Early-Age Electronics Education

With Creative Electronics Kit

A Cognitive Design Project Study Proposal

ED 333A

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Introduction

In today’s world, development of science and technology brings human being into “e” era, and the science of electronics is the genesis for this computer and internet age. This new era has been changing our daily lives, as well as children’s lives. An article from American Association for the Advancement of Science noted: ‘The notion that science is necessary only for scientists and engineers is outdated in today’s high-tech world. A solid science education is essential for students of all backgrounds, talents, interests, and abilities. All kids need the knowledge and skills that make up what we call ‘science literacy’” This information technology boost requires experts: it requires electrical engineer, computer engineers, software engineers, network administrators, technicians, programmers, and more. The best way to get more hi-tech worker relies on the early age education. Many famous scientists and inventors, such as Edison, and Bill Gates, started their learning practice at early age. However, learning the electronics is a not easy and fun thing for children in traditional way.

How can we build up the basic conceptual understanding for children when they are still in elementary school or even in kindergarten? How can we transfer the complicated electronics theory to be easily understood for children? How can we build up their interesting, motivation, and curiosity, which may lead their future resolution to study technology related major in colleges and universities, and finally become an expert, or even a future inventor.

One solution to this problem might be found in a specific case -- using Kid Inventor Creative Electronics Kit with specifically designed learning materials to teach kids basic electronics knowledge at their early age.

Learning Environment

Children gains some electricity and electronics knowledge in their daily life, such as turning on and off the lights, using remote control to operate TV, DVD, or VCR, using telephones, playing electric operated toys, and even replacing batteries. However, these activities could not lead them towards the direction to be an expert with conceptual knowledge that was developed by the previous scientific genius and technology pioneers. In the public school system in America, most schools will not teach physics until 4th grade. Even at the physics class, only very basic electricity concepts will be taught. Children neither have chances to get hands on experience for the components and circuit, nor to know the circuit schematics. Some high school may have some electronics classes with science projects, but the theoretical electronics only teach at college with electrical engineering related course or some professional training programs.

Background of the Electronics Experiment Products:
The traditional electronics lab kit since 1960’s are designed primarily for teenagers who have already had the some physics and electricity background from their school. To make a circuit, they not only need the basic knowledge of electronics, but also the skills of using solder and making printed circuit board. It is a big, complicated, and costly project. The solder set is also dangerous for youngsters without proper training. At 1980’s, a newer designed method with springs connection on a build-in bred board was introduced. This method reduced the difficulties with solder and welding, but the spring
connection is easy to lose which cause the frustration of non-working project and troubleshooting. It is still not suitable for children aged under 11.

The newly designed snap-connected electronics kit was introduced in the market recently, named Kid Inventor Creative Electronics Kit. It was originally designed as a constructional toy with a few simple circuits and little explanation, but this design provided an innovational possibility for children’s early age electronics education.

Feature of the Kit design contains 3 major parts:
• The main clear “motherboard.”
• Colorful plastic “Blocks”, each with a visible component and a standard electrical symbol. An ID code for each component is also printed on each block for easy assembly.
• An instruction manual with fun projects.

The Kid Inventor Electronics Kit Series is designed for kids to study electronics with fun. The Special Snap-Connection Method makes circuit connection and assembly EASY and SECURE with a simple click. No solder, no wires, no mess, just "snap", "snap", and done. In this design approach, finishing an electronic project is as easy as a puzzle or a Lego project. There are two versions of Kid Inventor Kit, BASIC and ADVANCED available on market now. BASIC version presents 120 projects for ages 6 and up. The ADVANCED version has more advanced components and more complex circuits, with 320 projects presented for ages 8 and up. The EXPERT version, with 800 more projects, is in the final design phase. Therefore, using this kit to give kids an early age electronics education becomes possible. The age group of kids who could use this kit is reduced from 11 to 6.

Circuit projects are stimulating to youngsters by allowing them to create different music, sounds, whistle, light, flash, turning fan, radio, and more. Children can utilize different control methods, such as light, manual, water, sound, touch, and movement, and provide different circuitries to make hundreds of exciting projects, such as: Music Doorbell, Auto Light, Radio Emitting Station, Leak Detector, Burglar Alarm, Sound-Light Metronome, and AM/FM Radio. Further more, using the experience and knowledge they gain from these projects, youngsters may enhance the creativeness on their own experimental circuits.

Science Camp Programs and School Science Project:
The Creative Electronics Kits have been introduced into many schools and summer science camp. One of the members in our group set up and taught personally with the beta-released Electronics Kit at SmartKid School, in Fremont, California in 2004 for the class entitled introduction to basic Electronics: “e-World: Electric, Electronics, and Circuits” The focus of the course was to teach students the basic electronic concepts with the kit and to see how the instruction manual and kit design can be improved. No analytical study or data collection has been performed at that time.

**Learning Problem**

Most science camps or science classes use some lab kits to build basic electronics circuit experiment without the electronics schematic, which cannot effectively create a meaningful mental model to lead kids towards the direction to be an expert with conceptual knowledge,
which was developed by the previous scientific pioneers. In addition, the experiments are too simple, which can not bring up children’s interesting, imagination, and motivation.

To teach children the electronics concepts and ask them to read the electrical schematic in normal way are very difficult because, without enough physics and mathematics background, this is too complicated for kids to understand. Then the kids will get bored and frustrated.

For this Kid Inventor Creative Electronics Kit, the hardware is designed for the kids to make a circuit with ease. However, to build a fun circuit with a little more complicity, we still have to use the like-kind standard schematics in instruction manual. If we do not use the standard engineering schematic, then where is the linkage for kids’ cognition development?

In most adults’ mind, children could not learn electronics because most adults even cannot understand it. That is another problem!

**Learning Goal:**

Based on the learning problem, here are the questions for us, which are also commonly asked from the customers of this product, such as schools, educational toy stores, and catalogs dealers:

- How to design instruction materials with the hardware to be easy to deliver the basic conceptual electronics knowledge to the children without any previous electronics concepts?
- How can we build a link from children’s basic conceptual understanding in their daily life to the cognitive understanding of electronics by using the kit?
- How can we bring up children’s interesting, curiosity, motivation, and even creativeness by using this kit?
- How to measure the educational value of this product design?

The learning goal aims on children ages from 6 to 9 in a classroom with the focus of the instruction manual design with a series of Method/Procedure for exploring the electronics concepts, include content structure, schematic illustration, and using project oriented design instead of experiments. The learning goal of the study is to examine:

1. The kids’ recognition of the popular symbols of electrical and electronic devices and the basic understanding of their functions with the kit.
2. The kids’ understanding of basic electrical schematic and the ability to assemble the circuit according to the schematic, and perform basic trouble shooting.
3. The kid’s ability to “create” a new circuit with exchanging different components, wires, and control methods.

From the above finding, our object of this study is how to improve the instruction manual and project design, as well as the improvement of the hardware in a real classroom, to effectively deliver the basic concepts of electronics for children.
Our goal is to increase the interest, excitement, curiosity, imagination, and understanding of the basic electronics for kids, thus enlarging the potential population of technological expertise in the future. With technology ever expanding into our society, these kids will be valuable in supporting and developing the new technological advancements in the world. Some of them may become future inventors.

**Design Principles**

We are proposing a cognitive study, with a focus on the following design principles as the foundation. Some thoughts on their implications for designing a kids-oriented user-friendly instruction manual for Kid Inventor Electronics Kit will be provided.

Greeno believes that “Sequences of learning activities can proceed from issues and problems that are within reach of students’ initial understanding and reasoning ability to issues and problems that require greater extensions of their intuitive capabilities, accomplishing conceptual growth by refining and extending their initial understandings.” (Greeno, 27) This principle suggests that kids start with an initial understanding of the basic components with simple circuit and the properties of each component that they have already have some initial concept in their daily life, such as light, fan, and switch. The beginning projects should start from some basic issue that kids could build up their initial understanding, such as “Why the light is off if you turn off the switch?” These initial understandings are then refined and extended to include more complex concepts such as current amplification, the Ohm’s Law, Kirchhoff’s Current Law, and radio transmitting theory.

The cognitive approach also suggests that “Learning environments can be organized to foster students’ constructing understanding of concepts and principals through problem solving and reasoning in activities that engage students’ interests and use of their initial understandings and their general reasoning and problem-solving abilities”. (Greeno, 27) This principle implies that the instruction manual should be organized in a way such that the understanding of complex concepts on electronics is constructed through interactive hands-on activities with interesting and playful value for children. Moreover, these activities should be able to invoke children’s curiosity, to encourage exploration and passion, finally to achieve the goal of using their understanding and reasoning in solving real-life problems such as how to perform step by step troubleshooting on a non-working circuit, and create different control methods for automated sensing circuit.

In the cognitive model, learning is assumed to occur through guided experience in instructional environments that provided progressive, explanation-based and otherwise generally supported practice in the mechanics of solving problem to make tacit knowledge explicit and thus knowable. (Gott, 99) Application of this principal requires that the instruction manual should provide a step-by-step, straightforward, simple-to-complicated guideline with explanations that help to make the abstract concepts on electronics easy to be followed and friendly to be manipulated through and finally to be deeply understood.
Proposed Study

The purpose of our study is to use a cognitive lens in evaluating the electronics learning materials in 2 elementary science classes that may not lend strong support for kids to learn electronics concepts. To achieve this objective, we will focus on if learning materials and activities are created and organized to start from electronics concepts and problems that are suitable for kids’ initial cognitive ability and then sequentially proceed to electronics concepts and problems that require higher level of cognitive ability which is built, extended, and refined on their initial understanding and reasoning ability. We also look for if the learning environment provides support for students to construct understanding of electronics concepts through problem solving and reasoning. Our qualitative research method will include the following:

I. Participants:
   Children aged from 6 to 9, 1st and 3rd grade in elementary science classrooms

II. Location:
   San Jose

III. Timeframe
   1-year study. This timeframe enables researchers to observe children’s mental development.

The course is taught in a 10-minuts lecture and 40 minutes hands-on lab format during the 50 minute class session. The class is about the size of 30 students with 3-4 children in one group.

Methodology

Are learning materials and activities organized to proceed sequentially to fit students’ cognitive development stages? Does learning environment provide support for students to construct understanding of electronics concepts through problem solving and reasoning? We will set up a comparative analysis combining data gathered in the pre-study interview, during- and post-study interview, content analysis of curriculum, and observations.

Pre-Study Interview:

The purpose of the pre-study interview is to determine the basic knowledge kids have about electronics. This survey will be conducted during the beginning of the school year. Since the class has only 30 children, all kids will be interviewed. The information gathered will be used to formulate questions for the later part of the study. The pre-study interview will focus on the questions such as:

- Can you corporate TV, DVD, VCR by yourself?
- Can you operate and play games on the computer?
- Can you load CD or disk on the computer?
- Can you replace the batteries on the remote control or flashlight?
- Have you made any electric experiments by yourself or with your parents?
- Do you know sensors? Give me a few examples of the sensors in our daily life.
- Have you assemble or disassemble any battery-operated toys by yourself?
**During- and Post-Study Interviews (or tests):**

Through the school year, interviews will be conducted every two weeks and at the end of the school year for all participants. Each interview’s questions will be based on previous interview’s result. The pre-, during-, and post-study interviews will be linked so that we can analyze the development of each child’s electronics knowledge and reasoning ability.

**Observations:**

Observations will take place in the classroom every two weeks. We will be observing these key aspects:

- If instruction material, activities, and class lecture provide support for students to construct understanding of electronics concepts.
  a. If systematic learning with the instruction manual is sense-making.
  b. If didactic teaching is employed
  c. If provide students opportunities to interact with concrete manipulate materials that exemplify electronics concepts
  d. If provide students social interactions in which kids discuss their understanding of those concepts and the meanings of manipulations of the concrete materials.
- If problem solving and reasoning are encouraged
  a. If the instruction material provides concepts initially with exemplifications and teaches students to solve applications problems later
  b. If teaching elicit the students’ understanding of situation in which the electronics concepts apply
- If instruction material with classroom activities build on children’s initial understandings and their general reasoning and problem-solving abilities
- If instruction material with classroom projects sequentially proceed to understanding higher level of electronics concepts.

**Content Analysis of Curriculum and Learning materials**

We will do a content analysis of curriculum and learning materials used in class in lens of cognitive approach. Our focus is on if electronics concepts and their representation are appropriate and if they are organized in a way in which students can best come to understand them. Our analysis includes:

- if electronics conceptual structure is constructed correctly
- if concrete materials (conceptual representation) really map the electronics concepts which are intended to learn and if they represent conceptual structures
- if concrete materials (conceptual representation) correspond to the electronics concepts directly
- if electronics concepts and their representations enable students’ intuitive understanding and are appropriate for their initial understanding
• if electronics concepts and their representations are organized in a way that affords students’ understanding in ways that can be extended toward higher level of understanding
• if the presentation of electronics concepts and their representations proceeds sequentially from simple to complex and fits students’ cognitive development.

Assessment:

Based on the data above, we are hoping to determine what aspects of the learning environment in the elementary science class contribute to the effective learning of electronics concepts and knowledge in lens of cognitive approach.

Potential Findings

By conducting the pre-study interview on the basic knowledge that kids have about electronics, we will be able to understand the concept level and motivation on learning electronics in elementary science classes and the intuitive knowledge students have on electronics. We expected that even though they have great passion on playing CD, DVD, VCR, electrical toys or some other electrical devices, students usually do not relate these real practices in real life with the underlining abstract concepts on electronics.

Through the during- and post-study interview, content analysis of curriculum, and observations, we expect that the learning environment in the elementary science class does not effectively build up a conceptual structure starting with electronics concepts and problems that are suitable for students’ initial cognitive ability. The abstract concepts such as resistor and voltage are very difficult for kids to understand at the beginning. The 2-D symbolized circuit diagram in beginning class does not help students to transfer the understanding of concepts to the concrete materials in real life. Projects named such as Switch Circuit, or DC Power Circuit do not motivate students for better understanding concepts and engage then into the activities on building the relation among concepts and the real life practices.

We also expected that the learning environment in the elementary science class does not provide strong support for students to construct understanding of electronics concepts through problem solving and creative thinking. The standard engineering circuit diagrams and symbolized experimental materials do not offer them opportunities to build the cognitive development on electronic sequentially from the basic components to a high level of understanding of the knowledge on electronics. Therefore students rarely construct the electronics conceptual structure that directly mapping the electronics concepts that suppose to learn onto concrete materials in their real lives.

Based on the findings above, we might able to figure out what aspects of the learning environment in the elementary science class contribute to the ineffective learning of electronics concepts and knowledge in lens of cognitive approach. We are hoping to determine what aspect of the learning environment can be put in the Kid Inventor Electronics Kit instruction manual so that it will most effectively build the conceptual model on electronics that enhance the deep understanding of electronics and its applications.
**Proposed Solution**

By conducting interviews and assessment, we will be able to better understand the mental models of cognitive approach as following:

1. Making 3-D placement illustration instead of 2-D schematic for beginning projects to allow kids’ to get an easy start, and making the later projects with the schematic to build the link of the standard engineering drawing.
2. Making circuit layouts to be physically identical with the 1:1 scale diagrams in the manual for beginning projects. It is very straightforward and easy for kids to build the circuitry and gain the first concept of a circuit.
3. Start with the basic devices that commonly identified by kids in their daily life, such as light and switch, and then the complicated devices, such as Transistor, IC, etc. Making a little concept explanation for beginning projects first and repeat then with more detail explanation at more advanced project later. Therefore, we can build core concepts and relations for kids, which underpin most tasks at a particular levels of competence, and provide foundation for development of higher level competencies.
4. Design fun projects that create music, sounds, whistle, light, flash, turning fan, radio, and more, in relation with the applicable electronic circuit world, such as, Vibration-Sensitive Alarm, and Auto Garage Light, etc.
5. Name projects with children’s interesting and imagination points in mind instead of just the nature of the project. For example: My Radio Station vs. Radio Emitting, Controllable Music Doorbell vs. Electronic Doorbell, Electronic Birthday Cake vs. Birthday, etc.
6. Design projects with the imagination and creation space, which not only focuses on the basic electricity and electronics, but also focuses on practical automatic control methods. For example, from a Manual-Controlled Light, to expend to Magnetic, Sound, light, Water, or Movement Controlled Light.

**Conclusion**

The purpose of this investigation is to evaluate the electronics learning materials with Electronics Kit in an elementary science classroom and how they affects students’ learning using a cognitive approach.

Our findings show that the traditional electronics learning materials and activities are neither organize to start from electronics concepts and problems that are suitable for kids’ initial cognitive ability, nor provide strong support for students to construct understanding of electronics concepts through problem solving. Findings shed some lights on how to improve the learning materials.

To create a learning environment which fosters kids to construct understanding of electronics concepts, we recommend using 3-D placement illustration for beginning projects, changing circuit layouts tailored to kids’ initial ability, starting with basic devices, and designing projects applicable to real electronic circuit world and fostering students to extend their conceptual understanding to a higher level.
References


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http://www.project2061.org/tools/sfaaol/Intro.htm

Highlights Magazine for Children:

http://www.highlights.com/jump.jsp?itemID=1932&itemType=PRODUCT&iProductID=1932

Edmunds’ Scientific Online:

http://www.scientificsonline.com/Product.asp_Q_pn_E_3053768
Appendix

Proposed Class Plan:

e-World: Electric, Electronics, and Circuits

Basic E-World Class (Grade 1-2. Use Basic K120 Kit)

1. Electricity Power
   Project: DC Power, Basics Light Circuit.
2. Conductor, Non-Conductor, Semi-Conductor
   Project: Conductor Tester. Coin, Plastic, Silicon Wafer
3. Relay and Magnetic Field
   Project: Magnet, Iron, Reed Relay Circuit
4. Voltage and Current
   Project: Multi-Sets Battery Circuit, Simple Equation
5. Resistor
   Project: Current Restriction by Resistors
6. Motor
   Project: Fan Circuit, Helicopter
7. Circuit in Parallel and Circuit in Series
   Project: Circuit in Parallel and in Series
8. Diode
   Project: Diode/LED Circuit
9. IC Chips, Speaker
   Project: Music Doorbell
10. Light Sensor, Photoresistor
    Auto Streetlight: Light Sensor Circuit
11. Water Sensor
    Project: Rain Detector, Leak Detector
12. Sound and Vibration Sensor
    Project: Control Circuit by Movement Sense and Vibration Sense
13. Sensor Applications
    Project: Music Birthday Card, LED Mail Box Indecator
14. Alarm Circuit
    Project: Alarm Chip Circuit, Burglar Alarms
15. Flash Light Circuit
    Project: Chip-LED- Light, Alarm Flash
16. Music/Sound Mixer Circuit
    Project: Music Alarm Circuit
17. Creative Project
    Final Project

Advanced E-World Class (Grade 3. Use Advanced K320 Kit)

1. Logic Basic 1:
   Project: AND Gate and OR Gate
2. Logic Basic 2:
   Project: NOT, NAND and NOR Gates
3. Transistor and Amplify Principle
4. Capacitor
   Project: Charge to Flash Principle
5. Capacitor Delay
   Project: Auto-off Garage Light, Delay Fan.
6. Sound and Capacitor-Resistor Circuit
   Project: Multiple Tones Generator, Horn of Tantanic
7. Transistor- Capacitor Circuit
   Project: Electronic Metronome
8. Sensor Signal Amplification
   Project: Amusing Lie Detector
9. Microphone
   Project: Simple Sound Amplification, Karaoke Indicator
10. Microphone Applications
    Project: Blowing off Light Bulb, Lazy Fan
11. Amplifying Circuit Application
    Project: High Volume Oscillator, Movement-Sensitive Burglar Alarm, Adjustable Timing Lamp
12. Antena and Atena Coil, Radio Signal in Air
    Project: My Music Radio Station
13. Remote Control
    Project: Intruder Radio Alarm, Remote Car Alarm
14. Variable Resistor Application
    Project: Adjustable Telegram Key, Blow-to-Dim Lamp
15. Simple Radio
    Project: Transistor AM Radio
16. Amplifying IC and IC Radio
    Project: Volume Adjustable Super AM Radio
17. Creative Project
    Final Project, Using extension wires.