Design and Implementation of IoT based Low cost, Effective Learning Mechanism for Empowering STEM Education in India

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Summary
India is a developing nation and has come with comprehensive way in modernizing its reducing poverty, economy and rising living standards for an outsized fragment of its residents. The STEM (Science, Technology, Engineering, and Mathematics) education plays an important role in it. STEM is an educational curriculum that emphasis on the subjects of "**science, technology, engineering, and mathematics"**. In traditional education scenario, these subjects are taught independently, but according to the educational philosophy of STEM that teaches these subjects together in project-based lessons. STEM helps the students in his holistic development. Youth unemployment is the biggest concern due to lack of adequate skills. There is a huge skill gap behind jobless engineers and the question arises how we can prepare engineers for a better tomorrow? Now a day's Industry 4.0 is a new fourth industrial revolution which is an intelligent networking of machines and processes for industry through ICT. It is based upon the usage of cyber-physical systems and Internet of Things (IoT). Industrial revolution does not influence only production but also educational system as well. IoT in academics is a new revolution to the Internet technology, which introduced "Smartness" in the entire IT infrastructure. To improve socio-economic status of the India students must equipped with 21st century digital skills and Universities, colleges must provide individual learning kits to their students which can help them in enhancing their productivity and learning outcomes.
The major goal of this paper is to present a low cost, effective learning mechanism for STEM implementation using Raspberry Pi 3+ model (Single board computer) and Node Red open source visual programming tool which is developed by IBM for wiring hardware devices together. These tools are broadly used to provide hands on experience on IoT fundamentals during teaching and learning. This paper elaborates the appropriateness and the practicality of these concepts via an example by implementing a user interface (UI) and Dashboard in Node-RED where dashboard palette is used for demonstration with switch, slider, gauge and Raspberry pi palette is used to connect with GPIO pins present on Raspberry pi board. An LED light is connected with a GPIO pin as an output pin. In this experiment, it is shown that the Node-Red dashboard is accessing on Raspberry pi and via Smartphone as well. In the final step results are shown in an elaborate manner.
Conversely, inadequate Programming skills in students are the biggest challenge because without good programming skills there would be no pioneers in engineering, robotics and other areas. Coding plays an important role to increase the level of knowledge on a wide scale and to encourage the interest of students in coding. Today Python language which is Open source and most demanding languages in the industry in order to know data science and algorithms, understanding computer science would not be possible without science, technology, engineering and math. In this paper a small experiment is also done with an LED light via writing source code in python. These tiny experiments are really helpful to encourage the students and give play way to learn these advance technologies.
The cost estimation is presented in tabular form for per learning kit provided to the students for Hands on experiments. Some Popular In addition, some Open source tools for experimenting with IoT Technology are described. Students can enrich their knowledge by doing lots of experiments with these freely available software's and this low cost hardware in labs or learning kits provided to them.

Keywords:
Internet of Things, STEM education, Low cost, effective learning, Node-Red, Raspberry pi, Python

1. Introduction

Our India Prime Minister Sh. Narendra Modi's has started 'Make in India' initiative that aims to make India a well-known global manufacturing hub. This project aims to fabricate highly skilled graduates from academic institutions, especially in the fields of STEM (science, technology, engineering and mathematics) [4]. It is an integrated, interdisciplinary approach to learning that provides hands on and relevant learning experiences for students. STEM Education has lately become a staple part of basic literacy .Therefore, it has become mighty important for kids to start early with STEM so they don't face significant hurdles in the later stages of their career. The main motive of this paper is to bridge the gap between existing education scenario and the industrial revolution.

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In the field of education, Raspberry Pi can aid in teaching Computer Science, general purpose Programming [3] Engineering, Robotics and other sciences and hobby project implementations [13]. To promote STEM education in India major goal is to elucidate the use of Credit card size computer like Raspberry Pi [12] and open source tool like Node- Red is available for IoT Programming to generate cost effective solutions to give real time exposure to the students. There are various challenges behind unemployed engineers are discussed as a consequence, this cost effective mechanism is required for developing nation. Cost estimation for a simple project is presented. This mechanism motivates the students and polishes their skills to fulfill the long term talent demand in the industry.

Raspberry pi foundation's goal is to see it being used by kids all over the world to learn Programming. It is a credit-card sized computer which is an incredible low cost device specially designed for those who passionate about STEM education. It is intended to help learners to grasp knowledge about electronics, programming, and basic computer science because they now considered an important ability for 21st-century students, and are getting a key component of the many curriculums, even in primary schools. While combining computer engineering and programming with electronics, we will be able to build many useful applications to be used in our lifestyle. For example: PIR automatic lighting, line tracking robot car, vehicle radar, weather station etc.

As there are various Open source tools are available for IoT programming but here Node Red is used which is the best suited for students and teachers to learn visual Programming Tool for Creating IoT applications [1]. It has light- weight run time, built in node.js which are suitable for edge-of-network environments or running in the cloud. It can be easily expanded to take add new nodes to the palette and taking full advantage of the node package manager (npm) ecosystem.

To develop Rapid applications Python programming language is the first choice for programmers due to its versatile features like it is an Open source, Object-oriented, high level programming language. In this paper python code is written to control the LED light connected to GPIO pins on Raspberry Pi board.

2. How IoT empowers STEM education?

IoT is an emerging technology which is a building block of 4th industrial revolution, it has already created many opportunities for Science, Technology, Engineering and Mathematics (STEM) disciplines like Computer Programming, Real time scenarios, Robotics, Physical computing and many more [7]. India and Indian educators are now focusing on changing their traditional methodologies and providing an effective and fruitful learning mechanism because while quoting the facts and predictions in mind, 80% of the jobs in near future must require science and mathematical abilities that would ultimately increase the demand for STEM education in India.

Each and every student must provided a Raspberry Pi Internet of Things toolkit to enhance their basic learning skills however Raspberry pi foundation is charity whose objective is to further advancement in the field of education and providing inexpensive tools for teaching students particularly in the field of Engineering , computer science and related subjects. It is a low cost, tiny, dual display, desktop computer with the diverse utility of hardware for experimenting with programming and electronics. The coding helps students understand how the software actually works and it also helps students to develop 21st century skills like creativity, collaboration, communication and critical-thinking. The physical computing in education gives students an understanding in how these works around them every day.

3. Background

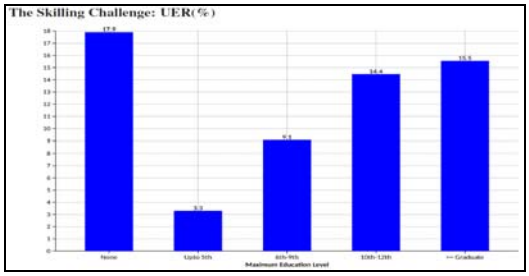
As per National Education Policy 2020 [10] which was approved by the Union Cabinet of India on July 29, 2020.This policy aims at making "India a global knowledge superpower". In Undergraduate education for the holistic development of students there is an assessment of educational approaches integrates arts and humanities with STEM for positive learning outcomes. It will increase their critical thinking enhances creativity, innovation and Problem solving abilities.

On the contrary, insufficient skills of our youth are the biggest cause of unemployment in India. The Centre for Monitoring Indian Economy Pvt. Ltd. (CMIE) is an India's leading business and economic database and Research Company which helps to take decisions [6]. It has released their 13th volume of "Unemployment in India, A Statistical Profile" for the period Jan-April 2020. According to http://unemploymentinindia.cmie.com it shows the Unemployment rate in all over India till date is 6.7% where UER of Urban areas is 8.5% and 5.9% is in Rural areas.

The estimation is done on probability based sampling design. Here stratified random sampling is used to increase precision. In stratified random sampling, the population is stratified into homogeneous subgroups called strata [6].

An Unemployment rate by maximum qualification is presented. The entire sample of 174,405 households is surveyed during a period of four months. The students are suffering from skill challenge issues. **Figure -1** shows the

Skilling challenge (UER) unemployment rate in %.



Source: http://unemploymentinindia.cmie.com

Figure -1

On the other hand, these days an Industry 4.0 revolution has changed learning system completely; now this new era is Education 4.0 [2] and it is developed as a response to Industry 4.0.

Table-1 shows the revolution of Education on the basis of some important parameters

Strategy	Education 1.0	Education 2.0	Education 3.0	Education 4.0
Process	Performance Oriented	Subsidiary	Innovative	Emerging
Person	Young Executive	Young age to Middle Age Executive	Young to Middle-Aged to Older Executive	Stakeholders
Tools/ Technology	Fast	Better	Faster, Better and Cheaper	Faster, The Best and Intelligence
Management	Left Brain	Right Brain	Whole Brain	Accelerated Learning
Goal	Based on process	Based on Exhibitor	Based on skills	Based on Human
Year	1970	1990	2000	Present

4. Challenges

a) India is one of the biggest producers of engineers in the world. But unfortunately only 7-8% of engineering graduates are employable. The major reason of unemployed engineers is their skill gap and requirement gap. Hands On experience & Real time exposure is not seen in most of the engineering colleges.

b) Outdated curriculum and lack of enterprising attitude among young people are the major reasons for unemployment. Technology is not considered as a disruption where as it is a creator of various employment opportunities. There is a Lack of good quality training to produce competent engineers hence, Training and re-Skilling is important.

c) Due to financial barriers Universities, school and colleges are rigid to adopt new technologies.

5. Objectives

d) A low cost mechanism is designed and an open source tool is explored to sharpen their skills and develop critical thinking, logic building to work upon latest technologies.

e) To develop a keen understanding of the relationship between science, math and their application in students will be exposed to create technology and engineering methods and solutions.

f) Coding is the fundamental need for this digital age. Basic knowledge of coding will help them to learn new technologies at a fast pace and it develop 21st century skills in students such as creativity, collaboration, communication and critical-thinking.

6. Open Source Tools available for IOT experiments

a) **Node-Red:** It is a visual tool for wiring the Internet of Things developed by IBM. It is a platform independent and has been developed with small computer, such as Raspberry Pi in Mind. It takes care of the technicalities and lets you to concentrate on the logic of your workflow.

b) **Flutter** is an open-source mobile SDK developer can use to build native-looking Android and iOS mobile applications. Flutter applications are designed to communicate with the IoT devices.

c) **M2MLabs** Mainspring is an application framework designed for machine to machine (M2M) communication. M2M applications are usually modeled in hours instead of weeks and afterward passed on to a high-performance execution environment which is made on top of a typical J2EE server and therefore the highly-scalable Apache database.

d) **Kaa IoT Platform** is highly flexible and scalable to design IoT solutions and managing

connected devices. It provides a gateway to connect intelligent devices for effective communication and to deal with interoperation capabilities.

e) **Thinger.io** is a scalable cloud base for coupling millions of devices. The developers and companies can start controlling their devices through internet in minutes without worrying about cloud infrastructure.

f) **Things Board** is recommended in IoT projects for device management, data collection, processing and visualization. It upholds all standard IoT protocols like CoAP, MQTT, and HTTP as quickly as cloud and on-premise deployments.

7. Experimental setup

Raspberry pi foundation's goal is to see it being used by kids all over the world to learn Programming. Raspberry pi is a computer on a single board that works on Linux operating system. To implement the user interface and Dashboard in Node-Red for remote access using Raspberry pi board following are the hardware and software requirements:

Raspberry Pi hardware requirements

a) Raspberry pi 3 Model B+
b) Power supply/Adapter
c) Keyboard
d) Mouse
e) Internet connectivity (Wi-Fi)
f) Jumper wires
g) LED
h) Monitor
i) Micro SD card with card reader

Raspberry Pi (Open source) software requirements

1. Raspberry pi OS (raspbian)
2. Node-red
3. python
4. Putty
5. VNC server
6. Advance IP scanner

8. Steps for implementation

1. In the first step install raspbian OS from its official website through https://www.raspberrypi.org/downloads/ then give power supply to your pi with the help of adapter.
2. An Advance IP scanner is used to find out the IP address of raspberry pi after that PuTTY is used for free implementation of the SSH (secure socket shell) on client side.
3. To connect to server side, VNC (Virtual network computing) server is used to control your Raspberry Pi remotely.
4. Install Node-Red from https://nodered.org/docs/getting-started/. Once done Node-RED is accessed via the browser using http://raspberrypi.local:1880 this address.
5. Connect an LED light on a bread board with the help of jumper wires with GPIO pins present on Raspberry Pi board.

9. Results and Discussions

1. In the initial step advance IP scanner is used to get the IP address of your raspberry Pi. You can see in **Figure-2** where the address of Pi is 192.168.1.207

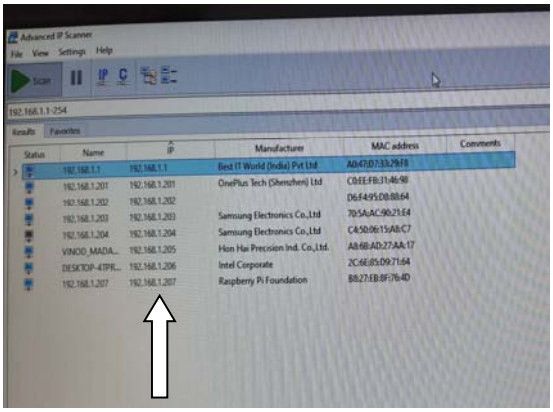


Figure-2

2. In **Figure-3**, at the Node-Red platform switch, slider and gauge nodes are dragged from Dashboard palette and drop it on the workspace, and then GPIO output node is dragged from the Raspberry pi palette on the workspace.

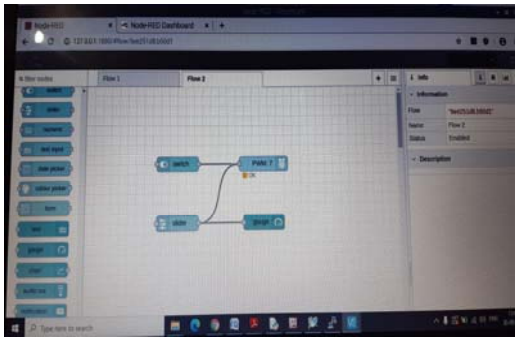


Figure-3

3. To receive output through GPIO pins present on the raspberry pi board **Figure-4** shows that here Pin number 7 from GPIO and GND are connected with an LED via jumper wires.

Figure-4

4. Now **Figure-5** shows from the Sidebar, set the value of a switch 0 for OFF state and 1 for ON state.

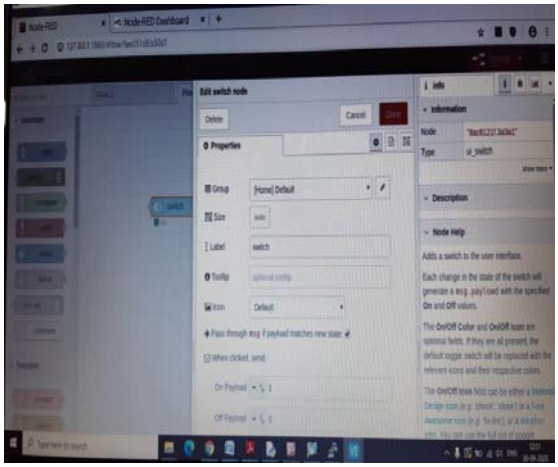
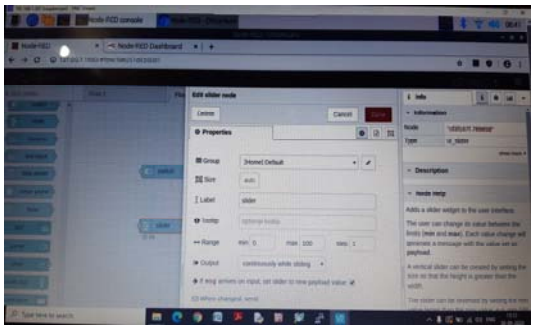
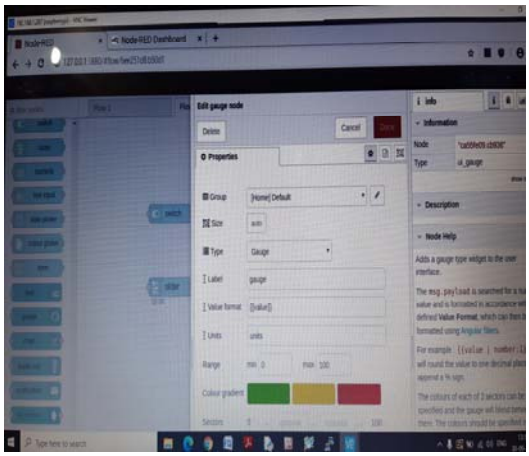


Figure-5

5. In the **Figure-6** value of the slider is set between minimum 0 and maximum 100. The Same value is set to gauge and output is set as PWM (Pulse width modulation).





6. Now click on deploy for the results. Figure-7 is showing the output on the Node red dashboard, through this user interface LED light will be controlled.

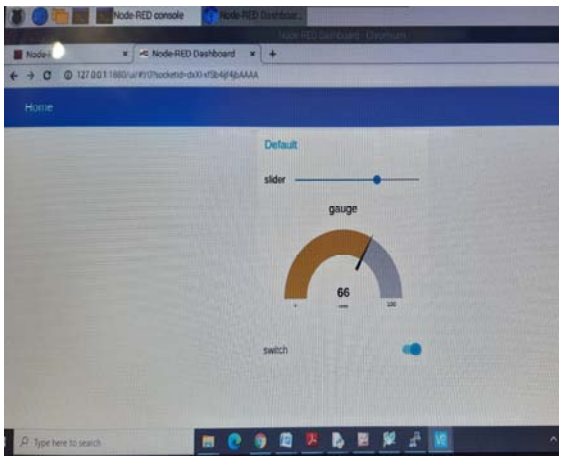
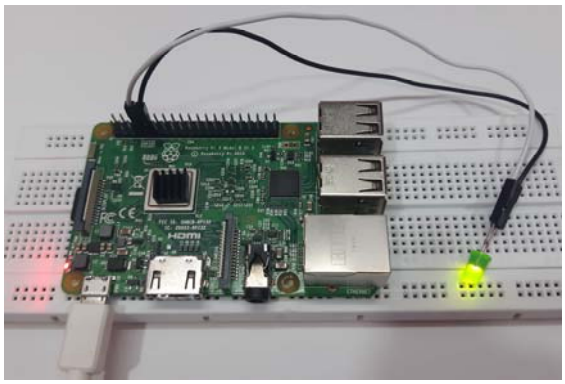


Figure-7



7. In **Figure-8**, same dashboard can be operated through Smartphone via the same IP address.

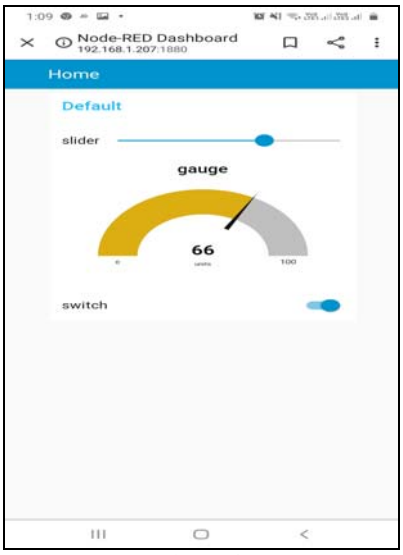
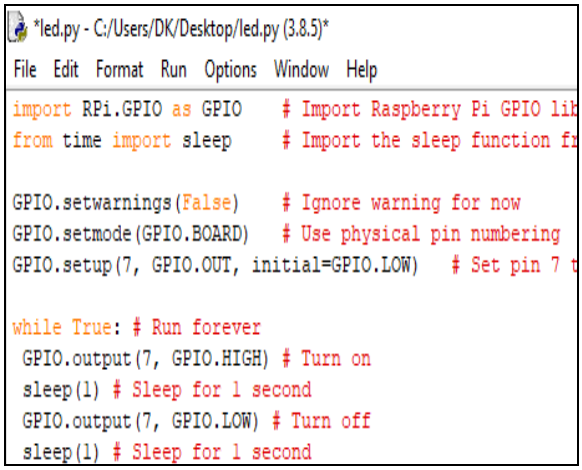


Figure-8

8. Without using Node-Red, **Figure-9** shows the Python source code is written to blink the LED light connected to the Raspberry pi board with a 1 second interval time.



```
*led.py - C:/Users/DK/Desktop/led.py (3.8.5)*
File  Edit  Format  Run  Options  Window  Help
import RPi.GPIO as GPIO     # Import Raspberry Pi GPIO lib
from time import sleep      # Import the sleep function fr

GPIO.setwarnings(False)     # Ignore warning for now
GPIO.setmode(GPIO.BOARD)    # Use physical pin numbering
GPIO.setup(7, GPIO.OUT, initial=GPIO.LOW)    # Set pin 7 t

while True: # Run forever
 GPIO.output(7, GPIO.HIGH) # Turn on
 sleep(1) # Sleep for 1 second
 GPIO.output(7, GPIO.LOW) # Turn off
 sleep(1) # Sleep for 1 second
```

Figure-9

10. Cost estimation for a learning Kit

Item no	Hardware required	Approximate cost in (₹) rupees
1	Raspberry Pi 3 Model B+	**3000**
2	Micro USB cable	**100**
3	Micro SD card 16 GB	**350**
4	Micro SD card reader	**50**
5	Resistors, LED's and Jumper wires	**400**
6	Breadboard	**80**
7	Mini Sensors Kit for beginners	**600**
	Total Cost Estimate Per kit	**4580 rupees**

11. Conclusion

The development of this low cost, effective learning for STEM Implementation via using Raspberry pi and open source tools like Node-red are successfully implemented and verified.
Different open source tools are explored to do experiments in IoT technologies. This research shows

that how these low cost learning kits will help the students to sharpen their analytical and higher order thinking skills. These experiments will prove eye opener for those students who working with IoT technologies and especially Node-Red that consists with colors and easy to use GUI which gives different dimensions of exploring and learning. This project-based learning system could be a good alternative to teach IoT technologies to meet industrial demand in near future. The students can develop various IoT based hobby projects to enhance their skill set. The learning kits provided to the students is the best practice to support them for their survival in the industry.

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