

# QR Code-Based Pedagogy for Laboratory Resource Management in Indian Higher Education Institutes

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**Abstract:** Blending digital education with traditional teaching learning requires revamping current pedagogical approaches. Recently India has adopted a New Education Policy 2020 (NEP 2020). NEP 2020 has given the focus on skill-based blended education with multiple entries and exit facilities. The learners will learn the skills in the laboratory. Students with varying skill levels and edges interact and have the opportunity to observe human behaviours as a result of the multiple entry and exit points. On the other hand, these gatherings can be viewed as opportunities to develop appropriate resources for both administrations and users. Hence there is a need to deal with and introduce a novel approach for updating laboratory management, administration and student handling approach. This article proposes a new methodology with the Internet of things and QR code technology. Proposed method has quickly and readily reading capability of a two-dimensional barcode called a Quick response code (QR code) arranged in systematic manner for ease of operation. The Laboratory components such as noticeboard contents,

lab manuals, safety instructions, video demonstrations, attendance can be methodically arranged and utilised in the efficient manner. In this research, we are presenting laboratory management system having a Raspberry Pi-based QR Code Scanner. The system implementation is implemented with OpenCV and the ZBar library to improve students' laboratory course learning experiences in higher education.

**Keywords:** QR code; NEP 2020; raspberry pi; thingspeak cloud; lab management; Internet of Things.

## 1. Introduction

The recently released National Education Policy 2020 (NEP 2020) has provisions related to skill based education in Indian higher education. The NEP 2020 is the culmination of extensive work to combine India's long-standing emphasis on instilling core values with the modern, technology-driven approach to education. NEP 2020 seeks to transform the current educational system through a multifaceted approach, one of which is the development of pedagogies that make education more experiential, holistic, integrated, inquiry-driven, discovery-oriented, learner-centered, discussion-based, flexible, and enjoyable. As the NEP 2020 strives to develop well-rounded, competent individuals with 21st-century skills, curricula and pedagogies must be reoriented

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and revamped to meet this goal, which includes raising the standard of curricula and employing appropriate pedagogies to effectively deliver to learners. Diverse pedagogies are being used to achieve the overall learning processes, core objectives, which included exposure to real-life experiences and hands-on learning, problem solving through explorations etc.

Pedagogical practises influence the learning experiences that students have and thus have a direct impact on their learning outcomes. As a result, the use of relevant pedagogy is required to successfully achieve the curricula's objectives. Such pedagogy must place a greater emphasis on an inclusive approach to communication, discussion, research, and opportunities for cross-disciplinary and interdisciplinary thinking. The pedagogy used in the laboratory must reflect an inclusive approach so that students can apply what they learn in classroom. For students, the primary goal of laboratory learning is to develop practical capabilities.

Laboratory learning enables learners to apply and strengthen the theoretical concepts taught in class. Assessing this learning can assist learners in improving their conceptual understanding of the theory-practice relationship, higher-level reasoning skills, and practical competence in laboratory work. The laboratory is a one-of-a-kind learning environment that promotes and integrates learning by doing. Laboratory learning occurs in an environment where students can observe, practise, and experiment with objects, materials, phenomena, and ideas individually or in groups. Learning can take place in the laboratory in a variety of ways, including observing a case or phenomenon, performing hands-on practical training, or conducting experiments.

Notice boards are essential in laboratories. The organisation uses noticeboards to keep students informed of academic alerts, accomplishments, and deadlines. Most laboratory notice boards include a timeline, experiment list, safety precautions, and so on. The main disadvantage of traditional noticeboards is that cannot access the instructions posted on them. Students or the intended audience may be limited in height or vision. The second issue is that the reader neglects the intended message on the noticeboard due to their absence or ignorance. Schedules, lists of experiments with safety precautions, course objectives and outcomes, and cost information for lab equipment displayed on noticeboards in the labs. In

addition, the science and technology laboratory courses a lab manual, equipment handling and safety instructions, equipment servicing, history cards, and calibration reports are essential. As a result, we are proposing a novel QR code-based method to assist students with understanding academic content and notifications.

Quick response code (QR codes), which are placed on the appropriate equipments or apparatus in the laboratory, are used to access short videos about the laboratory exercise's topic. The videos' size ensures an acceptable download time, making them suitable for use on smartphones and tablets. The QR codes allow students to watch the multimedia material multiple times, allowing them to learn at their own pace. In the field of education, QR codes can be used to store URLs and for many other purposes in colleges, such as saving time on login. In addition, we can create QR Codes to digitally save a student's data evaluation. The digital camera, or Pi camera, allows the proposed system to easily access internet information. The teacher could even ask students to find more articles, videos, or other resources on a topic related to the course and create QR codes to share what they found with their classmates. QR codes are another way for students to reach more people. Students can bring attention to important issues by making Public Service Announcement (PSA) videos or websites and giving out QR codes around campus.

The rapid adoption of smartphones is allowing the QR code to evolve at a rapid pace. A QR Code is a two-dimensional model of a code that is used to store data and can be used for a number of purposes, including educational, marketing, and quick-type information. It may also include text containing an email address or other contact information, indicating that it is a specific engineering and scientific laboratory setting. ZBar is a state-of-the-art library for locating and extracting formats as well as a variety of QR codes.



Fig.1 : Scan QR Code using Raspberry pi

As shown in Fig.1, a new framework for processing video streaming using OpenCV is proposed with the revolutionary credit card-sized computer known as the Raspberry Pi. When OpenCV has finished capturing the noticeboard, we can pass it on to a Python barcode library, such as ZBar, which determines the barcode and converts it to personal information.

### 1. Why Laboratory management is required?

Laboratory resource management is an intelligent tool that helps instructors in coordinating laboratory courses and their resources to enhance teaching learning processes, ease improvement, and long-term planning. This will allow for greater insights into lab course improvements as well as faster response times from all data and information stored in the Optimal database.

Learning can take place in a variety of ways in the laboratory, including observation of a case or phenomenon, hands-on practical training, and experimentation. The primary goal of organizing laboratory learning for students is to help them develop practical skills in their field of study. Laboratory learning allows students to apply and reinforce the theoretical concepts taught in class. It also aims for a range of learning outcomes, such as experiential learning. Computer-based representations and simulations of natural phenomena, as well as large scientific databases, are more likely to be effective when integrated into a well-planned sequence of classroom instruction that includes laboratory experiences.

Laboratory experiences can assist learners in better comprehending specific scientific facts and concepts, and how these facts and concepts are organized in scientific disciplines. Laboratory experiences can help learner to identify questions and concepts that guide scientific studies. Laboratory experiences may facilitate students to address the challenges for observing, manipulating, troubleshooting observation - based equipment, understanding measurement errors, and interpreting and aggregating the resulting data. Students can learn how to use scientific tools conventions and equipments correctly and safely, make observations, take measurements, and carry out well-defined scientific procedures (Seth and Rehman, 2022).

Thus there is need of the solution which can offer

following benefits to stakeholders in higher education institutes in following way:

(a) To Enhance the learner's abilities like- a) Critical thinking skills b) Analytical skills c) Interpersonal skills d) Management skills e) problem-solving skills f) Organization skills with available resources and transparency g) Interpersonal skills.

(b) To help administrative and teaching staff in laboratory management in multiple ways of administration procedures.

### 2. Objectives Of This Work

a) The primary goal of this paper is to share our implementation strategies with QR codes in teaching higher education laboratory courses.

b) To implement a model of Laboratory management which will felicitate ease of access and usability to stakeholder's students, administrators, visitors.

c) To facilitate the knowledge management and resource sharing with QR code scan 24 x 7-time slot

d) To share the knowledge in the format of audio useful for visually impaired students

e) To share the knowledge in the format of multimedia video for grasping stepwise experiment procedure.

f) To share the knowledge in the format of text for getting acquainted to resource, deadstock budget, timetable

g) To make smart noticeboards friendly to youth students using technology on their smart phones

h) To provide administration a technological assistance and modern laboratory pedagogy for resource management

i) To provide instructional material to advanced learners by providing a pathway to complete the experiments on their own with well-defined process. This objective is contributing to enhance peer learning, problem solving and interpersonal skills

j) To enhance critical thinking ability of learners by

adding the questions after experimentation

- k) To add transparency to the documents like Budget, Standard Procedure, document, Regulatory and safety plans, Time table, Long-term plans, safety precautions Workflow Lab manual etc.
- l) To implement the principle of learning by doing
- m) To have check on proxy attendance for Practicals by adding student id, longitude latitude
- n) To utilise modern tools like cloud, QR codes for attendance and other administrative work
- o) To perform information management handy with QR codes about Inventory management, scrap /waste disposal, shared equipments, quality collection, processes of handling verification and validation.

### 3. Literature Survey

QR codes can help higher education institutions create more interactive and engaging learning experiences. Karahan and Bilici (2017) discovered that QR codes can increase students' interest and motivation in science classrooms. Furthermore, Sharma (2013), Mehendale et al. (2017), and Saprudin et al. (2014) all agreed that QR codes were used as an effective learning tool to improve student knowledge during the teaching and learning process. Although many previous studies have been conducted on the QR code, the study of its use in the context of polytechnics in Malaysia has received little attention.

The QR code lab manual also allows for independent and cooperative learning, which inspires and draws beginners' attention to actively participate due to its ease of use and lack of paper (Shin & Kang, 2015). Furthermore, the development of the QR code lab manual as a "technology-based educational aid" designed as a new pedagogical approach promotes student-centered learning (Myllari et al., 2012; Sharma, 2013) and a comfortable learning environment (Al-Khalifa, 2011). During the learning process, the m-Learning approach provides opportunities, convenience, benefits, and a dynamic environment (Liaw et al., 2010).

The suggested system includes a security and monitoring system made up of smart mirrors powered by Raspberry Pi. The system's architecture allows for

three types of input: voice, touch, and input instructions. The hardware parts are expensive and have a short lifespan. Additionally, the Raspberry Pi employed in this suggested system has constrained processor and memory capabilities. There are several uses for QR codes in the educational system. One of these is the administrative portion, which will receive all the student data. When students visit a lab by scanning a QR code, thingspeak server stores all of the students data. This suggested system will be utilised for educational reasons, including the display of notices and student results student list, via QR codes,

### 4. Methodology

The proposed laboratory management methodology addressing all expectations and objectives is as shown in Table I. The methodology describes following modules. The System consist of three parts and four types of modules. Three modules are listed covered in Table I. The three parts of systems are as follows:

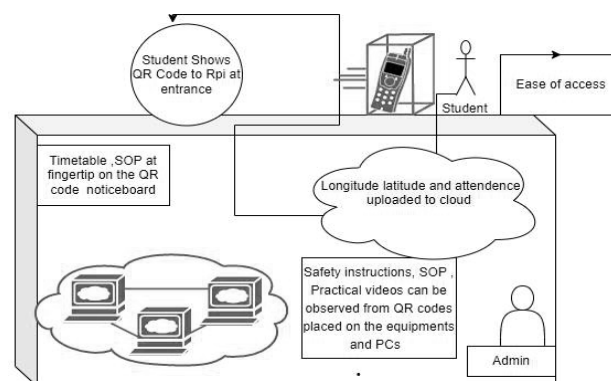
A. Student Part

B. QR Codes placed at Laboratory on the Notice boards, Equipments parts

C. Admin Part The conceptual diagram of proposed system is as shown in Fig.2.

The proposed laboratory management system contains four modules which are explained in different parts of system.

A. Student Part: Student are allocated identity numbers. As per identity numbers QRcode is



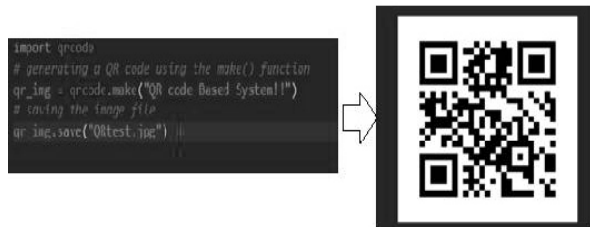
**Fig.2 : Conceptual diagram and Placement of the QR codes for proposed Laboratory Management system**

generated on student's Smart phone.

The QR code generation on student's mobile can be done either by small piece of program or by using by importing the QR code package into the application code. The QR code generator for the QR code package is shown in Fig. 3.

The string "QR code Based System!!!" is encoded in QRcode format by the expression QRcode.make ("QR code Based System!!!"). The code variable contains the encoded QR. The generated file name code. save('QRtest.jpg') is saved with the QR code as shown in the Fig 4.

The Raspberry pi camera module fixed at the

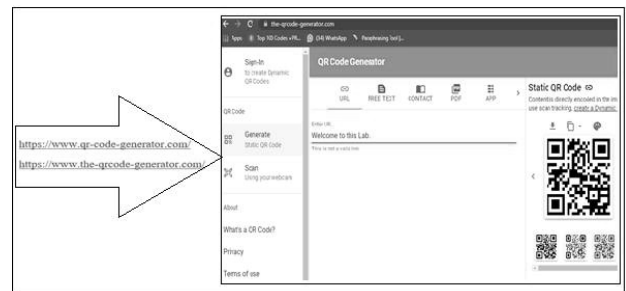


**Fig. 3 : Generation of QR code on the smartphone QR Codes**

entrance of the laboratory scans it. Longitude latitude appears on mobile. The pre-recorded audio message of welcome to the Lab number is audible with student id. For admin part Attendance is registered. And on cloud like thingspeak number of visitors per day is visualised.

B. QR Codes placed at Laboratory on the Notice boards, Equipments parts :

Module 1: A Raspberry Pi-4 with camera module is installed. The registered students entering into the lab are identified.

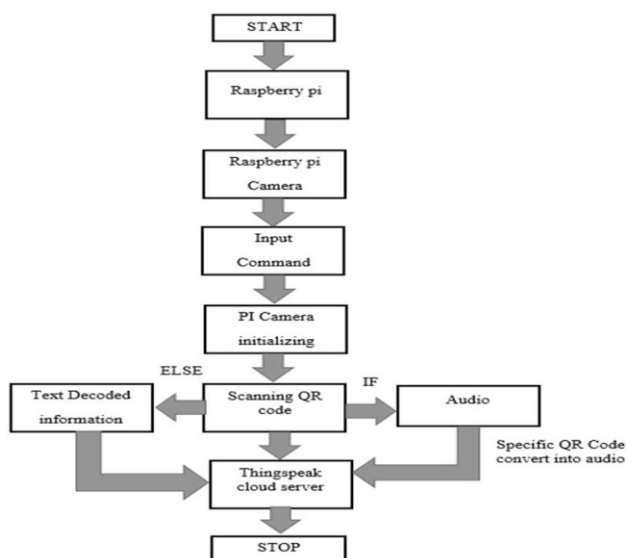


**Fig.4 : QR code generation using website**

**Table 1 : Laboratory Management Methodology Parts**

Sr. No	Module	Contents of module	Location of the module	Objectives satisfied	Action to be done	Remarks on outcome
1	Module 1	Raspberry Pi-4 with camera module and speaker	At Laboratory entrance	a ,b, c ,d are highly mapped and from objective a to objective o are mapped	Student are allocated identity numbers. As per identity numbers QRcode is generated on his Smart phone. The Raspberry pi camera scans it. Longitude latitude appears on mobile.	The pre-recorded audio message of welcome to the Lab number is audible with student id. For admin part Attendance is registered. on cloud like thingspeak number of visitors per day is visualised.
2	Module 2	QR codes <sup>1,2,3,4</sup> for time table , SOP and safety instructions, concern staff ,inventory control	At notice board	a ,b, c ,f, g, h, i ,l ,m, n, o are highly mapped and from objective a to objective o are mapped	Scan following if you are student: QR <sub>1</sub> : List of equipments QR <sub>2</sub> : time table QR <sub>3</sub> : SoP and safety instructions Lab Incharge Lab assistant contacts QR <sub>4</sub> : Budget of lab Inventory control	The teacher is moving in the lab and can observe the sequence of scanning of QR codes and learning process.  The number modules vary as per how many equipment sets are made available to students for weekly turn.
3	Module 3a	QR codes <sup>5,6,7</sup> placed on the equipment 1	On the equipment set 1	a ,b, c ,e are highly mapped and from objective a to objective o are mapped	Scan following if you are student: QR <sub>5,8,9</sub> (SOP): Standard Operation Procedure QR <sub>6, 9</sub> : Safety Instructions for equipment QR <sub>7,10</sub> : Respective Experiment video with instructions	The QR code scan output is in various forms such as downloading text information of doc or audio or video.
4	Module3b	QR codes <sup>8,9,10</sup> placed on the equipment 2	On the equipment set 2			
5	Module 4	QR code <sup>11</sup>	In front of Admin /Lab assistant	j, k , m , n , o are highly mapped and a to o are mapped	Scan QR code 11	Admin /Lab teacher/assistant will mark the entry and do continuous evaluation

- a) The ribbon cable connector on the camera module is connected to the Raspberry Pi.
- b) Following that, two white connection ports are placed near the Ethernet and USB
- c) ports.
- d) Next, use a few commands to boot up the Raspberry Pi and turn it on.
- e) Raspberry Pi 4 interference speaker module: A speaker for converting voice to QR
- f) code. Bluetooth is compatible with the Raspberry Pi, so connect Bluetooth speakers.



**Fig. 5 : Process Flow for QR code to Voice**

We have tested system then decoded message from QR code where we listened to the voice welcome to lab no 307. Our proposed system. Worked as per following flowchart for QR code to audio conversion.

Module 2. QR Codes placed at Laboratory on the Notice boards

Module 2 contains QR codes for time table, safety instructions. The conversion of knowledge from theoretical concepts to implementation in practice requires experimentation in the laboratory. This conversion of knowledge requires laboratory management. Laboratory management is useful for inventory, shared equipment, resource management. Noticeboards are Scanned and information, resource management is done.



**Fig. 6 : A sample Notice board with QR codes**

C. Admin Part:

Admin/ Teaching Lab assistant is the person who is managing laboratory for multiple fronts such as information management (eg. Material of course contents, attendance of students), financial management (eg. Budget workflow, Duplication of equipments), operational research (eg Maintenance of information / equipments). He / she is responsible person for Regularity and safety.

Module 3. QR Codes placed QR codes placed on the equipment

Scanning of QR codes placed on the equipment provide the details of Standard Operation Procedure (SOP), Safety Instructions for equipment, Respective Experiment video with instructions. The teacher is moving in the lab and can observe the sequence of operation of scanning of QR codes and learning process. The number modules placed on the equipment vary as per how many equipment sets are made available to students for weekly turn. The QR code scan output is in various forms such as downloading text information of doc or audio or video.

Module 4. QR Codes placed QR codes placed in front of Admin / Lab assistant

Scanning QR code in front of Admin / Lab teacher/assistant will mark the entry and can be useful for continuous evaluation or posing questions to advanced learners.

## 5. The Software Design Of Proposed System

We are using raspberry pi4 connected to camera module with the help of Rabin cable. Using following commands, we can access the camera module and

some library are used. Following steps for to run our proposed system.

Step I: The OpenCV library will be used by the Raspberry Pi QR scanner in this scenario. Install OpenCV following a Raspberry Pi update.

Sudo apt-get update

Step II: Add the prerequisites after that so your Raspberry Pi can install OpenCV.

Step III: The Raspberry Pi may then have OpenCV installed via the command line.

Pip3 install opencv-contrib-python=4.1.025

Installing Zbar

Step IV: For discovering and extracting codes from various barcodes and QR codes, Zbar is an amazing library. To enter the library, use the command listed below:

Pip3 install pyzbar

Installing argparse

Step V: Installing the argparse library requires the command shown below. The transmission of command line arguments is handled by Argparse.

Pip3 install argparse

Installing Imutils

Step VI: Imutils is used to quickly and simply display Matplotlib pictures and carry out critical image processing operations including translation, rotation, and scaling using OpenCV. To access the Imutils, use the command below:

Pip3 install imutils

Installing urllib.request

Step VII: If you want urlopen to utilise that opener, unlocking is only necessary in such case; otherwise, sim The urllib.request module contains classes and methods for opening URLs (particularly HTTP) in a complicated environment, including redirection, cookies, and basic and alert authentication. Enter urllib.request using pip3.

Pip3 install urllib.request

Step VIII: PI camera-its use for scanning the QR code

a) Connect the camera module

b) Make certain your Raspberry pi became off

c) Find the digital diagram module port

d) Gently pull up on the rims of the port's plastic clip

e) Insert the diagram module ribbon, make certain

f) Collectors at the bottom of the ribbon cable are going through the contacts within the port

g) Push the plastic clip lower back into vicinity.

h) Initialize the PI camera: Commands: Using below input commands to initialize PI camera

i) Python3-m venv; source venv/bin/activate

Step IX: Thingspeak Cloud server:

a) Signup & login for ThingSpeak

b) Create a Channel in your records

c) API Key in ThingSpeak

d) Python Code for Raspberry Pi

e) Test ThingSpeak web page for statistics Logging

## 6. Hardware Design:

In our project three modes of operation.

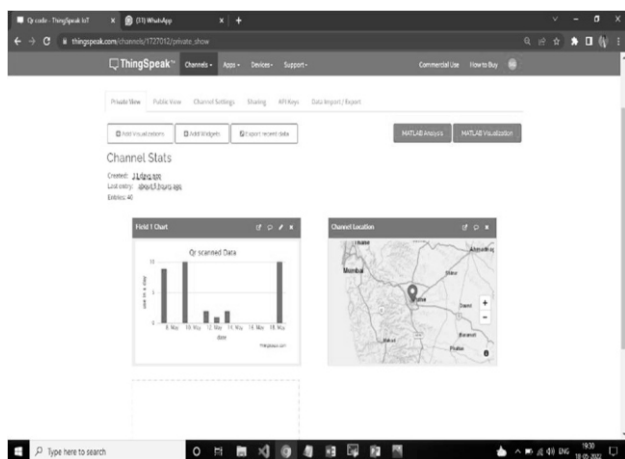
1. Scan QR Code using Raspberry PI

2. Scan QR Code using Smart Phones.

3. Store data at Thingspeak cloud server.

Scanning using Raspberry PI:

Component Used: Here raspberry pi component is used for scanning purposes and also scanning code is converted into voice with the help of raspberry pi.



**Fig.7: Thingspeak cloud records**

Store data at Thingspeak cloud server: Here we used some IOT (internet of things) for display how many students scanned QR code in day also it showing the location and graph representation shown in Fig. 7.

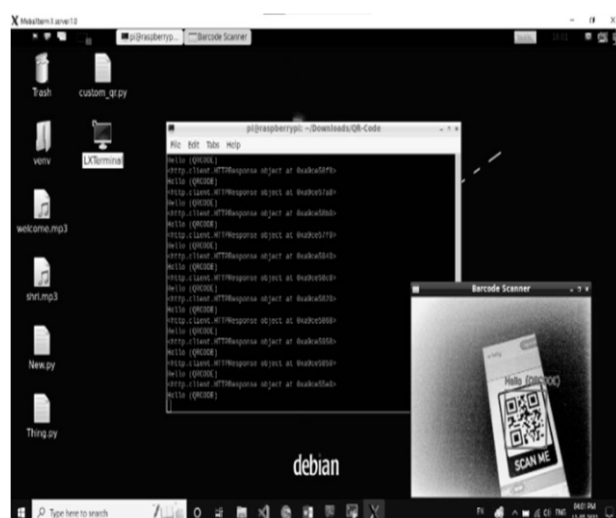
## 7. Test And Result

### a. Results observed at entrance of the laboratory



**Fig. 8 : Test and results of our proposed system**

After adding all the libraries of code and clicking on command prompt with codes described in above section camera is turned on automatically. On turning on the camera if student comes in front then from his mobile login credentials he generates the QR code. The scanned QR code data is decoded and converted into voice. For that reason, you need to one speaker for hearing the sound. The pre-recorded audio message of welcome to the Lab number is audible with student id. For admin part Attendance is registered. on cloud like thingspeak number of visitors per day is visualised.



**Fig. 9 : Output Command Window having QR code interface to Raspberry pi for getting output from audio speaker and QRcode scanner**

### b. Results observed at Noticeboard of the laboratory:

Students scanned QR codes QR1, 2,3,4: they could download successfully List of equipments, time table, SoP and safety instructions Lab Incharge Lab assistant contacts and Budget of lab Inventory control.

### c. Results at Noticeboard of the laboratory:

Students scanned QR codes QR5,8,6,9: they could download successfully Standard Operation Procedure(SOP), Safety Instructions for equipment

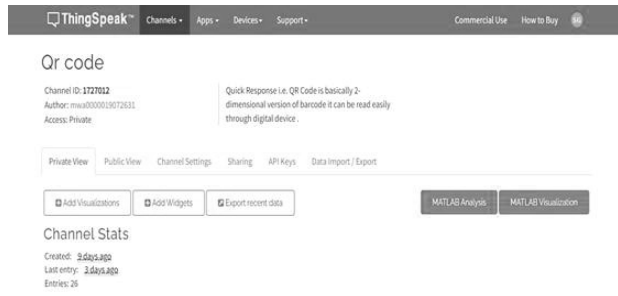
### d. Results at Respective Equipments of the laboratory:

Students scanned QR codes QR7,10: they could download successfully respective Experiment videos with instructions. The teacher is moving in the lab and can observe the sequence of operation of scanning of QR codes and learning process.

### e. Thingspeak Cloud Server output 1:

To store the data, ThingSpeak is used as a cloud server. The data that the Raspberry Pi reads and sends to ThingSpeak may be seen online from any location in the world. The figure shows the thingspeak channel we have utilised showing public view, private view and channel setting. Admin /Lab teacher/assistant will mark the entry and do continuous evaluation.





#### f. Thingspeak Cloud Server output 2

Graphical representation and Location of the QR code is given below and it shows the location of the student who scan QR code. HTTP and GNSS can be used for implementation.



#### Future Enhancement:

This educational system can be extended for a number of educational purposes, including colleges, workplaces, libraries, and office managers. Similar management systems can be used for supermarkets, products, business malls, billboards, museums, and restaurants. GNSS features can be utilised for the future enhancements.

### 7. Conclusion

This article proposes a cyber-physical method for the laboratory management system. This cyber physical technological method that connects the physical laboratory with digital world with QR codes and thingspeak cloud. The Laboratory Management with QR codes is useful for resource management. Our suggested method is useful for stakeholders.

Advanced learners get the benefits of covering more number of experiments by covering more number of experiments by scanning QR codes on the

next set of equipments. Weak students get opportunity to revise concepts by watching the videos on their smart phones by scanning QR codes on the equipments. The proposed laboratory management system is also useful for the physically challenged learners by means of the addition of sound.

The administration and teaching staff is benefited by benefits of Information management by providing information to visitors at fingertips. The information like Budget, SOP, Regulatory and safety plans, Long-term plans, Lab manual, Time table can be scanned via QR codes and can be managed on the cloud. The other advantage of scanning QR codes and using clouds is equipments management for Shared equipments, Quality collection, Inventory management and Scrap /waste disposal.

Students benefited by accessing instructional materials quickly and easily, and they complement the design of more interactive and engaging learning experiences. But Instructors should ensure that all students have access to QR codes when planning to have students use them for laboratory activities. The other limitation of the system is to conduct QR code activities free Wi-Fi campus, with backup plans are required. For numerous users, and uses including the education system, marketing, and security, the system can be used to provide better resource management.

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