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Creative K-16 Learning Inspired by Technology and Spirituality

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I. INTRODUCTION

Traditionally, school science has been built around well-defined problems, mostly involving top-down approaches where the decisions on learning methods are made by educational experts and organizations. In the real world, however, the problems are not always well defined and clear-cut decisions on the best learning modules are very difficult. Consequently, a restructuring of school science around real-world problems has been suggested by educational experts and organizations [1] [2] [3] , leading to several studies focusing on inquiry [4] [5] [6] [7] . Notable examples of inquiry-based studies are Design-Based Science (DBS) [8] [9] [10] [11] [12] [13] [14] [15] [16] [17] and Learning By Design (LBD) [18] [19] [20] .

Considering how important problem solving is when it comes to STEM (Science, Technology, Engineering and Mathematics) design, it is surprising that, despite all these learning techniques and presence of multi-million funded learning centers, math and science scores are not improving as expected. Recently, new learning techniques have focused on the use of technology that sparks the interest of children. A learning technique may be approved by educational experts and organizations but if it does not spark the interest of children, its efficacy may be limited or questionable. A further development of the Design concept has benefited from virtual reality (VR) and augmented reality (AR) [21] [22] [23] [24] [25] [26] [27] , the later combines real and virtual worlds. Not only do studies suggest that spatial abilities can be improved through AR [22] [23] VR/AR can also help explain complex concepts, devices, and systems in an interesting manner to students. For example, using characters from popular animated films, such as Bug's Life, to explain complex concepts of math and science can substantially increase student interest.

This paper explores possible link between technology and spirituality in developing educational techniques that are based on technology that is very simple to very complex.

II. VERY SIMPLE TO VERY COMPLEX TECHNOLOGY FOR LEARNING

Innovative technology-based education programs have been developed in collaboration with K-16 students and teachers [28] [29] [30] . As the technology keeps developing, applications in new areas make technology creative, stimulating and fun. For creative learning this paper explores the link between learning technology, BCI (Brain Computer Interface), and spirituality.

Recent research that focuses on learner interest and excitement level has sparked curiosity of over 6,000 K-12 students during 2003 - 2018 in Macomb and Oakland counties of Michigan, as well as worldwide. Graduate students involved in cutting-edge micro and nano technologies acted as role models for the learner in the study. Starting with examples of things that the learner is already familiar with, it takes them on an exciting journey into the unknown.

Currently, the creative approach is continuing [31] [32] . As shown in Fig. 1, Creative learning modules embedded in LEGO blocks [31] to (i) build static charge sensors, (ii) miniaturize LEGO blocks, (iii) simulate electronic circuits using a smartphone-based circuit simulator called EveryCircuit [33] as shown in Fig. 2, and (iv) explain micro and nano dimensions using a gear train.

Fig. 2 also shows a LEGO gear train that explains dimensions in the range of cm to nm. The last gear in geartrain completes one revolution in days.

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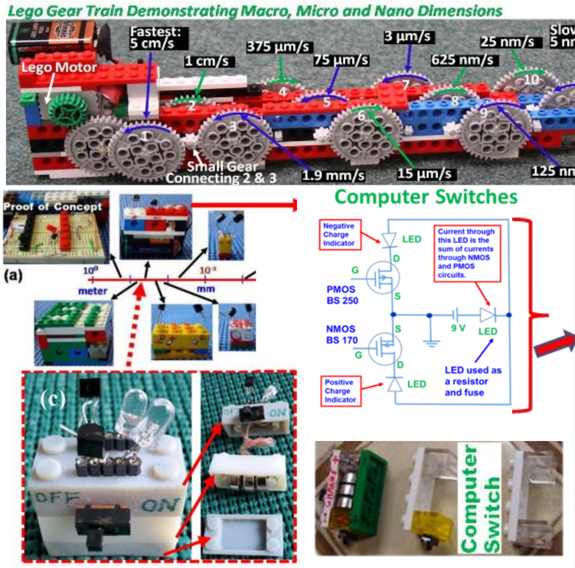
These modules are also being used in K-12 and graduate research-oriented teaching methods at Michigan State U.

Another basic technology task is to measure distance using a LEGO gear. Distance is a fundamental concept that is part of nearly every aspect of our universe. This experiment will allow distance measurement using a robot and a light sensor.



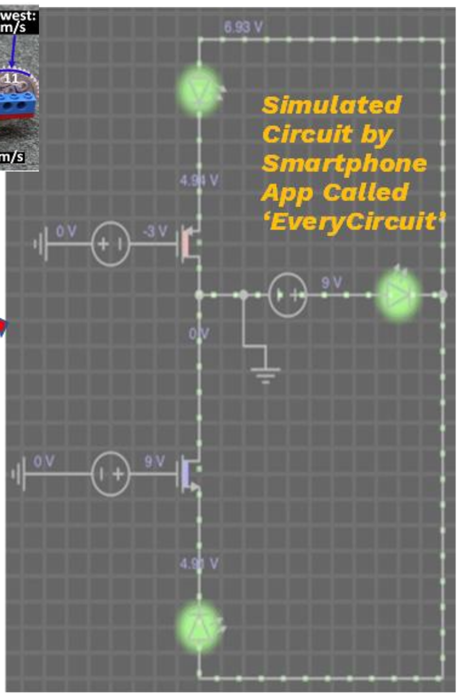


Fig. 1 Creative learning modules embedded in LEGO blocks [31] to (i) build static charge sensors, (ii) miniaturize LEGO blocks, (iii) simulate electronic circuit using EveryCircuit, and (iv) explain micro and nano dimensions.

Normally the distance is measured using a measuring tape but here we use a LEGO gear and light sensor to measure the distance. This gear has 40 teeth and one of these is marked with a red arrow. The red tooth in Fig. 3 (a) acts as a starting point. As the gear completes one turn (revolution), the total distance, for a gear with 40 teeth, is 13.1 centimeters (cm) as shown in Fig. 3 (b). In science and mathematics, we call this ***circumference***. Thus, the circumference of the 40-tooth gear is 13.1 cm. This means that the distance measured by the wheel when it completes one revolution is 13.1 cm. The distance for two complete revolutions will be 13.1 + 13.1 = 26.2 cm. Because the distance that we measure depends on the number of revolutions of the wheel, we may call the distance a ***variable***. Thus, a variable is something that is not constant because it changes or varies. In science, we use letters from the English alphabet to represent (or denote) a variable. Now you are ready to measure any distance. If the number of revolutions is ***n***, then the total measured distance ***d*** is computed by the following equation: ***d = 13.1 times n* cm.** For example, if *n* is 5, then *d* = 13.1 x 5 = **65.5 cm**. You can use an RCX robot to measure distance as shown in Fig. 3(c). Fig. 4 shows how the distance can be measured using a light sensor and an RCX robot. RCX programming code is also provided in Fig. 4.

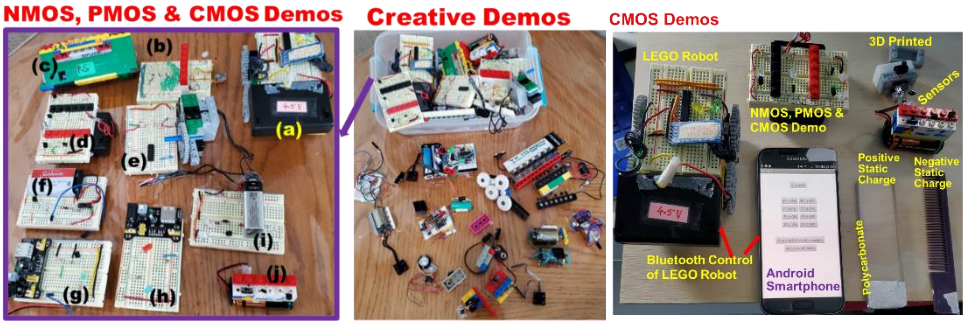


Fig. 2 Creative simple to complex learning modules; smartphone-controlled and -programable robot (a), LEDs as solar-cell (b), NMOS demo (c), NMOS, PMOS & CMOS demo (d), LEGO motor powered microcontroller (e), MOS inverter (f), BJT inverter (g), inverter (h), LEDs and Ge/Si in series (i), NMOS & PMOS sensor (j), and CMOS demos.

III. UNDERSTANDING MICROCONTROLLERS

A Microcontroller has billions of computer switches integrated on an area of approximately 1-2 cm^2. The use of a transistor as a switch is a key concept in today's computer systems.

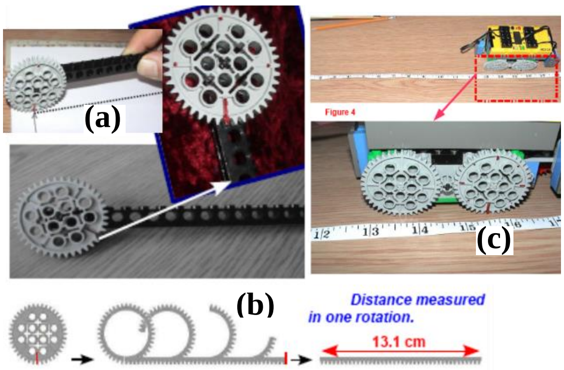


Fig. 3 measuring Distance

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What is a transistor (computer switch) and how does it work as a switch? How can billions of transistors can be integrated on a small area? If a transistor is as small as a nanometer, can it still function as a switch? While the answers to these questions may be obvious to researchers in the field, it is not so easy to recognize for K-12 children. The only way of keeping K-12 students interested and excited is through fostering creativity. Such questions have been crossing the minds of many educators including 3 teachers from Okemos High School (OHS) in Michigan. A very intriguing suggestion was made by these 3 science teachers. They said that if one can fabricate a big (millimeter size) transistor such that the children can see its structure with a naked eye, and perhaps do some measurements on it, one can explain how microcontrollers are made. The K-12 team took this as a challenge and designed a K-12 chip shown in Figure 5. The chip was then fabricated at University of Michigan's Lurie nanofabrication facility. This chip also had logic gates and a ring oscillator. The MOSFET (Metal Oxide Semiconductor Field Effect Transistor) characteristics were measured by the high school students supervised by Ph.D. students at MSU and UM.

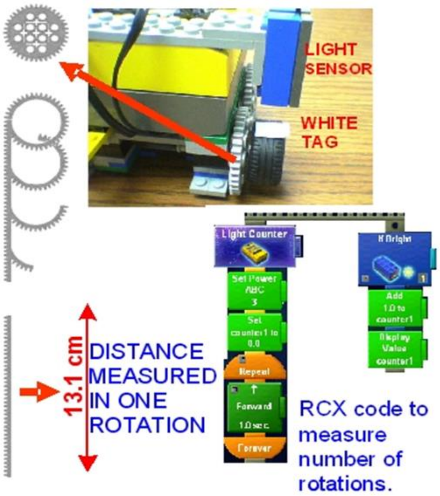

Fig. 4 measuring Distance.

The work on K-12 chip revealed a bigger challenge, for our teams, of explaining the fabrication and operation of a MOSFET to the K-12 students in a way that is simple and exciting [30] [31] .

To further address the issue of nanometer size devices, a second generation of the K-12 chip was fabricated. It had metal lines for making nanosensors for chemical detection. Carbon Nano Tubes (CNT) were randomly scattered on these metal lines to fabricate CNT nanoresistors. These are shown in Fig. 5 (near left side). A TEM (Transmission Electron Microscopy) picture of a multiwall CNT is also shown, in which each wall layer is made of carbon hexagons. The bond length between carbon atoms in these hexagons is approximately 140 pm or 0.14 nm. An animation of a single wall CNT was also shown to the children. The devices shown in Fig. 5 start with dimensions that are large enough that children can put their hand on and play. The grad student instructors' team can then take the children on a journey into the unseen world of nano and pico dimensions with the help of concepts depicted in Fig. 5. Children's remarkable imagination and curiosity facilitates this journey.

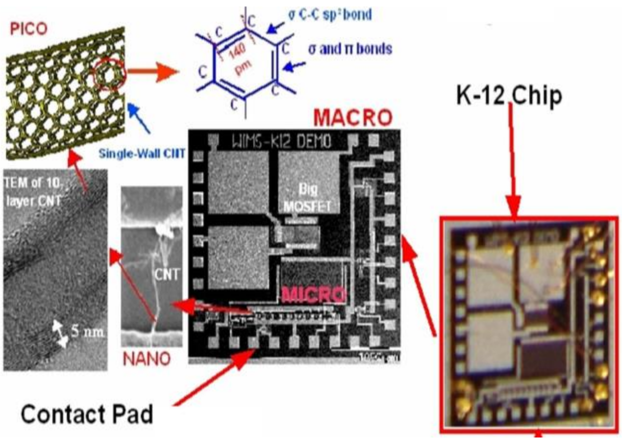

Fig. 5 Creative K-12 chip and modules explaining macro, micro, nano and pico concepts.

Fig. 6 elaborates the operation of the NMOS switch using LEGOs. An actual NMOS and a red LED are present inside the LEGO construction with wires for source, drain and gate connection. From Fig. 6(a) it may be noticed that there is no channel because the gate voltage V_G is not high enough. However, as shown in Fig. 6(b), a high enough gate voltage is applied at the gate. The channel appears typically at 5 V and the blue LED (Fig. 6b) lights up. The visualization of the red channel region was accomplished by mounting tiny red LEDs in the Lego plates representing the channel region. More detail is seen in Fig. 6(d).

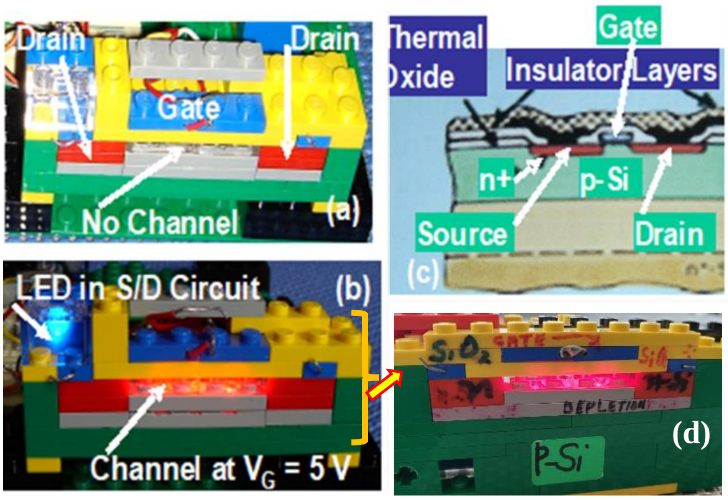

Fig. 6 MOS fabrication process explained by LEGO constructions (a, b). Actual NMOS (c).

The children and teachers who saw this demonstration of the use of an NMOS as a switch were impressed by the fact that switch could be turned on and off by the static charge accumulated on a polycarbonate sheet after rubbing it on fur (or carpet). Of course, too much static charge can also destroy the NMOS. The children were fascinated by the usefulness of static charge, which they are so familiar with inside a heated home after they walk on a carpet in winter.

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This demo is a very interesting way to introduce the electronic circuit concept to children at an early stage (parts of the demo are suitable for 4 – 8 graders). For comparison, Fig. 6(c) shows a typical NMOS cross-sectional view found in textbooks [34] .

Circuits containing NMOS and PMOS together are called Complimentary MOS (CMOS), which is the latest technology used in microcontrollers. The channel length in a CMOS based microcontroller was decreased to 5 nm in 2020. As shown in Fig. 7, a microcontroller is a single chip computer and there are approx. 100 of them in every American home. Microcontrollers fabricated in 2020 had smallest feature size of 5 nm and a total number of 57 billion devices (human brain has 86 billion neurons).

Fig. 7 Microcontroller miniaturization.

Some fascinating applications of microcontrollers are shown in Figs. 8 and 9. Normally a microcontroller requires very precise supply voltages (e.g., 5 V). Interestingly, as shown in Fig 8, the microcontroller is powered by a LEGO motor. As the LEGO motor can supply 3 - 12 V depending upon the speed of the motor which is not acceptable by a microcontroller. Using only LEDs this problems is solved by using (a) a forward-biased LED to keep the voltage approximately constant, and (b) LED-based fullwave rectifier that helps visulize which way the current is flowing.

Fig. 8 Microcontroller powered by a LEGO motor.

An Android phone is used to (a) program a microcontroller and (b) control a LEGO robot as seen in Fig. 9. This provides a smartphone based programming in C using an App and remotely controlling a LEGO robot or any other device or system. Children in 8-12 grades were able to understand the programming in C code.

A series of creative systems were built to demonstrate to learners the application potential of systems. Fig. 10 shows a wall-climber robot with two suction cups and a motor controlled by a microcontroller [35] [36] . This robot can climb smooth walls.

Fig. 9 Programming of a microcontroller by Android Smartphone.

Fig. 11 shows an LED-based solar system for generation, usage and storage of energy. Direct-gap materials such as AlGaAS are used for LEDs but if they are used to fabricate solar systems, solar cell effiency will be much higher. However, such materials are not used for solar cells because they are too expansive.

Fig. 12 shows a static charge piano that can be operated by static charges. Fig. 13 shows a robotic doll built by girls from Okemos High School. A mind-controlled LEGO robot was also built [37] .

Fig. 14 shows [38] dendrimmer cancer killer therapy and a LEGO model of a neuron [31] . See also gear train in Fig. 1. Such modules introduce concept of dimensions and biomedical research.

Fig. 15 shows an anxiety-controlled LEGO robot. The Anxiety Algorithm (AA) is defined by:

AA = 1/[(Attention Algorithm)^2 x (Meditation Algorithms)^2], in our study, was tested within our research group (a statistical study is needed and is in progress). The attention algorithm, as seen in Fig. 15, is given by: $R = E_\alpha/E_\beta$ [39] . The meditation algorithm, as seen in Fig. 15, is given b y: $R = E_\alpha/E_\theta$ [39] . This model of AA was tested using NeuroSky's Mindwave Mobile headset shown in Fig. 15. The higher the value of AA the higher the anxiety. Further work is in progress to develop algorithms for depression, ADD, ADHD and autism.This will lead to self-study of such conditions by K-16 learners using LEGO robots.

Figure 10 Microcontroller based wall-clamber robot.

IV. Role of Technology and Spirituality in Creative Learning

Religion and spiritually [40] , Human Computer Interface (HCI) and human behavior [41] , and techno-spirituality research have recently been studied [40] [42] . There is a direct connection between Artificial Intelligence (AI), robots, consciousness, and spirituality. It takes awareness of a body for AI or a robot to function. AI must interface with a user for it to function. In short, it must respond. To be able to respond to a user, AI must be able to differentiate itself from outside stimulus [43] . Machine intelligence, whether in the form of

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AI functions best if it has a body [44] . For a robot to move, it must learn to recognize its position in relationship to the environment around it. Moving from here to there requires a robot be aware of itself to move itself. Recognizing self is the beginning of consciousness, and some say that consciousness is the beginning of spirituality [45] . Spirituality will have a unique and currently undefined relationship to AI and robotics as college students who identify as spiritual typically identify as non-religious, while students who identify as religious identify as spiritual [46] .

As according to new scientific model of mind [47] spirituality and consciousness relate to mind, the role of technology and spirituality in creative learning mentioned in this paper is intriguing. Mind is the decision maker for everything a human does while brain is in-charge of survival [47] . Thus, K-16 students may have different views about spirituality and religion but their focus on technology will help in creative learning and role of technology in spirituality.

V. CONCLUSIONS

Extremely simple to extremely complex learning modules are developed for creative K-16 education using unique approaches for the first time. The focus on technology is expected to help understand its benefit to understanding complex concepts for K-16 education and the use of technology in understanding spirituality. Today, technology is everywhere including religious and secular institutions. This is for the first time that several creations, realized by LEGO-embedded systems, are produced, and tested.

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