Stress Detection in Learning STEM Subjects Among Primary School Students by Using EEG Signal

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Abstract

Stress in learning Science, Technology, Engineering and Mathematics (STEM) subjects has become crucial among students in Malaysia. Malaysia education Blueprint in 2020 reported that Malaysia has scored at the lower ranked in programme for international student assessment (PISA) for mathematics and science test. Thus, this research study aims to provide sufficient proof of correlation between STEM topic questions and stress levels through emotion detection during the test time. The research was conducted according to a conventional methodology for an EEG machine. Mel-Frequency Cepstral Coefficients (MFCC) will be used to extract features from the data, and MLP will be used as a classifier. The result of this study shows that, low grade students tend to have low stress level compared to medium and high-grade students. This research may benefit the students, teachers, parents to have an early detection for stress level among primary school students especially in learning STEM subjects.

Keywords— Electroencephalography (EEG), Stress, STEM subjects, Students, MFCC, MLP.

1. Introduction

1.1. Problem Statement

Science, technology, Engineering, and Mathematics, called STEM, are the most important subjects for students to do well in school. Unfortunately, most of the students are struggling to cope with these subjects. In 2018, 45.2% of secondary students (aged 17) in Malaysia were enrolled in STEM, however that percentage has declined to 43.7% in 2019. Student's answers to the programmed for international student assessment (PISA) 2015 questionnaire revealed a strong desire to study science and math's. Students expressed an interest in studying science and mathematics in their replies to the PISA 2015 questionnaire. 91.3% of 15-year-old pupils agreed that studying science is worthwhile because it would benefit them in future employment, and 91.5% felt that knowing science is essential for the future. Only 13.2% want to be scientists and engineers, 14.0% would like to be healthcare professionals, 1.3% want to be information and communication technologies professionals, and only 0.6% get to be scientific specialists when it comes to science-related professions [29]. STEM education does not only help students who plan to go into STEM careers. Students may establish mental habits that will help them succeed in any subject by focusing on logical thinking processes and problem solving. The problem in this research study is to find out whether a STEM subject might cause stress or not.

1.2. Project Objective

The first objective is: Identify the level of Stress among primary school students towards STEM. As the primary school students tend to have the stress while they are doing STEM relates tests or exam. We need to find out how they get stressed when they are trying to solve the STEM questionnaires by make an assessment test for psychology and pattern of brain signals from EEG machine.

The second objective is: Analyze the correlation between emotion and stress among primary school students by using neural networks. The connection might be subjective and behave differently depending on the subject while negative (-ve) emotion will indicate stress and positive (+ve) emotion indicates non-stress.

1.3. Significance of project

STEM education prepares students with skills that make them more employable and equipped to meet the needs of today's workforce. It encompasses a broad variety of talents and experiences. Each STEM component plays an important role in a well-rounded education. We must change since the world we live in is changing. STEM education benefits society by instilling in students a new mindset and skills that are

valued in any sector. They encourage young people to be adaptable, to seek for patterns, to make connections, and to assess information. Also, STEM education develops social awareness. It raises public awareness of global challenges, and STEM possibilities help us move to a knowledge-based economy with improved sustainability literacy. Through this research by stress detection for learning STEM subjects, it can help the students to identify their motivation and interest towards STEM subjects and help the teacher to understand more the student's ability in learning STEM. In addition, the execution of computing techniques used can measure stress among primary school students in learning STEM

2. Previous Works Review

Stress

Stress is defined as a personal interaction between people and their environment that is seen as challenging or surpassing coping resources. [1]. According to Stress and coping theory [2] Hypotheses concerning the stress process and its relationship to physical and mental health are tested using a framework. Anger, humiliation, and anxiety are frequent stress-related emotions, suggesting a relationship between stress and emotion. Based on Lazarus and Folkman's theory [2], How a person perceives (appraises) interactions with their environment determines stress and emotions. Individuals may feel significant amounts of stress when they realize something vital to them is uncontrollable throughout the examination.

Regarding the relationship between stress and negative emotions, researchers agree that they are closely related. For instance, according to some studies, depression is a kind of stress reaction. [3,4]. Fiedler, et al. [5] found that Anxiety symptoms may be predicted by stress. Furthermore, according to a study of 5236 college students, the more concerned they are about their schoolwork, interpersonal relationships, and other problems, greater likely students are to display angry. Another study of 939 American teenagers discovered that people's perceived stress predicts their anger, which in turn drives their bad behavior, such as drug usage [6]. Also, in cancer patient's stress perceptions, there was a significant positive connection between anger and depression. [7].

Science, Technology, Engineering, and Mathematics (STEM)

The term STEM was first used in the early 1990s in the United States to describe government programs. The objective is to ensure that every person of the United States is eager to pursue Science, Technology, Engineering, and Mathematics (STEM) degrees and, as a result, be able to work in STEM-related sectors such as scientists, engineers, mathematicians, and technicians [8]. Many students feel anxiety in educational environments, according to an increasing number of research in Education Science [9,10]. Stress may come from a variety of places. Physics, math's, and statistics are among the STEM topics that have been documented to induce frightened emotional states of increased attentiveness across many educational systems and levels, from primary school to college students [10,11]. Mallow was the first to notice this phenomenon, He also invented the phrase "science anxiety" and linked it to bad scientific performance [12]. Anxiety-induced enhanced arousal inhibits students' focus on the work at hand, having a significant influence on problem solving and even information retention [9,10,13]. In any school context, anxiety may come from a variety of sources.

It's important to note that personal evaluation in education is a difficult subject, with impending exams usually producing "Test anxiety," a sensation of anguish, over-arousal, and tension that is most identified before to taking an exam or a test [11,14]. Cassady and Johnson showed that Moderate levels of anxiety were linked to higher academic accomplishment, but higher levels of anxiety had a detrimental influence on test performance [9]. Science anxiety may also be caused by a lack of role models and a drab image of the topic [12,9]. It is essential to emphasize that the emergence and intensification of anxious emotions from any of the aforementioned causes has negative consequences for children' performance in school and beyond, lowering academic success [9] and deterring kids from pursuing jobs in science, technology, engineering, and mathematics (STEM) [15].

Electroencephalogram (EEG)

Electroencephalography (EEG) is a non-invasive test that monitors electrical activity in the brain. Voltage variations within brain neurons are the cause of EEG activity. As a result, it reflects synchronized neuron activity. The EEG exhibits oscillations at various frequencies. The frequency of this rhythmic

activity is separated into bands, and it is frequently linked to distinct phases of brain function [16]. These EEG signals may then be analyzed to determine the student's dynamic emotions as well as the antecedent emotion. Many researchers have used an EEG gadget to capture brain activity from the cortical surface in milliseconds. [17]. The differential stress inventory was validated using a probabilistic stress profiler [18]. The binary classifier successfully predicted 30 of the 41 cases.

Russell's model

In this research study, Russell's model [19] has been adapted according to recent studies, it's important to comprehend human emotion [20]. According to psychology, there are eight primary emotions: joyful, calm, fear, sadness, anger, disgust, and surprise [21]. In figure 1, Russell's Affective Space Model (ASM) is a two-dimensional way to describing emotion. Four fundamental emotions, derived from a mix of valence and arousal, have been chosen as the foundation. Analyzing and comprehending brain waves may reveal brain activity in a dynamic method.

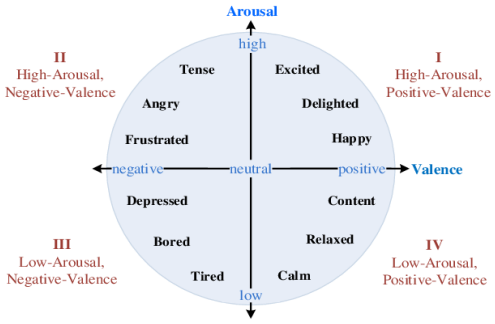


Figure 1. Russel's model of affect

MLP – Multi-layer perceptron

Several machine learning classifiers were implemented to accomplish emotion classification. An average of 78.11 percent accuracy was achieved using the multilayer perceptron (MLP) as a classifier to categorize happy, love, fear, and sad [23]. In another study, MLP was used to distinguish happy, sad, fearful, and calm people based on their valence and arousal levels [22]. Emotion's classifiers are also used to assess elementary school teachers' stress levels. In addition to that in MLP, the 12-point affective circumplex and the recalibrated speech affective space model (rSASM) are used to categorize emotion (12-PAC) [24]. The accuracy of categorizing emotion using MLP based on rSASM was 78.5 percent on average, which is 14.5 percent lower than the 12-PAC model's accuracy. Based on few more researcher it has proven that to perform emotion classification multilayer perceptron (MLP) is giving better accuracy than any other machine learning classifier [25,26,27].

3. Methodology

3.1. Research Protocol

In this experiment, we used an experimental design in which we placed electrodes from an EEG machine on the individuals' heads using 19-channel guidance. The electrode is physically placed on the subject's head using the special cap. Then we go on to the next stage of the experiment, which involves recording the subject's brain activity while their eyelids open and shut for one minute each. The experiment continues with a one-minute viewing of the International Affective Picture System (IAPS) emotion sequence pictures, which include happy, calm, sad, and frightened images, and a recording of the brain signal as it moves through the pictures.

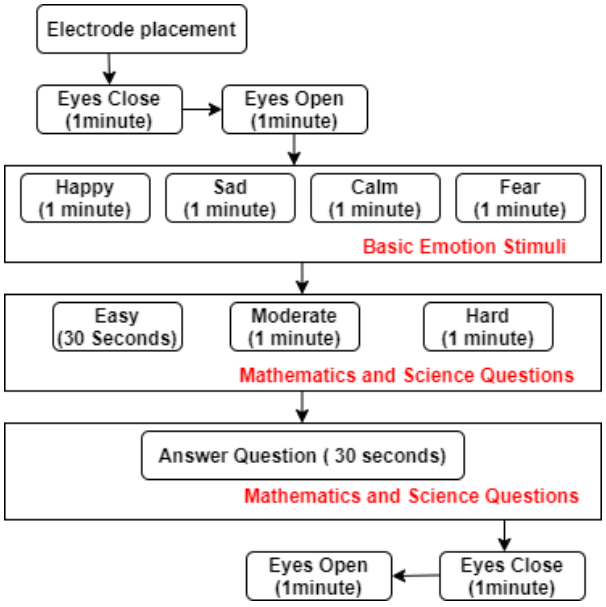


Figure 2. Experimental design

After that, students read each Mathematics and science question by themselves that consist of 12 questions on easy (30 seconds), moderate (1 minute) and hard (1 minute) and being displayed on the screen to the subject. If they can, they must answer the question and record their brain signal for each of the 12 questions. Finally, before concluding our experiment, we perform and record the subject's brain signal while open eyes and closed eyes for one minute. The experimental protocol as in figure 3 below.

3.2. Data Analysis

The technique used in this experiment can be split into two important parts that must be carefully followed to get the best results for stress detection and avoid errors. Following the collection of data in the form of brain signals, mathematics, and science, additional actions are requiring technological procedures must be completed before the final result can be obtained.

The first stage is to extract the key characteristics of brain waves from the EEG machine's 19 channels. Before moving on to the next step of the process, classification, we used Mel-frequency cepstral coefficient (MFCC) to extract the features. In the second section, we employed MLP classifiers to determine whether or not the outcomes of Stem subjects for students are influenced by stress. In MATLAB, the result produced with the MLP function is simply accessible. The procedure is shown in detail in the figure below. However, for Mathematics and Science questionnaires for subjects to answer, we used that to identify the level of stress based on psychological perspective. The response for each subject can be considered as a preliminary result.

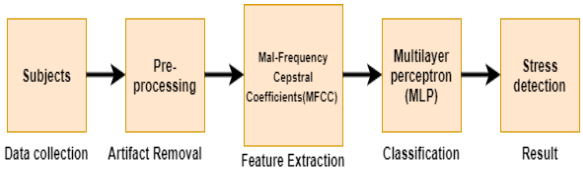


Figure 3. Data analysis process

Following the collection of data from individuals, the data will be subjected to a procedure known as feature extraction. Feature extraction is used to simplify the dataset in order to speed up the classification process in the next step. To provide high reliability and accuracy for training the dataset, important features are retrieved using MFCC. The MLP algorithm is used to train brain signals from participants during the International Affective Picture System (IAPS) emotion sequence.

Russell's model of affects proposes that training is necessary by matching the value of arousal and valence with the appropriate kind of emotion. As seen in the figure below, Russell's model includes numerous emotions with different levels of arousal and valence.

Table 1. Valence arousal expected output

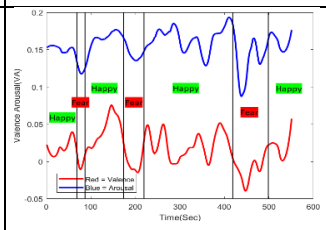
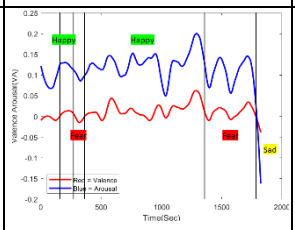
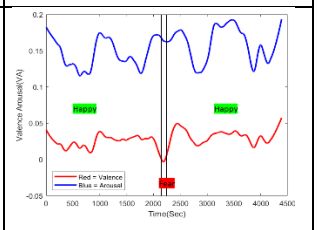
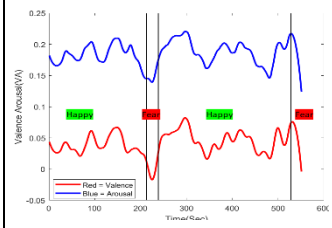
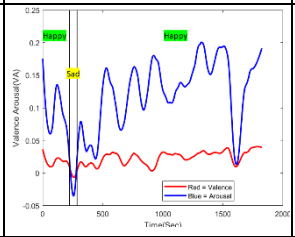
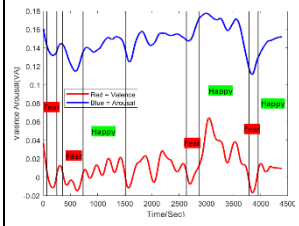
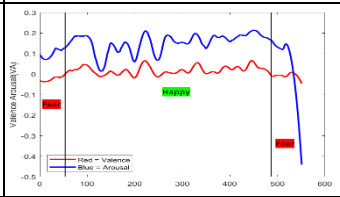
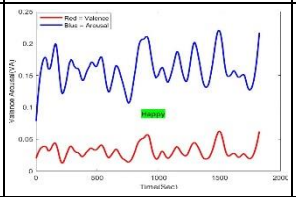
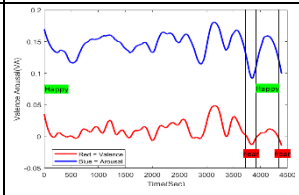
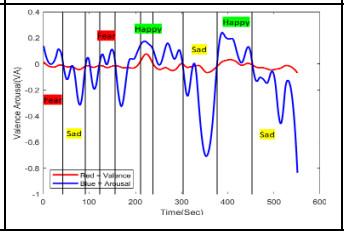
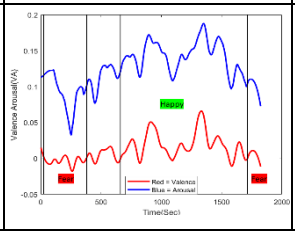
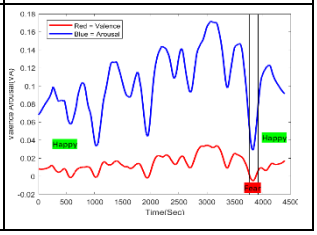
Emotion	Valence	Arousal
Happy	1	1
Calm	1	-1
Fear	-1	1
Sad	-1	-1

Additional feature extracted brain signals, such as signals of shutting and opening eyelids, as well as answers to Mathematics and Science questions, will be used to test the training datasets. A displayed valence-arousal graph will eventually be used to classify the test's findings.

4. Result and Discussion

One of the most challenging courses to master in primary school is STEM (science, technology, engineering, and mathematics). Because of STEM subjects, students may have low motivation and unpleasant feelings. However, when it comes to STEM questions, most of the time subject 1 has an increasing valence value while reading them, indicating that the subject is intrinsically motivated to answer them.

Table 2. Dynamic movement of emotion for subject 1

QS	Easy Question	QS	Medium Question	QS	Hard Question
Q1		Q5		Q9	
Q2		Q6		Q10	
Q3		Q7		Q11	
Q4		Q8		Q12	

Even though the subject is experiencing negative emotions (fear and sadness) for a limited period, however, after reading the questions, the subject appears to be motivated.

From table (2 & 2.1) shows that subject 1 increase his valence during reading questions (2,3,5,6,7,8,9,11 and 12). When subject 1's valence increases while reading questions, it indicates that his intrinsic desire is high and he is eager to answer the questions, according to the signal. The individual has (fear and sad) emotion for the other two questions (1 and 4), indicating that he had low motivation with poor valence when reading those two questions. This is very unusual in exam hall while answering science and math questions. In conclusion it is clearly shown that in subject 1 result for STEM questions test, most of questions the subject had positive(happy) emotion while doing the test. Therefore, we can say that this student is lowest grade student in math and science subject, and normally score F in her exam. Because she didn't experience any tension during the exam period, it's fair to presume that she didn't bother to give answers. For subject 3 and 4 is showing same pattern as subject 1, which indicate that they have lack of stress and showing positive valence emotion all the time.

Table2.1. Dynamic movement of resting state for subject 1

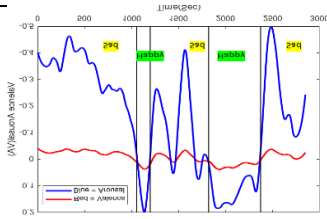
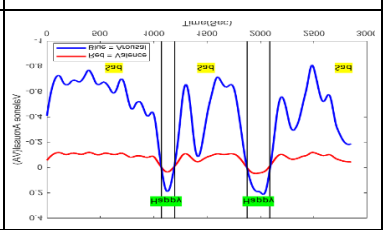
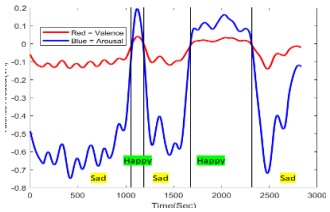
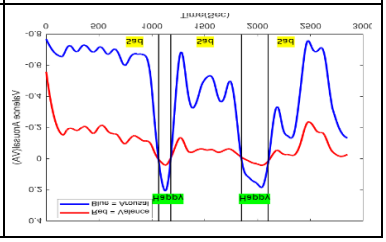
Task	Emotion Signals	Task	Emotion signals
Eyes Open		Eyes Open End	
Eyes Close		Eyes Close end	

Table 3. Dynamic movement of emotion for subject 2

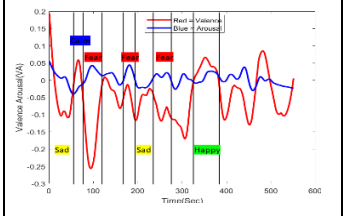
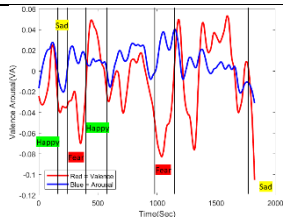
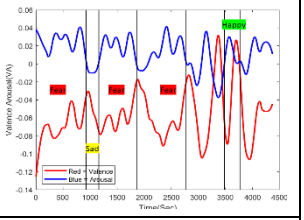
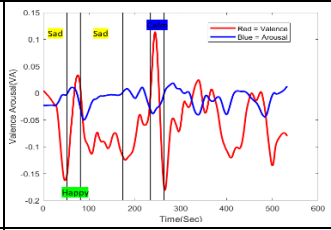
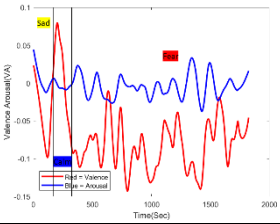
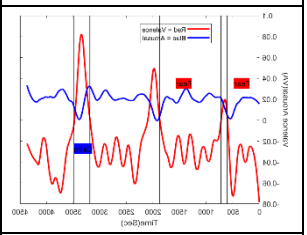
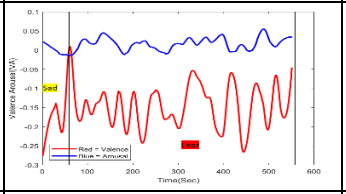
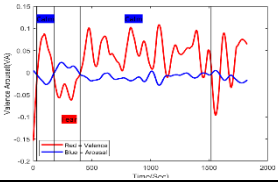
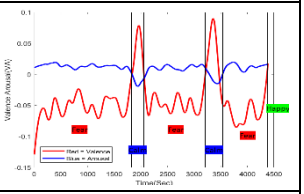
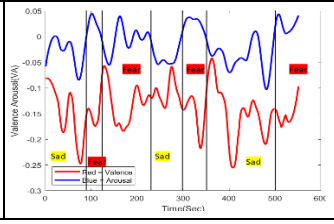
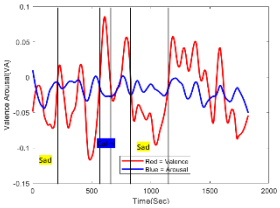
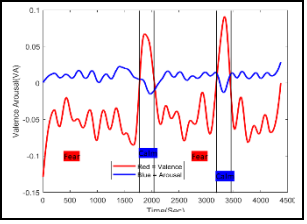
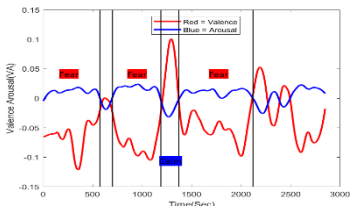
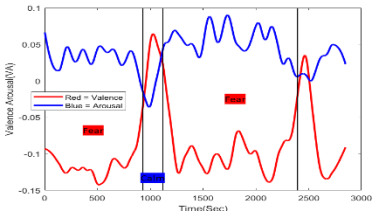
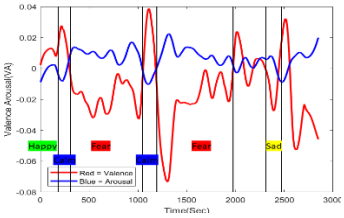
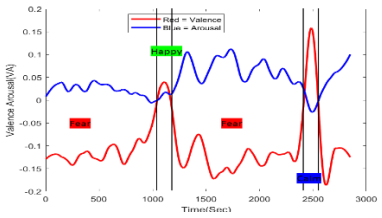
QS	Easy Question	QS	Medium Question	QS	Hard Question
Q1		Q5		Q9	
Q2		Q6		Q10	
Q3		Q7		Q11	
Q4		Q8		Q12	

Table 3.1. Dynamic movement of resting state for subject 2

Task	Emotion Signals	Task	Emotion signals
Eyes Open		Eyes Open End	
Eyes Close		Eyes Close end	

Subject 2 on the other hand, when reading STEM questions, had a predominantly negative valence and motivation, indicating that the subject is stressed by STEM questions. Despite of having some positive emotions, the subject was unable to maintain her motivation while reading the questions.

As seen in table (3 & 3.1), subject 2 had negative valence while reading questions (1,2,3,4,6,9,10,11 and 12). This clearly reveals that the subject's valence decreased during the reading questions, indicating that she felt stressed and afraid to answer the questions. While reading the other three questions (5,7, and 8) she improves her motivation by using positive valence. Finally, throughout the STEM test, subject 2 shows a lack of motivation, even though she did well on some of the questions, her enthusiasm for learning STEM subjects was poor due to her negative valence emotion (fear) during the test. As a result, we can deduce that she may experience stress while undergoing STEM testing as she scored B in their test at school for math and science test. Subject 5 exhibits the same pattern as person 2, indicating that the subject is stressed and displaying a negative emotion.

For most of the questions, Subject 7 exhibited both positive and negative valence and arousal at the same time. This indicates that while this student was happy when reading and answering questions, they were also stressed since he desired to excel in this topic.

In the table (4 & 4.1) presents While reading the questions one to nine for simple and medium questions, this subject 7 had mostly positive valence with some sad and calm emotion. However, as he reads the difficult questions (10,11, and 12), his emotions become even more stressful, which is extremely traditional of a bright student. Subject 7 displayed a combination of happy and sad emotions throughout the STEM questions. As a result, we may conclude that this student was pleased to respond to the question and that he occasionally feels sad because he wished to receive an A on the exam. Subject 6 demonstrates the same pattern as subject 7, implying that they are constantly combining positive and negative emotions.

Table 4. Dynamic movement of emotion for subject 7

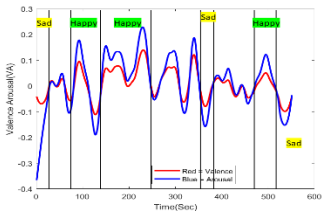
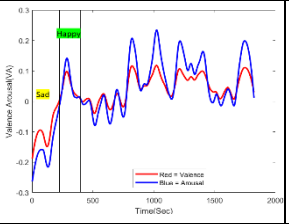
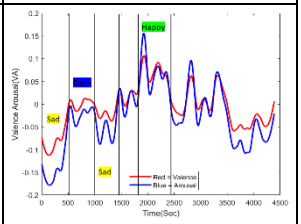
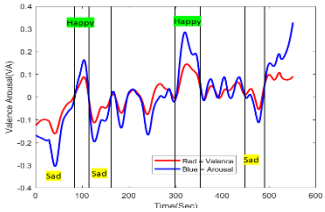
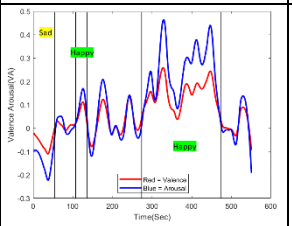
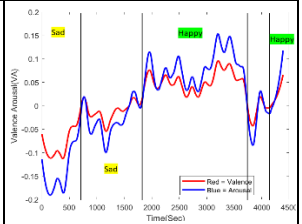
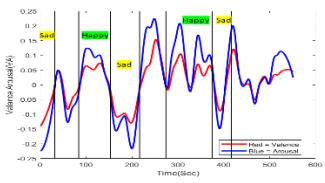
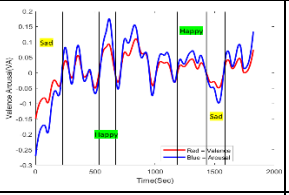
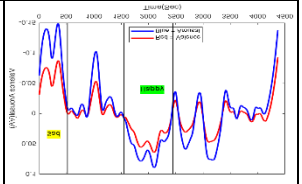
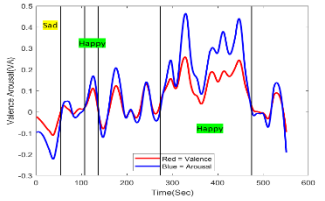
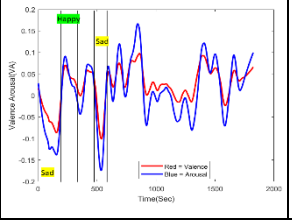
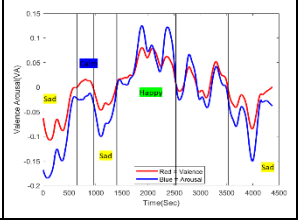
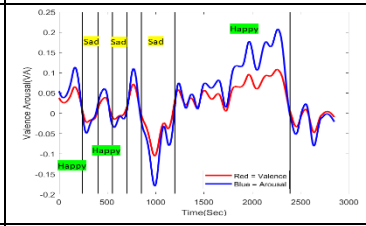
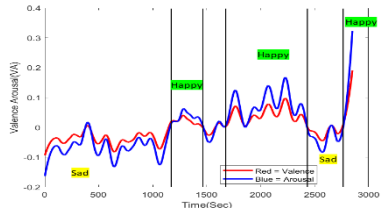
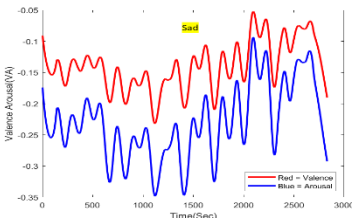
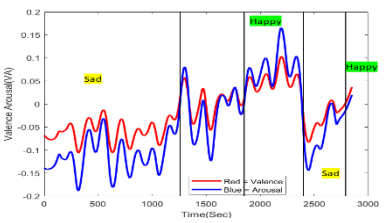
QS	Easy Question	QS	Medium Question	QS	Hard Question
Q1		Q5		Q9	
Q2		Q6		Q10	
Q3		Q7		Q11	
Q4		Q8		Q12	

Table 4.1 Dynamic movement of resting state for subject 7

Task	Emotion Signals	Task	Emotion signals
Eyes Open		Eyes Open End	
Eyes Close		Eyes Close end	

5. Conclusion

As the conclusion, the lowest grade (F) students are having (+ve) valence and arousal which shows happy emotion. This indicates that low scorer student might having less stress condition because they do not bother about the result at all. While intermediate scorer subjects are having both positive and negative valence which shows fear emotion. This shows how stressful they are when dealing with STEM exam or test. Finally for high scorer subjects, they are having negative valence for hard questions which indicate that High grade students having stress due to high expectation to score high in exam but still manage to answer the questions correctly. Thus, this kind of profiling is important to help the student to improve their emotion and stress level. In addition, teachers and parents can also identify their student who is having difficulties in dealing with their emotion and stress level, so they can pay more attention to the students.

6. Future work

Based on assessment we'd like to suggest some improvements for future study based on the progress we've achieved and the problems we've encountered. We recommend that the dataset from the EEG machine being feature extracted and the data be analyses using another appropriate technique. For instance, the usage of Kernel density estimation, ANFIS and Support Vector Machine (SVM) should be included to the machine learning algorithm for feature extraction and analysis. To get the best possible results, we could compare and cross-validate the accuracy of data testing between different sorts of feature extraction and two types of machine learning algorithms.

Moreover, we'll also be looking towards analyzing more data, since more data will lead to a more accurate and consistent outcome. Finally, we'll compare stress levels and early detection of anxiety among STEM students.

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