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# A New Framework Based on The Internet of Things to Improve the Quality of Education by Detection of Student Stress

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*Abstract*—**The Internet of Things (IoT) is one of the new technologies that has received significant attention in the last decade and has been used in all aspects of life (including agriculture, medicine, business, industry, education, etc.).**
**One of the most important applications of the Internet of Things is in the process of student education, which has been discussed a lot in recent years and has led to a significant progress in the education industry, however, there are still many challenges in this field, which includes managing classrooms, conference halls, teaching in offices, public schools, and e-learning websites. Therefore, it is necessary to create a new framework to improve teaching methods. On the other hand, providing educational materials for students according to their level of understanding and learning goals can have a significant effect on improving the quality of teaching and learning.**
**In this research, a framework for improving the quality of teaching to students in the context of the Internet of Things has been presented. In this framework, the mental and psychological condition and stress conditions of the students are investigated and provided to the teacher in real-time, so that they can make the right decision with sufficient information based on the conditions of each student in the classroom and use the information to adapt their teaching methods and tests. This framework, with the help of the Internet of Things, provides information about each student and mental and psychological elements (such as heart rate, body temperature, etc.) as well as factors affecting the classroom environment (including the amount of noise pollution, ambient temperature, light, etc.), collects and uses fuzzy logic to place students in different categories with and without stress conditions. Kuja simulator and MATLAB software are used for simulation. The results of the simulation show that this framework can detect the students' stress and by adapting the test and teaching conditions to the mental and psychological state of the students, it can indirectly improve the educational quality for students**.

**Keywords:** Internet of Things (IoT), e-learning, Stress, psychological elements, environmental influencing factors.

**Article type:** Research Article


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## I. INTRODUCTION

At present, various technologies (such as IoT, cloud computing, artificial intelligence, and other techniques which are related to human interaction with machines or computers, etc.) are used to create and develop smart cities. The IoT was first proposed by Kevin Ashton in 1999. Cisco has introduced the IoT as a web of all interconnected physical objects [1]. Currently, Internet of Things technology is widely used in all aspects of human life, including education. At the same time, huge progress has been made in distance learning techniques and many new methods have been adopted by teachers. One of the most important challenges in education is that the quality of education largely depends on the level of motivation and morale of students. Therefore, creating a new method to discover these moods and taking advantage of these moods to improve the level of student learning is critical for the success of using new technologies in distance education. In this regard, the most common application of the IoT in education is the rapid transmission of data or information using a set of network rules, between teachers and students to increase the student participation and interaction with the classroom and teachers. Another application of the IoT in education is that it can be used to control the student’s motivation in participating in classes. It is also possible to control the amount of stress, the amount of motivation, and the amount of learning and intellectual presence of students by using IoT technology, both in teaching and holding exams. This can also be used for various regulatory purposes. In this research, we have focused on using IoT technology to enhance the quality of students' learning, using the plural. Numerous studies have been conducted by researchers on various applications of the IoT in different areas of human life, especially education.

Salsabeel et al. [2] provided an overview of the applications used in distance learning. These applications use sensors and middleware devices and are often created for advertising purposes and mostly use web-based protocols such as HTTP. In addition, they provided a list of programs currently available for learning and identifying the various components of the IoT stack that are needed to run these programs. Barakat et al. [3] examined IPv6, which helps to obtain IP (unique address) for all different types of devices. The IoT allows different objects to interact with each other and connect to different devices. Cheng et al. [4] examined the benefits and successes achieved over time due to the use of multilingualism in educational settings. They used the IoT to create a comprehensive multilingual learning environment for children to use robots and entertainment devices. The researchers used the results from this environment to create and develop a design framework for guidance in comprehensive multilingual learning environments. They tried to improve the educational process by integrating artificial intelligence and the IoT. They finally proposed a framework for improving student motivation. In that research, they put the IoT in the category of entertainment devices to measure the motivation and mood of students. This method can be suitable for a limited age group and requires further research to generalize it. Guo et al. [5] used the features of the IoT, along with the professional requirements for using this technology to curriculum training to connect the robot to the main periodic system that meets the needs of graduates and engineered curriculum for learners. This research proposed an advanced robotics curriculum for distance learning and a theoretical model for robotics training. This model can be adjusted based on the requirements in each semester, training content, training hours, credits, and other content related to the robot and IoT training course. Veeramanickam and colleagues [6] investigated the creation of smart universities equipped with the IoT. They emphasized on adoption of the goals and requirements of a particular university for IoT technology and e-learning. Their results showed that new technologies and IoT applications can be used as leverage to improve the quality of e-learning programs, reduce costs and help improve educational outputs. Gligoric et al. [7] used IoT to identify the attractiveness of course content in a classroom. They proposed an intelligent system to identify the level of interest that the content of a lesson can create for students. The performance of this intelligent system was evaluated by different groups of students and teachers. The results showed that the presence of sound and movement in the classroom can be considered as two fundamental factors that indicate the level of attractiveness of each lesson. Temkar et al. [8] used the IoT to make classrooms smarter. They looked at the concept of smart classrooms from a completely different perspective and used the immediate feedback from these classes to improve the quality of teaching by using the Internet of Things. They also focused on student control and enhancement technologies in smart classrooms to discover student behaviors in an intelligent environment. Hung et al. [9] used data mining techniques to analyze different patterns created by learners’ behaviors during online learning and provided predictions about the educational performance of learners. In their study, statistical models and data mining techniques of machine learning were used to analyze 17,934 records of learners. The records show the learning behaviors of 98 undergraduate students in a business education course in Taiwan. Their study satisfactorily identified students' behavioral patterns in online learning environments and identified the steps taken by active and inactive learners. Ratnapala et al. [10] used data mining techniques to analyze data on the learning quality of students who interact with the e-learning system to teach assessed or non-assessed disciplines. In that study, behaviors that are related to access and use of the e-learning system of 412 students were examined and analyzed. The results showed that differences in learning environments can change the behaviors of learners during online training. In their study, by means of clustering techniques, students were divided into five groups based on their behaviors in accessing content related to a field. The behaviors and amount of access performed by each of these groups were examined separately. Hershkovitz and colleagues [11] examined how the web was used by users and blog files throughout the learning process. They analyzed the learning activities of students and examined the activities of a large group of learners, in order to develop an assessment of learners' interests based on their behavior in using the web. Vharkute and colleagues [12] designed a system that would improve the efficiency of the existing education system. This system examines the rate at which students' talents, communication, and thinking skills develop in critical situations. Therefore, it can be argued that various researchers have emphasized the use of the IoT to play brain teasers in the classroom. These games can play a significant role in increasing children's cognitive development. In this study, it was found that students' motivation and enthusiasm when attending class or preparing for exams, can play a crucial role in their educational progress. Therefore, we tried to present a new framework that can examine the usefulness of the training provided in the classroom by analyzing students' facial expressions. For example, in many cases, students just have a physical presence (and not a mental presence) in the classroom. This can be considered as one of the reasons for the poor quality of the class and the transfer of taught concepts. In other words, by recognizing the facial expressions of students, the quality of the classroom can be analyzed. As stated in previous research, the Internet of Things can play the most effective role in increasing the quality of teaching and transferring concepts to students. In traditional teaching methods, the teacher cannot get the necessary feedback from all the students in real time and adapt his educational conditions according to the students' conditions in the classroom. In this research, an attempt was made to provide a framework based on the Internet of Things that can instantly inform the teacher about the mental and psychological state of the students and their stress levels, so he can adjust the classroom conditions and the way of teaching and testing. In this framework, factors affecting the increase of students' stress, are taken from several articles, which include environmental noise pollution and the environmental conditions of the classroom, as well as the effect of stress- factors on heart rate. The heart rate, body temperature, and face of students, etc., can be collected and recognized in the context of the Internet of Things by using sensors at the first level. In this research, for the first time, a framework for detecting the mental state and stress of students, and providing appropriate feedback to the teacher in real time, so that he can make appropriate decisions for using different teaching frameworks and adapting them according to the conditions of students, has been presented. The results of the simulation show its impact on the quality of students' learning.

## II. The Proposed Framework

Since all the frameworks and methods based on the Internet of Things must have adequate coverage of its four different levels, in this research, the presented method has been tried to be based on all the four levels of the Internet of Things.

The first level is embedded systems that sense the same data from the surrounding environment.

The second level of communication protocol is to send sensed data from the first level and send it to the next level. The third level of the platform server for review and processing and data mining and the fourth level is the application or user interface

In the proposed method, it has tried to use four different levels according to the application followed in this research. An overview of the proposed framework is shown in Figure 1.

Different levels of proposed framework are as follows.

The first level: It consists of a series of Embedded Systems. There are actually two types of Embedded systems; each one senses a set of data.

The first type: This type is connected like smart gadgets on the student's hand. The internal structure of these smart gadgets consists of a sensor to detect heart rate, body temperature, etc., plus a raspberry pi microcontroller.

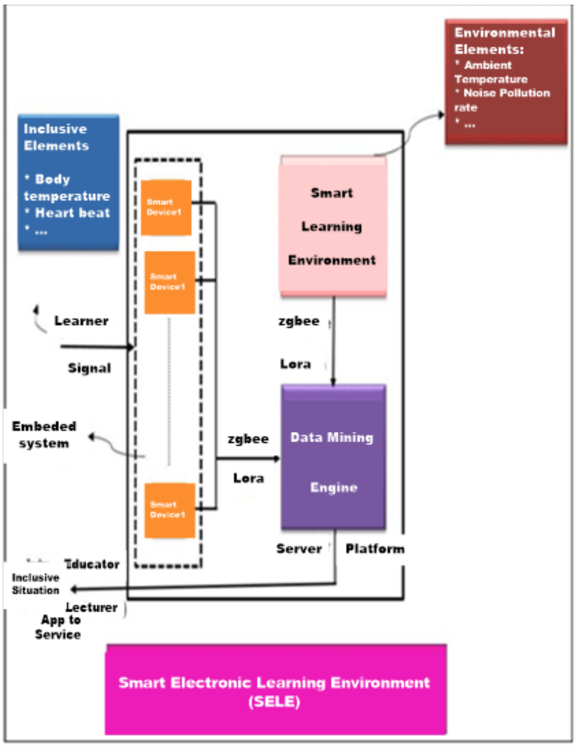



Figure 1. Overview of the Proposed framework

The second type: This type is available in the environment, through which data, such as ambient temperature, noise pollution, ambient humidity and etc., are measured. Each of these cases by itself can be effective in education. similar to the first type, it uses a sensor plus a raspberry pi microcontroller.

- The second level: To achieve the goals of the IoT and the tasks that are assigned to it, smart devices must be able to exchange information seamlessly. The collected data must then be sent to the server for analysis through the infrastructure, and then the necessary commands must be sent to the devices, programs, or people.

The main objective is to make this exchange of information and delivery of applications and services from almost anywhere. This is done by using different IoT protocols. There are many protocols in IoT technology that can help to build an intelligent system. From device identification and management to information exchange and communication aspect, each protocol can interact with different devices and guide them on a mission. There is a wide range of operating systems or protocols that can be used to implement an intelligent system. Each of them has its own language. Each language connects to different devices and forces them to perform a mission.

As shown in Figure 1, embedded system outputs are sent to the platform server by IoT protocols, such as ZigBee or LoRaWAN or . . . Therefore, communication protocols are used in the presentation framework.

- Level 3 of Proposed framework: IoT platforms are a set of Components to help set up and manage IoT-connected devices. Anyone can collect and manage the data of connected objects through a remote system. There are a number of IoT platforms available on the Internet, but setting up an IoT solution for a company depends on the particular IoT platform and the quality of support.

As illustrated in Figure 1, there is a Data-Mining Engine in the platform server and based on the outputs of the embedded systems (pervasive and environmental elements), produces an output that determines the student's status. It determines whether this student is ready to learn the lesson according to his own circumstances and environmental conditions?

According to the proposed method, in this step, fuzzy logic is used and the fuzzy inputs and outputs are defined according to the proposed method. In addition, the necessary analysis and conclusion are performed according to the fuzzy rules. Fuzzy logic is usually used in applications that create specific outputs based on specific inputs and can be the basis for decision-making. This is the most appropriate method for controlling applications. The reason for using fuzzy logic in the third level (platform server) of the proposed framework is that the teacher, based on a series of specific inputs that may occur at different times (fuzzy inputs cover the entire problem), creates different outputs that can be the basis for the teacher's decision based on the level of student’s stress.

- Level 4: One of the most important parts of any IoT-based product is its capabilities in the mobile application area. With the help of mobile applications, it is possible to remotely control objects or receive information from the Internet, wherever you are. Many companies now rely on the benefits of IoT data for optimization and innovation.

The results of the third level which were obtained by using fuzzy logic can be provided to teachers in the fourth level through a mobile application. An example of these outputs is shown in full in Table 1. According to this table, the teacher determines whether the student is ready to accept the lesson or not. This is done based on the existing conditions and the obtained outputs. Various inputs can be used to analyze this framework. In here several inputs are selected as a sample, and the output, which is the student's situation, is obtained based on sample inputs.

**Overview of the proposed framework for discovering the feelings of several students:**

The framework presented for several students is shown in Figure 2.

TABLE I. OUTPUTS CREATED VISIBLE BY A MOBILE APPLICATION

| **Outputs Related to Students** | | | | **Outputs Related to Environment** | | | |
|---|---|---|---|---|---|---|---|
| $L_1$ | $L_2$ | …. | $L_n$ | $SLE_1$ | $SLE_2$ | ….. | $SLE_m$ |
| | | | | | | | |
| | | | | | | | |

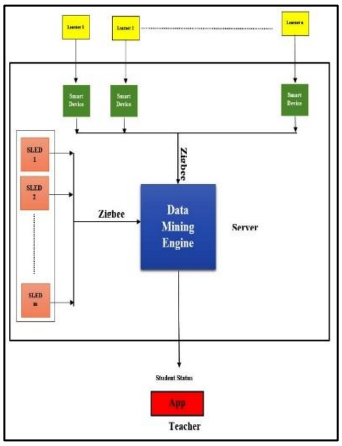



Figure 2. Overview of the proposed framework for discovering the feelings of several students

The output in a typical application on the tablet or Smartphone of the relevant teacher can be shown in Table 1. This table is constructed by using the outputs obtained from the application of fuzzy logic and sent to the platform server. Finally, the student's learning status is sent to the teacher's mobile application or tablet.

## III. Simulation and Experimental Results

In order to implement the proposed framework and review its results on the sample data set, MATLAB programming language was used. To simulate the framework, we also use the Cooja emulator, which runs under the Contiki operating system and is used for IoT programming.

**Dataset used in this research:**

The Poisson distribution is used to generate the required data, which is a normal distribution. The reason for random data generation is that the proposed framework requires smart gadgets or smart watches to be placed on the student's hands so that it continuously sends the body temperature and the heart rate status.

As well as the heart rate collection, other sensors are also installed in the classroom to sense noise pollution and environmental sounds outside the classroom.

This framework was presented for the first time in this research and no dataset (with all the above collection) was available. In this research, the data was randomly generated based on the standard and predetermined range of inputs, as well as with normal and Poisson distribution, and it was used for validation.

This database consists of 4 features that make up the columns of the table and 32,000 rows that are selected as a set of training data. By using Simple Random Sampling, the analysis of 1000 records is facilitated. An example of the data used in this study is given in Table 2. In order to facilitate Data Mining analysis, the simulation stage of pervasive elements (heart rate only) and environmental elements (noise pollution only) was used. Stress indicates a special relationship between the person and the environment (which is considered as a threat to his health). Various factors affect stress which includes environmental factors and the physical and mental condition of the person. As it was mentioned before one of the aims of this study was to investigate the effect of the different factors on reducing students' stress in the classroom and during the teaching process. One of the effective educational factors in new education systems is the architecture of educational spaces. In the new education, the space governing the physical environment of the schools and Universities is not only a dry and soulless environment but also plays a role in reducing enthusiasm and damaging dynamic factors and eventually has a negative effect on the quality of educational activities of students.

In the discussion of the conditions governing the physical environment of education, which has been considered by psychologists and is referred to as the environment in which human behaviors and interactions occur, responding to mental and physical needs leads to the psychological-physical comfort of users. On the other hand, an inappropriate educational environment can cause great physiological and psychological damage to students and significantly reduce the motivation. The desired educational environment is the one that paves the way for increased learning and the emergence of normal behaviors by students. Therefore, in order to achieve the ideal learning goals, appropriate learning spaces must be created. Many types of research have been done in this field, most of which has been performed by preparing questionnaires and distributing them among students of a school or a district and analyzing them with software such as SPSS. In this research, using the concept of IoT, we have presented a framework and performed the necessary simulations with IoT-related simulators such as Cooja and used MATLAB software to perform fuzzy analysis and inferences.

TABLE II. An example of the data set used in this research

| Environment Signal | | Learner Signal | |
|---|---|---|---|
| Noise pollution (db) | Ambient Temperature (C) | Body temperature (C) | Heart Beat |
| 69 | 31 | 36 | 57 |
| 50 | 23 | 39 | 67 |
| 66 | 21 | 38 | 58 |
| 64 | 27 | 37 | 51 |
| 76 | 25 | 39 | 64 |
| 66 | 23 | 37 | 69 |
| 57 | 31 | 30 | 63 |
| 73 | 27 | 38 | 47 |
| 51 | 22 | 37 | 65 |
| 49 | 27 | 32 | 66 |
| 59 | 34 | 37 | 75 |
| 53 | 24 | 37 | 54 |
| 52 | 26 | 37 | 75 |
| 57 | 28 | 37 | 78 |
| 57 | 18 | 37 | 61 |
| 56 | 25 | 37 | 60 |
| 60 | 17 | 34 | 52 |

**Simulated system (Embedded System) in Cooja simulator:**

As seen in the design of the proposed structure for the IoT, the first level of the proposed framework consists of a series of Embedded Systems. For the real design of gadgets, which are Embedded Systems, a simulation is first performed in a software environment to determine the system defects to some extent. Then, we continued with the implementation and design stages. As mentioned earlier, the Cooja emulator is one of the most powerful IoT emulators running under the Contiki operating system.

**Analysis in MATLAB software:**

In this study, from the available data and according to the proposed model, from the pervasive elements (students), only heart-beat (heart-beat) and from the environmental elements only the amount of sound pollution (sound-pollution) was considered. The output of the platform server is considered as Student-Status in the proposed framework. In addition, in the following tables, fuzzy ranges (for analysis in MATLAB software) are considered for the defined fields (Tables 3, 4, and 5).

**Fuzzy defined inputs and outputs:**

Based on the existing data set, the model was analyzed by using a field inference system. In this system, both the first part of the rules and the last part (result) of the fuzzy rules are defined. The inputs and outputs of the proposed system (student-status based on heart-beat and sound-pollution as input) are shown in Figure 3.

TABLE III. HEART-BEAT

| Status | Heart-beat rate |
|---|---|
| low | 20-40 |
| medium | 40-60 |
| high | 60-120 |

TABLE IV. ENVIRONMENTAL NOISE POLLUTION (SOUND-POLLUTION)

| Status | Ambient noise pollution range (db) |
|---|---|
| low | 45-55 |
| medium | 55-65 |
| high | 65-75 |

TABLE V. STUDENT STATUS

| Status | Student Status |
|---|---|
| low | 35-0 |
| medium | 70-35 |
| high | 100-70 |

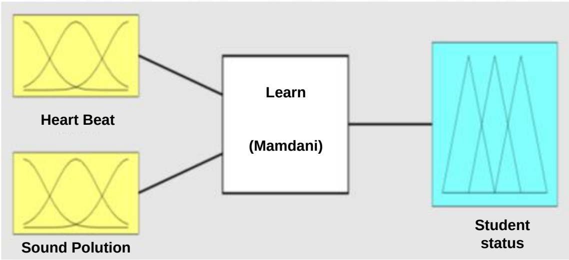
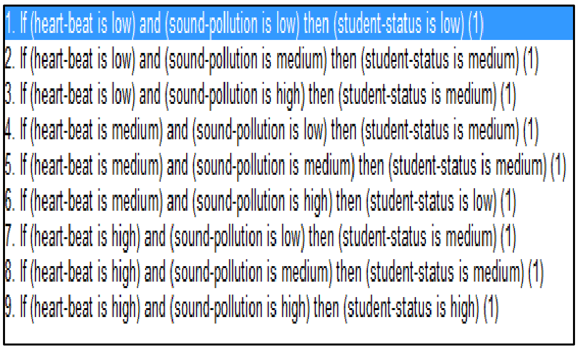



Figure 3. Inputs and outputs of the fuzzy system



1. If (heart-beat is low) and (sound-pollution is low) then (student-status is low) (1)
2. If (heart-beat is low) and (sound-pollution is medium) then (student-status is medium) (1)
3. If (heart-beat is low) and (sound-pollution is high) then (student-status is medium) (1)
4. If (heart-beat is medium) and (sound-pollution is low) then (student-status is medium) (1)
5. If (heart-beat is medium) and (sound-pollution is medium) then (student-status is medium) (1)
6. If (heart-beat is medium) and (sound-pollution is high) then (student-status is low) (1)
7. If (heart-beat is high) and (sound-pollution is low) then (student-status is medium) (1)
8. If (heart-beat is high) and (sound-pollution is medium) then (student-status is medium) (1)
9. If (heart-beat is high) and (sound-pollution is high) then (student-status is high) (1)

Figure 4. Fuzzy defined rules

**Fuzzy defined rules:**

At this stage, the facts are defined based on the fuzzy system. After determining the input and output of the system, the if-then rules are applied appropriately. In fuzzy rules, two important components are

- The general form of the rule
- Determining the parameters of the rule (including the shape and parameters of the membership functions of the fuzzy words introduced in the introduction and sequence)

Accordingly, the following 9 rules (Figure 4) are defined according to the assumptions made:

**Simulated heart-beat input in MATLAB software in fuzzy:**

Having Table 3 and its assumptions as well as the range determined for the heart rate, the resulted fuzzy diagram is shown in Figure 5. The model of diagrams that can be presented in 3 forms (a triangular function, Gaussian function, and bell function) is defined by rules of the model, and uses a form of triangular function. (Figure 5).

**Simulated input of ambient noise pollution (sound-pollution) in MATLAB software in fuzzy:**

Having Table 4 and its assumptions, as well as the range determined for ambient sound-pollution, the fuzzy diagram obtained in Figure 6 can be seen.

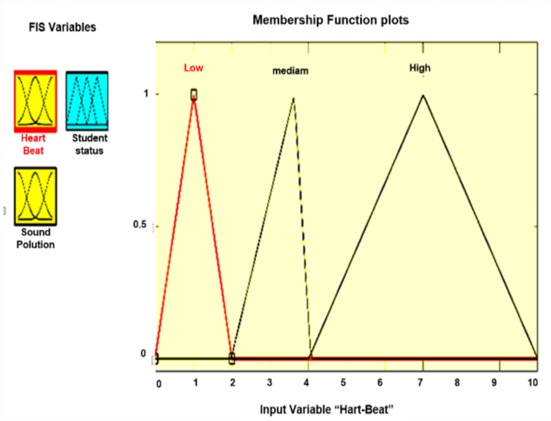



Figure 5. Simulated heart-beat input diagram

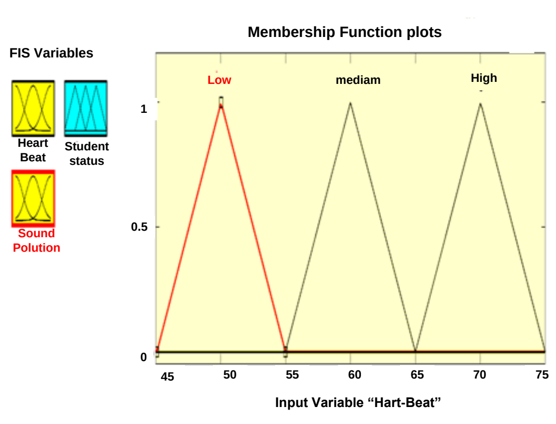



Figure 6. Simulated input diagram of ambient sound-pollution

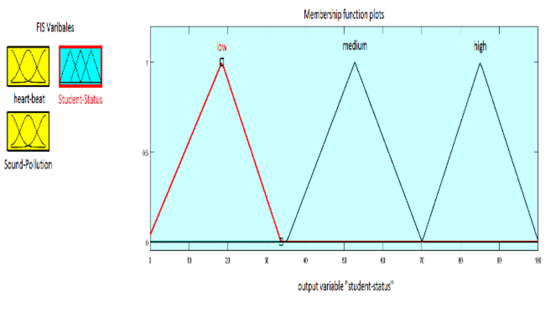



Figure 7. Simulated input diagram of student status (student-status)

**Simulated input of student status in student-fuzzy MATLAB software:**

With Table 5 and its assumptions, as well as the range set for student status, the resulted fuzzy graph is illustrated in Figure 7.

## IV. Evaluation Results and Discussion

Analysis of fuzzy inputs and outputs in the proposed framework is simulated using MATLAB 2013 software. To compare the output of the created results, with the two considered inputs (heart rate and noise pollution), the desired output (student status) is obtained. By changing two inputs, different fuzzy outputs are obtained. Figure 8 shows an example of these changes for Heart Rate = 66.4 and Sound-Pollution = 61.8, which results to student-status = 52.7. That is, according to the defined table, 3 students are in Medium position in terms of stress level.

**Table of input and output data and results:**

Table 6 is obtained for the generated input and output of sample data, based on which the necessary diagrams are drawn below to perform comparative operations. The Student-Status column is the output of the table that displays the student's status in terms of a number. This number, as defined in Table 5, becomes a status that indicates the student is ready to begin the teaching process.

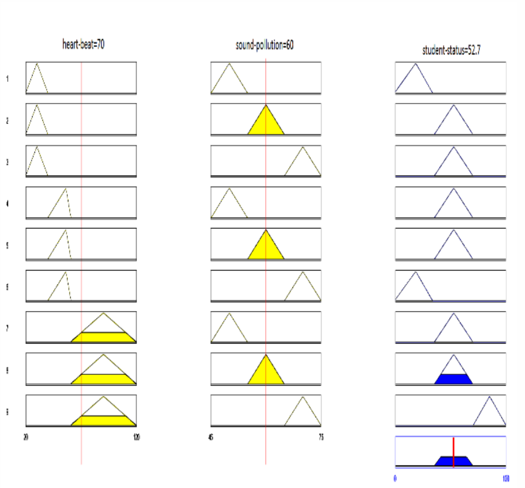



Figure 8. Fuzzy outputs created by changing inputs 20

TABLE VI. GENERATION OF INPUT AND OUTPUT DATA WITH DEFINED FUZZY RULES

| Smart Electronic Learning Environment (SELE) Model | | |
|---|---|---|
| **Input Data** | | **Output Data** |
| **Heart-Beat** | **Sound-Pollution** | **Student-Status** |
| 20 | 46 | 16.5 |
| 20 | 55.1 | 52.8 |
| 20 | 74.1 | 52.8 |
| 27 | 49.3 | 17.1 |
| 38 | 49.3 | 16.7 |
| 40.3 | 49.3 | 52.7 |
| 68.8 | 49.3 | 52.6 |
| 68.8 | 64.6 | 85.1 |
| 68.8 | 65.8 | 85.1 |
| 68.8 | 74.5 | 85.1 |
| 68.8 | 46.6 | 85.1 |
| 68.8 | 65.2 | 52.7 |
| 68.8 | 65.8 | 85.1 |
| 100 | 46.6 | 52.7 |
| 100 | 65.2 | 85.1 |
| 100 | 74 | 85.1 |
| 116 | 46.9 | 52.7 |

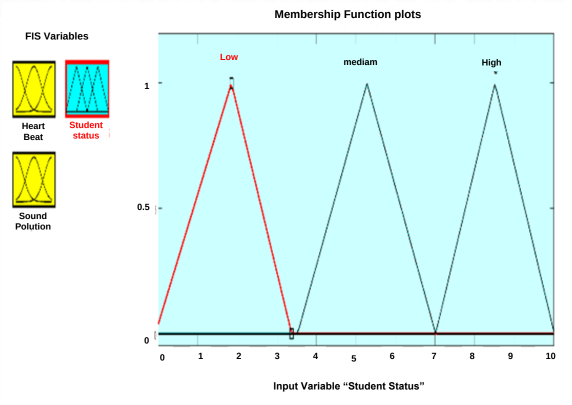



Figure 9. Graph of changes in inputs and output based on the data in Table 6.

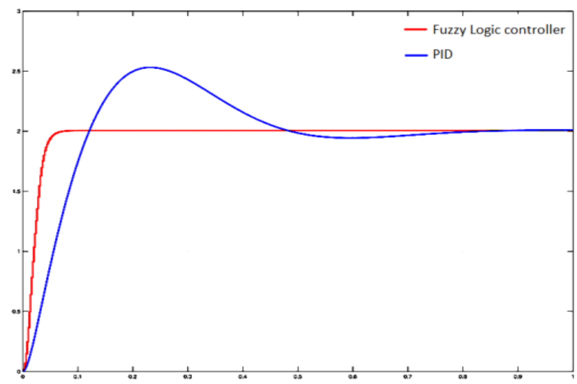



Figure 10. Speed comparison diagram between the fuzzy controller and non-fuzzy controller

As shown in Table 6, the proposed SELE framework performed well in most of the datasets that were considered. The results of using fuzzy logic show that each of these input factors alone or together can affect the student's situation. Of course, other human factors (such as body temperature, etc.) and environmental factors (such as the brightness of the classroom, etc.) can also affect this model Figure 9 shows the proposed SELE framework with two inputs and one output. The output is shown in the diagram, rows 9, 10, 12, and 13 of the sample table show the best fuzzy performance for student learning.

A comparison of the fuzzy controller with the non-fuzzy controller is shown in Figure 10. Pay attention to the waveforms generated.

As you can see, the response of the fuzzy controller marked in red was faster. The horizontal axis shows the time and the vertical axis the speed. The tests were performed on a device with Pentium Core I5 specifications with a working frequency of 2.4 GHz with 8 GB of memory and a GEFORCE 920 (2 GIG) graphics card and Windows 10 operating system. In order to better compare the inputs and outputs, which were considered in the SELE model, comparison charts are drawn in MATLAB software. All of these diagrams show the performance of the two considered inputs: heart-beat, sound-pollution, and student-status output in two-dimensional and three-dimensional diagrams (Figures 12 to 16).

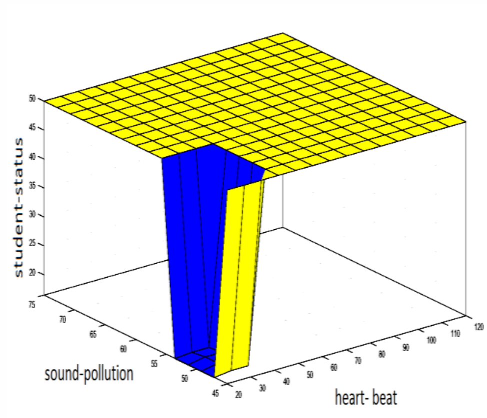



Figure 11. Comparative diagram 1, input and output data defined by fuzzy rules

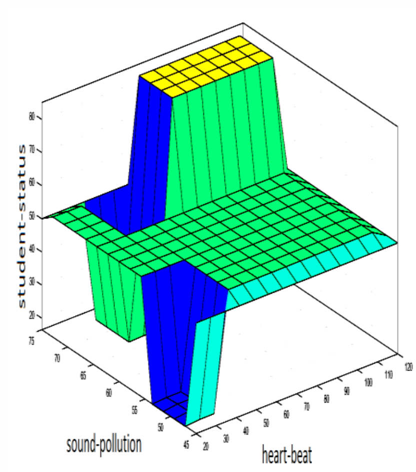



Figure 12. Comparative diagram 2, input and output data defined by fuzzy rules

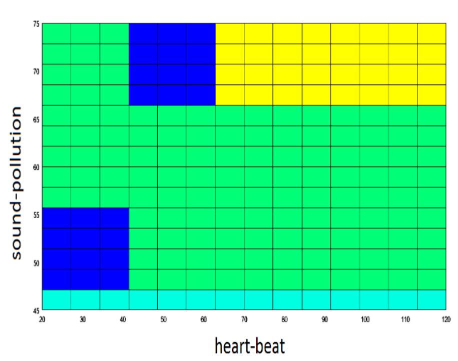



Figure 13. Comparative diagram 3, input and output data defined by fuzzy rules

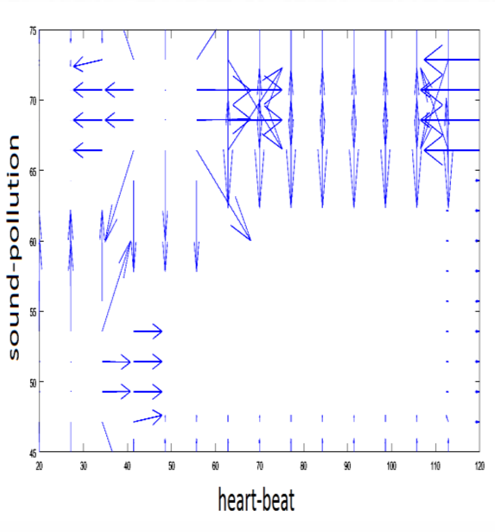



Figure 14. Comparative diagram 4, input and output data defined by fuzzy rules

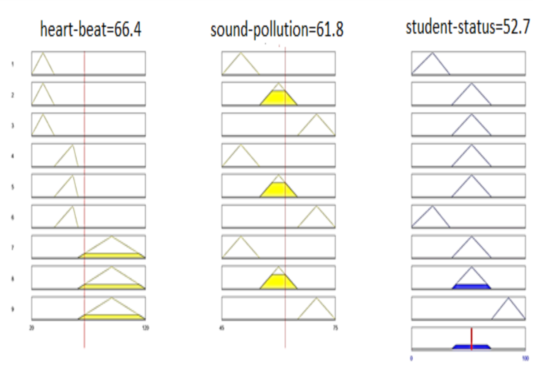



Figure 15. Comparative diagram 5, input and output data defined by fuzzy rules

## V. CONCLUSION

This study addressed the issue of how the Internet of Things can be used together with traditional teaching methods to improve the quality of teaching and learning. The two most important components in the IoT-based teaching and learning process are the teacher and learner, and in this process, it is possible to collaborate collectively and access the vast amount of information produced by these two components at any time and place. The possibility of information sharing, planning, implementation, and evaluation of the teaching process and creating safer learning environments, and saving time and money are some of the benefits of IoT-based education that have been addressed in this research. In this research, a system that allows students to interact with the virtual physical objects around them (which are related to the learning process) has been proposed. Experimental validation provides evidences that this model improves students' learning outcomes and their stress level can be controlled despite of various factors. Examining the student's stress level in a fuzzy way and also analyzing and simulating it with the Internet of Things, can provide information about students' readiness to start learning process, and subsequently the teachers can plan the best way for teaching. The results of the simulation show that this framework can detect the students' stress and by adapting the test and teaching conditions to the mental and psychological state of the students, it can indirectly improve the educational quality of the students.

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