hz Waveform

This exercise begins by asking students what electricity looks like. Most students have no concept of electricity so the exercise begins by probing a 110VAC 60Hz outlet using an oscilloscope and probes. The waveform on the oscilloscope will look like the picture in Figure 2.The frequency or period and amplitude can also be measured. Using the methodology described above, this seemingly simple exercise easily expands into an in-depth detailed technical discussion including, but not limited to, the following related topics:

1. Sinusoidal (sine) waves.
2. Periodic waveforms.
3. Electrons
4. Static charge Q.
5. Kinetic charge dQ/dt = Current (i).
6. AC/DC electricity.
7. How to use oscilloscopes.
8. Frequency.
9. Amplitude.
10. Phase.
11. Voltage.
12. Current.
13. Resistance.

14. Power.
15. Transducers.
16. Power generation (e.g. Electric companies).
17. Power distribution.
18. Power consumption.
19. Radio modulation (FM, AM, PM, QAM)
20. Wireless communication.
21. Resonance.
22. Dissonance or interference.
23. Harmony.
24. Pitch.
25. Acoustic energy.
26. 100VAC, 220VAC.
27. Single phase.
28. Polyphase.
29. Root Mean Square (RMS) power.
30. Electromagnetism
31. Electromagnetic induction.
32. Transformers.
33. Tesla, Faraday, Edison, etc.
34. Trigonometric and other mathematical relationships.

Project-

We believe that hands-on projects are an important and essential component of any engineering curriculum. We also believe that projects should provide a foundation with which students become proficient and can leverage opportunities by combining their imagination with the knowledge they gain. Projects should not only act as a vehicle for students to learn valuable skills and principles but also provide opportunities to publish research papers, file patent applications, and generate revenue through their own business ventures. The Field Programmable Gate Array allows students to achieve all of these things.

Field Programmable Gate Array (FPGA)

Field programmable gate arrays (FPGAs) are programmable integrated circuits used throughout industry, academia, and federal research and defense. Industries and applications using FPGAs include aerospace, medicine, manufacturing, power generation, automotive, marine, wireline, wireless, research and development, computers and storage, national security, defense, test and measurement, entertainment, and the Internet. They compete with application specific integrated circuits (ASICs) in low power operation, performance, and complexity but offer a significant strategic advantage over ASICs in that they are reconfigurable simply by reprogramming, even in the field. Working with FPGAs requires a broad technical foundation that includes digital logic design, binary math, Boolean algebra, DeMorgan's theorem, input/output protocols, coding/decoding, ASCII characters, hardware description language (HDL), simulation, verification, floor planning, timing, and much more. The two industry leaders in FPGAs are Xilinx and Altera Corporation, the latter being acquired by Intel Corporation in 2015.

Skilled FPGA designers are in demand today in industry, academia, and research and product development on a global level. Courses on FPGAs are limited despite FPGAs' ubiquitous presence and widespread use worldwide. Furthermore, there is a huge learning gap between general purpose microcontrollers, microprocessors, and programming, such as the Raspberry Pi, Arduino, Python, and the FPGA. We have bridged this gap and made FPGAs the focus of our workshop projects that includes digital logic design, binary math, Boolean algebra, DeMorgan's theorem, input/output protocols, coding/decoding, ASCII characters, hardware description language (HDL), simulation, verification, floor planning, timing, as well as the FPGA platform itself.

Project Description:

The following project description was used successfully during 2 two-week workshops in the summer of 2015 in Tampa. We believe this is the first time FPGAs were successfully taught to middle and high school students during a two week period. Although the schedule shown here is limited to two weeks we offer a full in-depth semester long program. The projects are integrated into the normal schedule of the workshops.

Equipment and Tools:

- Terasic DE0 FPGA Development Kit
- Altera Quartus II web version software
- Oscilloscope and Probes
- Assorted sensors and transducers
- Computer with Internet access

Outline and Schedule

Week 1

Monday	**Tuesday**	**Wednesday**	**Thursday**
Install Quartus II sw	Review	Review	Review
AND, NAND, OR, NOR, Inverter	Review	Part 7: Multiple 7-segment displays	Review
Binary, octal, Hexidecimal math	Part 3: BCD to 7-segment decoder/driver	Part 8: Manual up/down counter	DeMorgan's Theorem
ASCII Characters	Part 4: Up/down counter	Review	Logic functions
Boolean Algebra	DE0 board discussion	Review	Part 14: Create games
Logic gates	FPGA Discussion	Part 9: Observe 50MHz clock with scope	Create games
I/O impedance	Quartus II discussion	Part 10: D-type Flip Flop	Create games
Drive current	Schematic capture discussion	Part 11: Clock divider using D-type Flip Flop	Part 15: FPGA Challenge
Part 1: Switch & LED	Part 5: Up/down counter, 7-segment decoder/driver, LED	Part 12: Binary counter Megafunction	FPGA Challenge
Part 2: Multiple switches and LEDs	Part 6: Single 7-segment display	Part 13: Auto up/down counter	FPGA Challenge

Outline and Schedule

Week 2

Monday	Tuesday	Thursday	Friday
Review	Review	Review	Review
Review	Review	Review	Review
Part 16: Simulation	Part 21: Verification, Test, and Diagnostics	Part 26: PLL Megafunction	Verilog
Part 17: Test vectors	Part 22: Business opportunities	Part 27: Verilog	Verilog
Part 18: Timing	Part 23: Applications	Verilog	Sensors
Part 19: Interfacing	Part 24: R&D	Verilog	I/O
Part 20: Intro to Verilog	Part 25: IP	Challenge	Expansion