EXCEL through IoT (Exploring Cognitive and Emotional Learning through IOT)

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Abstract*: *Cognitive Learning is a process that involves learner's knowledge into consideration. It involves the use of human brain. These days understanding students's emotional state of mind is one of the research area where student face problems in tackling academic tasks. It has been observed that emotions are a crucial part of students' psychosomatic life, and that they may strongly influence academic motivation, cognitive strategies of learning and achieving the desired results.So, our research is to augment student learning and teacher instruction by giving the real-time reaction of students' state of mind, so that teacher can engage students in the learning processes, help them to learn or use the brain in much and far better way to relate thing with the previous one while learning something new.

***Keywords*: EEG (Electroencephalography), Arduino Brain Library Processing IDE, Neurosensor, Cognitive library**

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I. INTRODUCTION

From decades, education plays an essential role in everybody's life. But what students are learning from that education, at what level they can understand the things, what is their catching power are some of the critical challenges faced by the teachers. Education provides the awareness or knowledge about everything present in the world and then it is up to that person how he uses that in his life. To make life better, it is essential to focus on education. But as a teacher, it becomes difficult to understand who learning from you or who is diverted from there. There are various methods or techniques to know the presence of student's mind in class like students' facial expression, eye movement, hand movement and asking questions randomly related to the concept or activity he did in that class. But using these techniques, we cannot always come to the correct conclusion and can take improper action. The paper aims to augment the learning process and teacher instruction by seeking the real-time reaction of the student's emotional state of mind. Towards that end, we are proposing a smart system that reports student's cognitive-emotional state in real-time and assists teachers to adapt their instructions based on students' state of mind. The system will use sensor devices like wristbands and video cameras to accumulate multiple streams of data from the students and will make predictions using machine learning. This paper focuses on the idea of mind activity from where we can get the actual data and can come to a suitable result or action. As we know that our brain generates brain waves in the form of electrical waves, so we will use some devices here to read and analyse those brain waves.

Electroencephalograph EEG

An EEG measures the electricity that a human brain makes; it does not measure opinions or feelings, and it does not transmit any electricity into the human brain. It also can be used to determine student's level of alertness or consciousness. This model comprises hooking up numerous pairs of electrodes on a human or students' head. These electrodes conduct electrical action, capture it from the brain and send it out to a machine that intensifies the signal. The electrodes detect and track what the electrical impulses look like when student is awake, drowsy and asleep at one point. EEG involves the application of electricity, but that is not the case an

EEG detects and records a person's brain's electrical signals which are sent from one nerve cell to another to get information from brain to the rest of the body or from the body to the rest of the mind. Brains electrical activity is seen as a pattern of waves on the EEG machine, which can be displayed on a computer screen or any other smart device. Once the test is over the electrodes are be removed from scalp.

In this model, the student wears this headset shown above, which measures the students' presence of mind. This device uses ThinkGear technology, which works as an interface between the device and the student wearing this device.

Fig.1. 14 Channel EEG Device

ThinkGear also works as an amplifier for the received brain signals and remove noise from those signals. This device also consists of a sensor, reference points and a chip used to process the data. This model uses the eSense algorithm to find out the mental state or concentration level of a student.

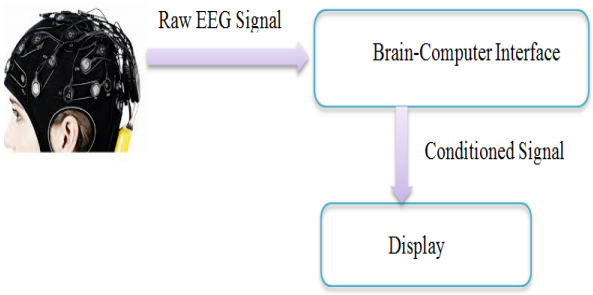

Fig.2. Getting Signals using device

Internet of Things

Internet of Things is defined as a system where multiple homogeneous or heterogeneous things are connected with the help of the Internet. The idea behind the Internet of Thing is connecting all physical objects that we use every day to make our lives simple or to bring smartness in every aspect or every system. As the term Internet of Things says that everything must be here related to Things and the Internet, but it is not the case. IoT is also about the vast amount of data generated by different physical objects and also about providing services based on that data. As we can see the refrigerator as an example in our daily life, it can be connected with our mobile phone, laptop, smart TV etc. As we know in today's scenario, people are too busy in their professional life that sometimes they forget about many things what he was supposed to bring at home. Like if we have a smart refrigerator which has a built-in sensor to count the items inside it or to think like today is Monday and family will have paneer in dinner, but it is not here. So, the refrigerator itself will send a message on family members phone to remind them to bring paneer at home.

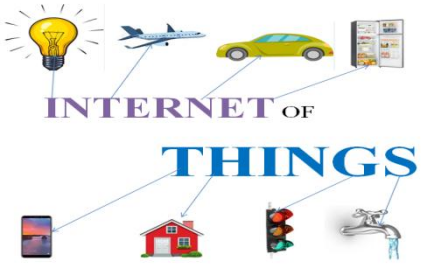

Fig.3. Devices Connected Through IoT

Today almost all companies are using IoT technology and gaining benefit from it. IoT based companies can see real-time insights and analytics as things can be tracked. The Internet of Things (IoT) units installed base or expected to be installed from 2014 to 2025 (in billions) are shown figure 4.

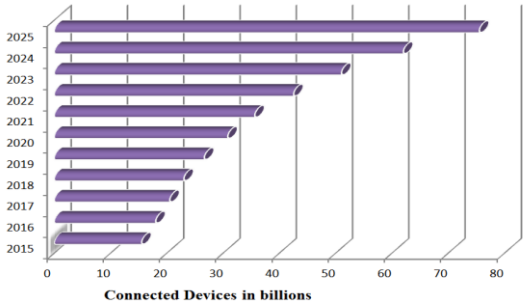

Fig.4. Expected IoT Units installation by 2025

Fog computing

Fog computing is somewhere similar to cloud computing, except its storage location. In cloud computing, data is stored centralized at remote place whereas in fog computing data is stored locally and in a decentralized form. So, information is stored somewhere between the data source or end devices and cloud. Fog computing does complete analysis locally and send only the required data to the cloud to make it globally

accessible. As complete data analysis is done near to data source, so only limited data needs to be sent, which makes it more efficient and improves overall performance. Fog computed was originated from cloud computing. IoT devices are overgrowing and handling a vast amount of data generated by these devices became quite complicated for cloud computing. Thus, a new idea for storing data came in the form of fog. Controller's devices, switches, routers, etc. can act as fog nodes. These fog nodes are installed in target areas like college, home, city etc., and Whenever any IoT device produce data, firstly it is analysed locally through fog nodes without sending complete data back to the cloud.

Fog works like intermediary nodes between end devices and cloud, and send data to the cloud through the following steps:

1. All IoT devices are wired to the automation controller at some place, and whenever IoT devices generate electrical signals, the automation controller is used to automating these smart devices.
2. Next, this data is transmitted to the local server or protocol gateway, which helps in converting that data into a protocol that is understandable by the Internet.
3. Finally, data is sent to fog nodes where it is analyzed and sent to the cloud, as shown in figure 5.

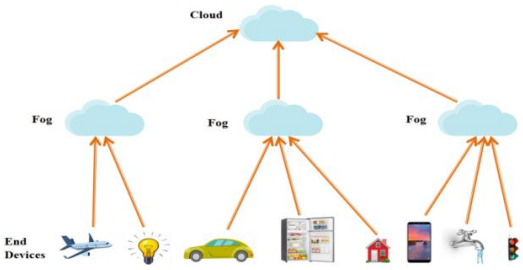

Fig.5. Fog Computing

II. PRESENT SCENARIO

There are already a variety of methods in use. These methods include interpreting the facial expression of the students, examining their hand-eye coordination, reading their body behaviour, and asking the question regarding what is going on in class. These methods are not much evolved as they involve fundamental ways which are unreliable as they are very ambiguous and may lead one to take inappropriate actions to reach the deviated goal although this method cost nothing but is abysmally inaccurate and ineffective as it involves guesswork and is not much backed by science. Here we will see different approaches related to the understanding or concentration level of the student in the class.

In paper [7], the author focused on Bloom's taxonomy to know about the student's concentration level. He only used only the first three levels out of six, i.e. remember, understand and analyze for this purpose. Here the teacher asks students to apply some concept that he taught in the class. A student could apply that concept in real life only if he or she understood that. He understands that concept if he can remember the things or hierarchy that relates to the understanding level. If a student can answer these three questions, that means he or she is present in class with full concentration otherwise not. Thus, this approach gives a better idea to know about the student presence level in class as compare to MCQ approach.

In paper [8], the author worked on discussion-based approach instead of MCQ and Bloom's Taxonomy. Discussion based analysis in the teaching-learning process leads to dialogic instruction between students and teacher. Using this approach, students get vast knowledge, come up with new ideas and experiences. This process shows interest in the cognitive process, and the teacher can easily understand the concentration level of the student in the class. In this paper, the author completely changed the typical classroom pattern where knowledge transmission is only from one side to the new approach, where knowledge is shared from both the ends.

Paper [9] proposed a "Metacognitive Learning process" based on ideas to explore the cognitive and emotional learning of students in a classroom. Here students and teachers talk about their opinions related to any field. Working together with the teachers and thinking on the same level enhances students' performance in all aspects. In this paper, the author worked on two approaches in two different classrooms. One is where the study was done using a simple learning process, and in the second classroom, students were taught using Metacognitive Learning process. After analysis of both the classes, only the students who were in the second classroom, i.e. Metacognitive Learning was able to represent.

In paper [10], the author focused on two theories. One is electroencephalograms (EEGs) and second is event-related potentials (ERPs). He performed some experiments where he recorded the signals coming from

the human brain using some device, then removed the noise, computed ERP signals and finally analysed the signals for better understanding the human brain activity. These analyses also help us in understanding the spatial activations and the temporary development of electrical signals in the human brain while doing creative tasks. Essential factors to be kept in mind to record clean EEG signal in creativity research were discussed. Here creativity was considered as the significant aspect of cognition and knowing about the understanding the level of student's brain.

In paper [11], one new concept was derived that works as an interface between brain and computer. This interface takes input from the human brain and shows that on some display device in graphical form. Here author used EEG headset as an interface to find out how actually brain waves or signals vary from time to time and how these signals react with the change in brain activity. EEG device consists of some electrodes. Here the author used two electrode EEG headset. These electrodes are placed on the human scalp. Now signals measurement can be done in two ways: 1) Using Bipolar and 2) Monopolar. Using bipolar approach brain signals can be measured by finding the voltage difference between adjacent points, whereas using monopolar voltage difference is estimated based on the reference points given on the EEG headset. In monopolar approach, reference point, electrodes are placed in some specific areas where its potential is not get affected by brain waves.

Paper [12] focused on changes in electroencephalography (EEG) to derive various measures of cognitive workload, involvement, and distraction as and when the individuals developed and improved their problem-solving skills. Here, the author worked to know that if we enhance the skills of a person, then does it reduces the workload. For this purpose, some of the students were taught with new skills and then gave them some severe problems. But he analysed that improving the skills does not affect the workload means as the skills were increased, the workload level did not decrease.
Presently many researchers are working on enhancing computation power with the help of machine learning to estimate the students' knowledge or learning capability based on their activities, which was taken to choose an incorrect answer.

In paper [13], the author worked on how to improve the cognitive skills in a person even if he is healthy or disabled. He proposed a game to enhance the learning skills of a person or student based on neurofeedback. Its analysis was done using a Brain-Computer interface that helps in decoding the signals that come from human brain activity. Before this, various neurofeedback based games were available, but none of them dealt with attention-related brain activities. So, based on attention-related signals he proposed a game where the player was supposed to refill a set of elements of a 3 X 3 matrix. The author used the entropy feature of EEG to analyse the attention level of the player. If the player's attention level crosses the threshold, it means he has good concentration otherwise not. Finally, this paper focused on the impact of neurofeedback based BCI game on the enhancement of attention.

Paper [16] discovered that importance of cognitive skills on human performance and also found the mathematical gap between cognitive ability and the human factor. To fill this mathematical gap author designed the theoretical relationship between cognitive skill and the human factor. To find out the effect of human factor on mental abilities, the author required antiseptic and most accurate analysis. Also, this paper provided a unified framework in the form of a mathematical solution for Cognitive skill based on Psychological and Neuroscience studies. In short, Table 1. Shows the existing research in this area:

TABLE 1. Existing Research Work

S. No	Paper (Reference)	Contribution (Main Idea)	Remarks
1	N. Applebee et al. [8]	discussion-based approach instead of MCQ and Bloom's Taxonomy.	knowledge is shared from both the ends
2	Lisa M. Blank [9]	explore the cognitive and emotional learning of students in a classroom	Working together with the teachers and thinking on the same level enhances students' performance in all aspects

3	Narayanan Srinivasan [10]	recording the signals coming from the human brain using some device, then removed the noise, computed ERP signals and finally analysed the signals for better understanding the human brain activity	Understanding the level of student's brain.
4	J. Katona et al. [11]	A concept that works as an interface between brain and computer	how brain wave signals depend on the changes of brain activity
5	Ronald H. Stevens et al. [12]	focused on changes in electroencephalography (EEG) to derive various measures of cognitive workload, involvement, and distraction	improving the skills does not affect the workload
6	Kavitha P Thomas et al. [13]	Based on a game to enhance the learning skills of a person or student based on neurofeedback	If the player's attention level crosses the threshold, it means he has good concentration otherwise not
7	Sadique Ahmad, Kan Li et al. [16]	To find out the mathematical gap between cognitive ability and the human factor	Mathematical solution for Cognitive skill based on Psychological and Neuroscience studies.

Scientific Contribution of our work

Till now scientific understanding is mainly missing in student's emotional state of mind which he experiences in tackling academic tasks. It is supposed, however, that emotions are a crucial part of students' psychosomatic life, and that they may strongly influence academic motivation, cognitive strategies of learning and achieving the desired results. So, the scientific contribution of our research is to explore cognitive and emotional learning of students to make teaching more effective.

III. PROPOSED WORK

This model includes the computation of EEG wave on several features like alpha, low beta, mid-range beta, high beta, delta, theta, gamma, and then finding out the students' state of mind using the digital values of waves. This numeric value of the several aspects is then compared with the experimentally computed value, and then, the level of students' state of mind is analysed. The objective of our paper to augment student learning and teacher instruction by providing real-time feedback of student states. Towards that end, we are developing an intelligent system that reports students' cognitive-emotional states in real time and enables teachers too.

The objective of our paper to augment student learning and teacher instruction by providing real-time feedback of student states. Towards that end, we are developing an intelligent system that reports students' cognitive-emotional states in real time and enables teachers to adapt their instruction based on students' states. The system will use sensor devices such as wristbands and video cameras to collect multiple streams of data from students and will make predictions using machine learning. Our goal is to demonstrate that these data can be leveraged to predict students' cognitive load and emotions in a learning setting. We plan to take three steps to prepare and analyse the data. First, we will pre-process the biometric data and essential engineer features. Next, we will examine the data using some traditional statistical methods which can help us understand the data better, such as data visualization, descriptive data analysis, and regression analysis. Finally, we will use the data to build a machine learning model with predictive power to indicate learners' cognitive load and emotions in a learning setting.

This research includes the following phases to carry out the work, as shown in figure 7.

1. At the start, 14 channel EEG Device is placed at student scalp to read the brain signals or waves. Then Arduino libraries are used to examine these signals and categories those into theta, alpha, delta, low beta, high beta, gamma waves. Now, the collected data from the EEG Device is sent to the Fog nodes for further processing to filter out the required data.

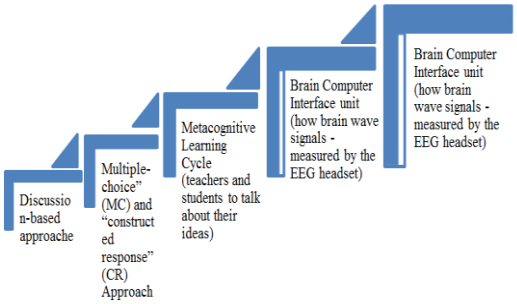

Fig.6. Evolution of cognitive learning Solutions

2. Then, fog nodes again process that data and send only the required data to the cloud.
3. After that cloud sends that data to receiver or computer or some other smart devices that can be visualised using some processing IDEs.
4. Finally, again, many values or mind waves are analysed to predict the emotions of a student.

As we know that EEG signal processing can be done for various purposes. We are doing EEG signal processing for cognitive learning purpose where we learn about the emotional state of students. For this analysis we used two approaches: Spectrum analysis and a Autocorrelation function.

Spectrum analysis

The approach we used to explore more about EEG signals is read the spectrum characteristics of brain waves. One of the foremost characteristic of EEG signals is to analyse them in their stationary condition. Here, stationary condition means when signals are not changing with respect to time. But this happens only for a limited time. Spectrum analysis gives detail about all frequencies that reflects the changes in brain waves level.

Brain waves are classified in various categories based on their certain rhythms. Alpha brain waves have less frequency (7-13 Hz). These waves are generated while a person is in the awake state but with closed eyes and helps him in overall mental peace, alertness and calmness.

Beta brain waves (13-39 Hz) have the greater frequency than alpha waves. These waves are generated when a person or student is in alert state or active thinking state. Like while delivering lecture, participating in debate, making decision and learning something new etc., while a person watching TV in relaxed state does not have that many beta brain waves. These waves are mostly found when a person is in awake state.

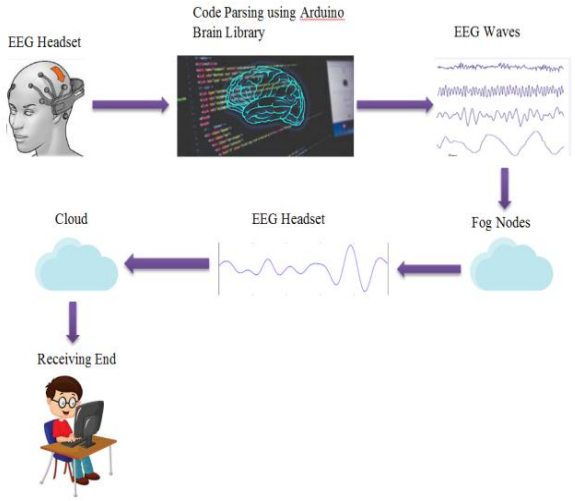

Fig.7. Process of our model

Gamma waves are known as brain waves with the highest frequency, i.e. above 40 HZ. These waves pass the information rapidly from one neuron to another. To access gamma brain waves a person or student need to be quite. If a student is vibrating at gamma wave frequency that means neurons are transferring information with higher speed, and student can remember the things word by word. Those students have a sharp focus on the moment and also the higher awareness using their five senses.

Theta brain waves (4-7Hz) are measured in a deeper stage than alpha waves, like if a person is in deep relaxation stage or doing meditation continuously. If a person is generating theta brain waves, it is believed that this person can think beyond his conscious mind like he is considered in the subconscious mind stage.

Delta waves are low frequency but high amplitude brain waves. These waves are generated even in a deeper stage than theta waves. These waves entirely suspend outer awareness and help in empathy. Researchers found that women create more delta waves than men. Delta waves are most profound in sleep states and play an essential role in health. If this wave is repressed, it leads to an inability to renew the body and revitalize the brain, and poor sleep. Delta waves vary between 0.03 and 0.08 seconds duration.

We used Discrete Fourier Transform (DFT) to perform EEG spectrum analysis. Following equation shows the DFT of particular EEG:

$$X(p) = \sum_{n=0}^{N-1} x(n) exp(-j\frac{2\pi}{N} pn) p = 0,1,2, \dots \dots N-1$$

Where,

N= Total number of EEG samples used for our analysis. To compute X(p) efficiently in above equation we used Fast

Fourier Transform algorithm (FFT). FFT is used to compute the power values of particular frequency band. These power values can be used for further analysis.

Besides power computation we can use other methods as well for spectrum analysis of EEG signals. These methods are based on variable and invariable spectrum analysis. Autocorrelation is also one another approach to analyse the EEG signals. This can be done using following formula:

$$R(t) = \frac{1}{N} \sum_{n=0}^{N-|t|+1} x(n)x(n+t)$$

Here, expected frequency can be measured based on the random data. If x(t) is having invariable data then R(t) will also contain invariable data within the same time period, whereas If x(t) is having variable data then R(t) will also contain variable data.

```
#include <Brain.h>
Brain brain(Serial);
void setup()
{
      Serial.begin(9600);
}
void loop()
{
      // packet to be expected once per second.
      // The .readCSV() function returns a string (well,
char*) listing the most recent brain
        data, in the following format:
      // "signal strength, attention, meditation, delta,
theta, low alpha, high alpha, low beta,
        high beta, low gamma, high gamma"
        if (brain.update())
        {
              Serial.println(brain.readCSV());
        }
}
```

Then using either of the above two approaches we represent EEG data in a particular format through above code.

Once the data has been read, data goes to the fog nodes based on the three parameters: distance, response time and energy. Here we have N number of fog nodes represented as FoN= FoN_1, FoN_2, FoN_3…. FoN_N and various requests are represented as a set of R=r_1, r_2….r_n. Here response time is the main reason which affects the overall execution time i.e. ExT_{pq}, where p=1,…,n and q=1,….N. ExE_{pq} is the consumed energy of r_p by FoN_q.

The first characteristic feature we considered here is the complete Distance D defined between students and the Fog nodes FoN. We pass over all the requests R to compute D. Points (R_{px},R_{py}) and (FoN_{qx}, FoN_{qy}) works like the coordinates of student and Fog node FoN_q respectively, the D is computed using following formula:

$$D = \sum_{p=1}^{n} \sqrt{(R_{px} - FoN_{qx})^2 + (R_{py} - FoN_{qy})^2}$$

Where R is the request set and n is the number of requests in set R. The main characteristic of Fog Computing is to keep the response time as minimum as possible. Thus we used Task scheduling algorithm to minimize the request handling time or execution time. Fog nodes can handle more than once requests at a time. Execution time ExT of a request R by the fog node can be computed using:

$$ExT = \max \sum_{p=1}^{n} ExT_{pq} \; ; q \in N, ExT(R, FoN) < TL,$$

Where TL is the Time Limitation, the total of all ExT_{pq} running on a particular Fog node gives the total time taken by each FoN_q. The response time is based on the last FoN_q to complete its request. The third most important parameter while considering fog computing is energy consumption. Energy consumption should also be as minimum as possible. Here we have set a limit on electricity supply. The overall energy consumption ExE in our case is always less than the limit set on on electricity supply. This energy consumption for dealing request set R by set of Fog nodes FoN is determined by:

$$ExE = \sum_{p=1}^{n} \sum_{q=1}^{N} ExE_{pq} \, , ExE(R, FoN) < EL$$

Where, EL refers to Electricity Supply Limit. Once we get all data on fog nodes in optimized way then only required data goes to the cloud and finally displayed at receiver end.

IV. RESULT AND DISCUSSION

In our research we have experimented on a class of 60 students. We placed EEG Devices on each student's scalp and found out the level of interest of each student in form of different waves as shown in fig. 8.

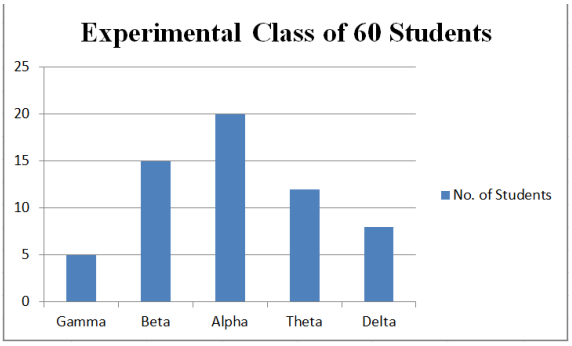

Fig.8. Experimental Class

After that the same experiment was done after controlling the class and again found out the level of interest of each student as shown in fig. 9. Thus we can see that using this experiment number of interest students has been increased.

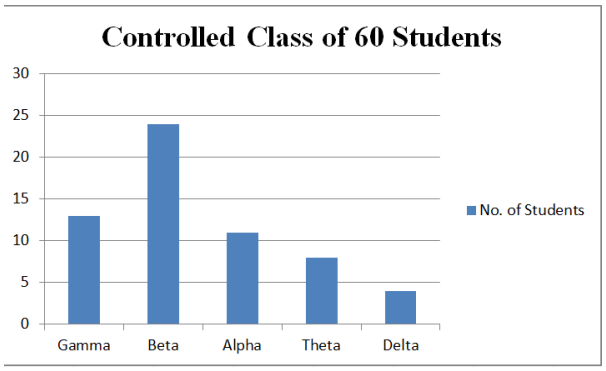

Fig.9. Controlled Class

Research challenges

The uniqueness of this model is the collection of data from the student's brain, analyse that data and find the attention level. Earlier researchers worked on this area using cloud computing, but we proposed this method using fog computing, which enhances the performance of data transmission from end devices to cloud. In future, this can be taken to the edge computing as well to make it more efficient. Earlier medical fields used to read the brain, but now researchers found that reading of mind plays a crucial role in various other areas as well like neurological and medical, education, multimedia applications, psychiatric, games etc.

V. CONCLUSION

Our research paper deals with augment student learning and teacher instruction by giving the real-time reaction of students' state of mind as we saw in fig. 8. Here we found that only 5 students with Gamma waves and 15 students with Beta waves means only 5 students pass the information rapidly from one neutron to another and student can remember the things word by word and 15 students are in alert state or active thinking state.After analysing this scenario we found less number of interested students so, teacher tries to engage students in the learning processes, help them to learn or use the brain in much and far better way to relate thing with the previous one while learning something new. In this way number of interested students has been increased as shown in fig. 9 (13 students with Gamma waves and 24 students with Beta waves). Thus, this paper is to augment student learning and teacher instruction by providing real-time feedback of student states.

Conflict of interest- The authors declare no conflicts of interest.

Data availability statement- My manuscript has no associated data.

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