IJCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Vol. 10, Issue.10, October 2022 E-ISSN: 2347-2693

NeoApp: Advanced Mathematics Learning Solution for Ordinary Level Students

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DOI: https://doi.org/10.26438/ijcse/v10i10.18 | Available online at: www.ijcseonline.org

Received: 20/Sept/2022, Accepted: 05/Oct/2022, Published: 31/Oct/2022

***Abstract*—** The revolution of Information and Communication Technologies (ICT) has enormously impacted the world. E-learning systems are superseding face-to-face learning. According to the 2019 statistics paper by the Sri Lankan ministry of education, the yearly failure rate of an Ordinary Level Mathematics subject is 33.08% which is higher than other subjects. We aim to introduce appropriate and equitable online learning methods for the 13-16 age group where they can build their self-studying abilities with more accurate methods and good confidence. Many students have poor mathematical skills as they do not have accurate and appropriate instructions for their studies. This system will assist students in developing their mathematical knowledge and skills gradually using video tutorials, examples, and tests. When they have a problem or challenging situation, a virtual assistant can help them to solve their difficulties. The proposed virtual tool will help students reduce the boredom they feel while solving mathematical equations or lessons by distracting them with a mathematically based fun game. Some students may not enjoy studying when teachers or parents sit beside them and focus on them. This tool has the ability to make the students keep focused on the lesson without letting them distract from mathematics by making it fun and simple. Therefore, the proposed system utilizes an attention monitoring system to capture student movements and emotions during the learning process. This solution will be highly customizable since it introduces automatic theory and quiz generation.

***Keywords*—**Self-learning, Mathematics, Hybrid voice assistant, Play and learn, Emotion capturing, Auto-generated quizzes

I. INTRODUCTION

NeoApp is a comprehensive online learning platform based on Mathematics which includes features such as learning theories based on videos, automatic generation of questions, Neo voice assistant, stress release play and learn games. A surveillance system to monitor student emotions. Passing Mathematics in the General Certificate of Education (GCE) Ordinary Level (OL) Examination conducted by the Department of Examinations, Ministry of Education, Sri Lanka, is one of the primary qualifications required for the GCE Advanced Level. However, the yearly failure rate of an ordinary-level mathematics subject is 33.08% which is higher than other subjects. Therefore, the system selects an age group many researchers do not focus on, such as from 13 to 16.

This virtual learning tool consists of four main components, and the first one is a video transcription system. It consists of an automated theory, question and answer generation mechanism, and scoring system for self-learners. The second one is the Neo voice assistant, which enables students to ask questions when they are experiencing difficulties or need more resources to continue their learning. The attention monitoring mechanism is the third component, and it captures all of the student's activities and emotions, which can be used to analyze and compare students with others based on the specific lesson. The play and learn game component are the final component. Whenever students feel bored or find it distracting, they can play a game and learn something related to the lesson.

A lesson-wise test is more of a mutual process between subject and student that improves the knowledge quality. These tests will enhance learning because it measures students' mathematical knowledge efforts. Test reviewing lesson by lesson will help to keep the confidence in self-learning. Therefore, students will be aware if they are not comfortable with the assigned test for each lesson or if they are stuck in the complex areas themselves. Hence the students can identify the lesson they should put more effort into. In such a situation, the system will suggest an assistant for their orientation. The Neo voice assistant can provide relevant resources for the students, like relationships, formulas, theories, and additional learning materials. This way, a voice assistant-based learning system will enhance the student's skills.

Additionally, a web-based game is generated based on the student's capability level and the lessons the students love the most. They can play this game anytime, allowing them to choose lessons that are based according to their needs. NeoApp can track the student's progress within these types of activities too. So, these will be used to suggest future content to students and for analytical purposes.

Mathematics is based on problem-solving, practicing with brief theories and formulas with patterns of math problem-solving. The test-based study method is the best way to

connect with each lesson unit. The student will also detect their hard and easy attempts with a time slot-based graph. Marks and time-based charts will display improvement and the student's performance, and they will be sent to the parent as an e-mail at the end of the completed lesson. It will help students develop achievable learning goals personally.

II. LITERATURE REVIEW

Within the field of mathematics, students must master both theoretical and practical knowledge with lots of problem-solving skills. In this modern world, many researchers such as Kiara Radinsky and the International Journal of Advanced Research in Computer and Communication Engineering (IJARCCE) discovered manual question paper generating systems and developed automatic question paper generator systems. A suitable design for generating automated question papers and managing related data will be vital in any educational institute. The system enables users to edit and enter data suitable for educational institutes by specifying grades, lessons, and patterns [1]. Textual learning, visual learning, and audio-video learning are the three general categories of online learning based on learning resources [2]. Learners who use a computer or other digital device to access the internet can engage in online learning. The manual questions from the learning materials, on the other hand, are required for the learner's assessment [3]. As a result, automated question production and evaluation methodologies can aid in automated testing systems. Due to its rapid and reliable evaluation policies, the objective question has become popular as an automatic assessment instrument in the exam-inaction system.

Computer-assisted subjective question evaluation is tough, and its accuracy has not yielded satisfactory results. Subjective examinations have been performed in a variety of ways at each university. Teaching must examine automated appraisal system assessment due to the rapid increase of e-learning courses. In a subjective examination, an automated method can overcome the challenge of manually scoring thousands of written responses. To automate the education system, this system discovered that the majority of question creation and evaluation systems rely on creating questions from textual documents [4,5]. Natural Language Understanding (NLU) and Natural Language Generation (NLG), both of which use a deep learning neural network, have advanced Natural Language Processing (NLP). Machine learning was primarily employed to produce picture captions in the visual question-generating approach.

Over the past few years, Artificial Intelligence (AI) has significantly impacted all areas of life. In education, many AI research trends have emerged and have brought many advantages, such as Machine Learning, Deep Learning, chatbots, etc. [6]. The application supports text and voice inputs with no predefined flow of conversation. Therefore, students are welcome to ask anything, and the chatbot can answer most of them. Most available products do not discuss giving hints or tips while students solve questions, but according to the survey, teachers said that the students need support while solving questions and learning theories. Hence that feature is also included.

Khan Academy is a United State (US) nonprofit educational organization established in 2008 by Sal Khan. The aim is to develop online tools that help educate students [7]. It is using its chatbot to improve the learnability of the students. It has a feature to suggest additional materials to the students while solving or learning. They used their resources to suggest, but NeoApp will use World Wide Web (WWW) to extract the relevant learning resources. Therefore, it can provide a variety of resources to the learners. The Joshua Grossman research team has done a survey on Kahn Academy vs. Chatbot [8]. They consider two areas: MathBot vs. Khan Academy videos and MathBot vs. Khan Academy written tutorials. Many responders vote on MathBot against written tutorials, and fewer vote MathBot against video tutorials. The survey results show that the responders think a chatbot is more efficient than a written tutorial.

Amy App is a chatbot provider of online learning for web applications. It helps to learn math by giving feedback in real time. The developer must provide questions, answers, and tips when creating a chatbot to design the chat stream. This chatting structure also has a unique ability, but Amy App cannot identify voice or customized entries. Currently, it only supports the predefined structure. The predefined structure with questions and answers in a modern solution is not enough to satisfy students' goals [9].

In 2003 Oliver Knill experimented with artificial intelligence in college math education. The goal was to find "How do we teach effectively?" and "How do students learn?" [10]. In this experiment, they found several Mathematics activities: lectures, projects, labs, discussions, web-based tools, and homework. These are very helpful in self-learning and e-learning systems. Also, they mentioned the importance of context in communication. Context in communication is a combination of explaining and remembering things. The experiment showed that a chatbot should be able to identify and explain.

The value of emotional recognition was realized in 1872 when Charles Darwin wrote "Emotion in Humans and Animals." This book has given a great deal of support to studying emotions. Various applications of emotional recognition are essential because they can be used to identify a sleeping driver using emotional recognition systems. Corneanu et al. The use of multiple approaches led to a critical summation for identifying emotions. The discussion focused on the strategies and limitations of emotional recognition. The applied techniques included face restraint using recognition and segmentation, and the Support Vector Machine (SVM) and Convolutional Neural Networks (CNN) algorithms were used. Along with all these techniques, Corneanu et al. focused on sorting emotion recognition, considering the two significant parts, parametrization and the other was recognition of facial expressions [11]. In his research, he used algorithms like

Viola and Jones to parameterize the emotions detected in facial expressions [12]. This study also experiments with other algorithms, such as CNN and SVM, concluding by demonstrating that CNN shows relatively better accuracy on the Viola and Jones algorithms. Mandal T et al. applied a Curvelet-based element extraction feature. They used discontinuities in Two Dimensional (2D) capabilities, which Curvelet discussed [13]. They turned the images into shades of gray (these were used to exploit the 256 resolution). Curvelet was also used to train the algorithm in this work. Multiple steps capture a single image because of significant curves with low binary resolution.

According to Ekman et al. man develops seven basic emotions: happiness, sadness, anger, fear, surprise, disgust, and contempt [14]. Sajid et al. confirmed in a recent Facial Recognition Technology (FERET) study that the impact of facial asymmetry is an indicator of age estimation. This suggests that the right side is more asymmetrical than the left side of the face [15]. Their findings show that right-face asymmetry is better than left-face asymmetry. Using CNN can solve many problems with postural expression. facial expression detection has been used to improve neuroscience and cognitive science, leading to advances in experiments in this area. Recognition of facial emotions is growing as computer vision, and machine learning can also obtain accurate results. Examples of such uses include Human Computer Interaction (HCI), polygraph, psychiatry observation, and the identification of drunk drivers.

In recent years, much research has been done on online educational gaming platforms, and they are rapidly being introduced to the world. Several research projects have been carried out on this topic. Most platforms are based on one main factor. That is, on education or playing. However, this application utilizes an appropriate online game-based platform to help junior school pupils study natural sciences. Here, researchers examine changes in demographics. Gender, talent, online gaming knowledge, and learning techniques are compared here. Several aids used by students are positively associated with their achievement [16]. Here, this article proposes an online medium established on solemn games that aim to improve the welfare of these kids and direct them to learn while promoting an Information and Communications Technology (ICT) subject based on the Portuguese National Curriculum through play. These last years have been characterized by the evolution of computer science, which has constructed new prospects to learn and teach. They acknowledge that with this medium, their intention contributes to changing the current education curriculum [17].

Kahoot is one way of learning through interactive online quizzes. They have created this with the help of fifty technological scholars from different study environments. The results of their study and analysis show that educational games influence students, causing them to be more enterprising and motivated in their deconstructions. This method has also positively affected student motivation [18]. E-learning methods are largely unsupported on mobile fora because they accomplish not use adaptive web structure and incremental improvements established on browser, instrument, or segment tribute. Based on this motivation, the University of Rijeka has created the MudRi online education medium based on the open source Moodle software [19].

III. METHODOLOGY

The proposed system contains four functions that collaborate to work as a single system (e.g., Figure 1).

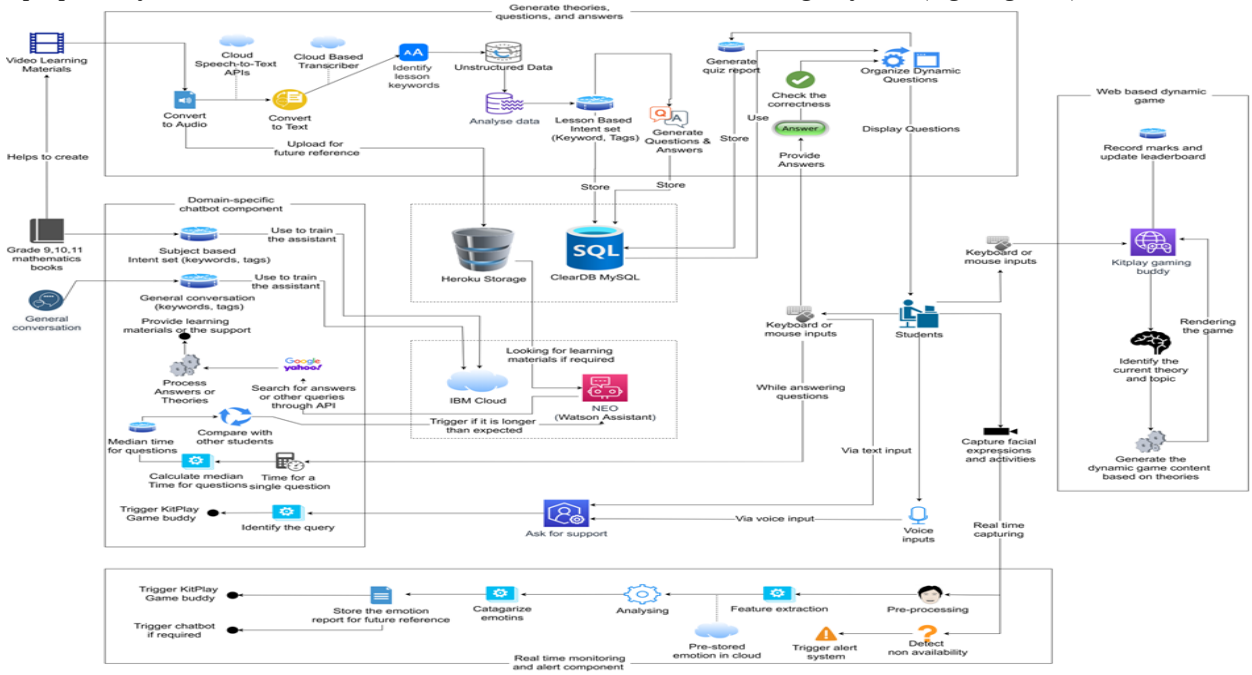

Figure 1. Overall system overview diagram

A. E-Teaching With Automated Quizzes

The system is mainly focused on Machine Learning (ML), Speech to Text (STT), Automatic Speech Recognition, NLP, and Sentiment Analysis [4,5]. It uses Google Speech Application Programming Interface (API) and multiple recognition APIs to convert embedded video images to text lesson wise. Identifying and processing voice in playing video to text is related to the AI domain. The semantic analysis aims to draw the text's exact meaning or dictionary meaning [5]. Knowing the correct subject matter and the correct teaching strategies is an essential component. The data obtained from those subjects are compiled into a set.

1) Creating a platform to learn mathematics

According to the survey results, several topics are selected from the grade 9, 10, and 11 mathematics textbooks published by the Ministry of Education to extract the lesson-wise keywords. This will contain mathematical videos that are led with selected lessons [1,2]. These videos are full of theories and problem-solving methods using formulas. Students can easily log in to the system and select the lesson they want to study further. All lessons are divided into parts. Also, videos will play partition-wise to continue the lesson. Here will use videos to gain learning materials. Students can pause and write an intricate part of understanding when they have a complicated part.

2) Identify the keywords and tags

Video to audio, and audio will convert to text. When systematic videos play, They will auto-convert to the text Through the audio. This system will be an auto transcript of the text and displayed beside the video. Also, that generated Text file can be downloaded as a Portable Document Format (PDF) for students' future use. When it generates the text file, the system will catch the mathematically based keywords and summarize them. Then those will save as tags or keywords in the system database.

3) Generate questions and answers

The system will automatically generate questions related to the selected lesson. The database's keywords and tags collection system will create questions and answers. Students can also read or listen to the questions. They can click on the listen to icon, and it will play the question as an audio record. When students enter answers, the system will display whether the answers are correct or incorrect. At the end of the marking process, the system will notify the student which solutions are correct with the student's score to mark. This system will display all the corrections. At the end of the lesson and test, students can download a pdf for the completed task containing significant theory points. The questions stored inside the database are fetched and checked for repetitions through a logical keyword-based shuffling algorithm. The system may use machine learning algorithms to do semantic analysis automatically by supplying semantically enriched machine learning algorithms with text data samples.

B. Domain specific chatbot component

The virtual assistant or the chatbot is named "Neo," It uses Watson ML to build and train the model since it can build analytical models and neural networks, train with customized data, and deploy them in custom applications. Many tech writers say that the Watson Assistant improves its intent detection accuracy and leads against other AI vendors. The comparison between the available providers is below (e.g., Figure 2).

	Full average	Subset average	Average
IBM Watson Assistant	**73.8**	**70.5**	**72.2**
Google Dialogflow	69.2	64.0	66.6
Microsoft LUIS	59.9	54.6	57.5
Haptik	73	67.6	70.3
RASA	67.4	58.4	62.9
BERT	71.9	64.1	68.0

Figure 2. Comparison between the chatbot providers

1) Local voice identification mechanism

Artyom Js is one of the major used local voice identification libraries, giving more customization features to configure the library per our requirements. This library is written in JavaScript and is a front-end voice identification technique. The identified voice through the microphone will be converted into a text format and moved into the python backend using an ajax call.

2) IBM Watson Assistant

International Business Machines (IBM) Watson is the cloud instance provider for the Neo chatbot. The text sent to the python backend will be sent to the IBM Watson Instance using the official API request. Then it will be processed according to the provided dataset in the cloud, return the relevant response, and send it back to the python backend. The same ajax call delivers the response to the chat window and uses the Artyom Js to speak out the response if needed.

3) Preparing the datasets

Preparing a dataset is crucial as it is the first step and requires two types of data sets based on mathematics lessons and general conversations. It is used in grade 9,10,11 mathematics textbooks published by the Ministry of Education, Sri Lanka, to extract the subject-based keywords. The survey results are used for the lesson selection. Keywords are used to design entities, intents, and dialogs. These elements will be saved in a Comma Separated Values (CSV) file and used to train the model in the cloud. There will be separate datasets based on specific lessons. It is decided to build another dataset with general keywords for the general conversation-based voice and text identification. With the help of this dataset, the assistant can continue general conversations with the student. When training the assistant, both text and voice samples are used to maintain the accuracy of the model.

C. *Emotion Monitoring Technique*

This consists of two steps. The first step is to find out if the child in front of the screen is in front of the screen within the allotted time. The other step is to capture the expressions on the student's face in the allotted time. For this, the webcam on the computer used by the student is used. The face position of a video frame can be determined using the Viola John Cascaded Classifier algorithm. The result is a face box framing the detected face. Within the detected face, facial landmarks such as eyes and eye corners, brows, mouth corners, nose tips, etc. are detected. After this, an internal face model is adjusted in position, size, and scale to match the respondent's actual face. Once the simplified face model is available, position and orientation information of all the key features is fed as input into the classification algorithm. After that, it compares with the pre-emotion data set like FER – 2013 and analysis the emotion. CNN and TensorFlow Js libraries are used for this analysis and detection. For the data set training will use CNN architecture to train the model by using FER – 2013 dataset. There are 28 000 training images in the collection.

D. *Dynamic Web-Based Game With Questions*

According to the gaming segment, When the child peeks at the readings, he repeatedly does not pay awareness to them, and this gaming segment commences with a catalyst. Here, three levels are used for one lesson. Here, when a level is described, the main timer commences at the beginning of each level in the gaming interface. After ten minutes, the hint option will be displayed. The first thing the pupil has to do is explore the objects hidden in the interface of the game within the given time. If it is difficult for the student to find the objects, the hint option mentioned above can be obtained. Here questioners are utilized for this hint option. Those questionnaires ask the student about a previous lesson or lessons he has comprehended. Once the student has preferred the correct answer to that simple question, one object in the game interface will spin or glow. After exploring all the objects in the object bar of the interface, the student will go to the main equation, and after decoding it, he will go to the next level. After completing all three levels, the student is asked to go to the level for the next lesson. If he accepts it, he will go to the next level of the lesson, and if he withdraws it, he will return to the lesson he was in. Here the background design is done by the object and the material design within photoshop. The gaming interfaces, object movements, and the game story are done through the wade game engine. The rest of the components are created in Hyper Text Markup Language (HTML), Cascading Style Sheets (CSS), and JavaScript (Js).

IV. RESULTS AND DISCUSSION

A. *E-Teaching With Automated Quizzes*

Using Natural Language Processing (NLTK) with accuracy trained the model the automatic question generates. Figure 3 shows the Raw text before the summarized (original text), and below the Original Text, it shows the summarized content The original text was converted to the summarized text, and this Summarized use cached the keywords. NeoApp, by considering the similarity between teachers and systematic summary, delivers a similarity score of 70.05%.

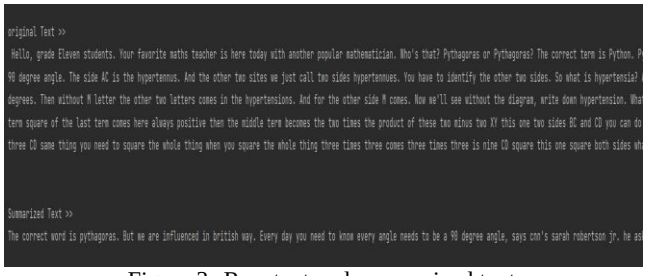

Figure 3. Raw text and summarized text

This system of mathematics based Multiple Choice Questions (MCQ) consists of a question bank. accuracy of 90.56% For MCQ keyword identification was trained to achieve. NeoApp prompts different types of questions According to the student's attention level. In NeoApp, teachers also enable the upload of videos and tutorials for the students. Using this MCQ tutorials system will evaluate the student performance based on the scores.

B. *Domain Specific Chatbot Component*

The STT process converts text and takes the IBM Watson Response via the API call. The continuous feature of the Artyom Js library is handy when it needs to identify long dialogues and can convert Text to Speech (TTS) too. So, it is a benefit per the two requirements covering a single library. Figure 4 shows the endpoint of getting Watson's response with the request message. It can configure for multi-responses with images, texts, videos, etc. Also, it can control the application by triggering Js functions as well.

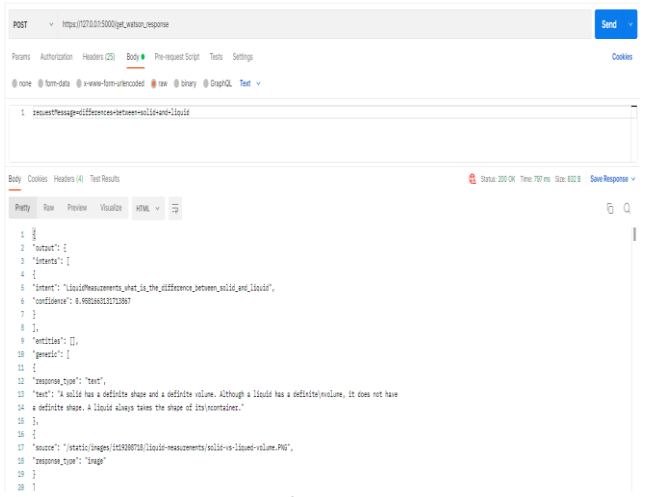

Figure 4. IBM Watson Assistant response via Postman

The User Interface (UI) is designed as a general chatting system to allow the students to interact easily with the assistant, as per Figure 5. Voice input and text input are included here so the students can choose the best option they want.

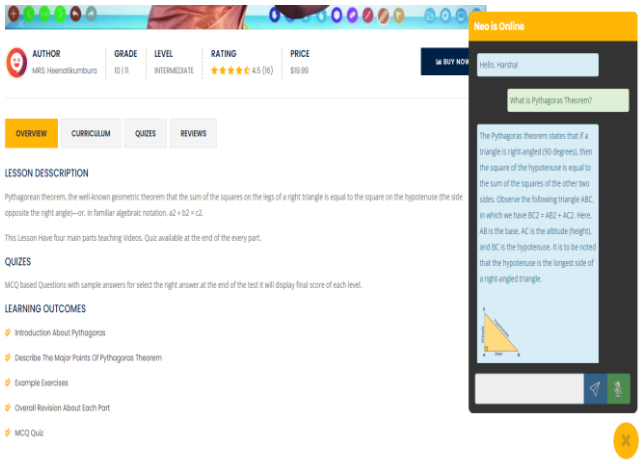

Figure 5. Chatbot window on the lesson page

Data sets are developed using two types of keywords: subject-related and general conversation-related. Intents, entities, and dialogs are used in the cloud to identify and provide the most relevant response to the requests. Figure 6 shows those elements in the cloud.

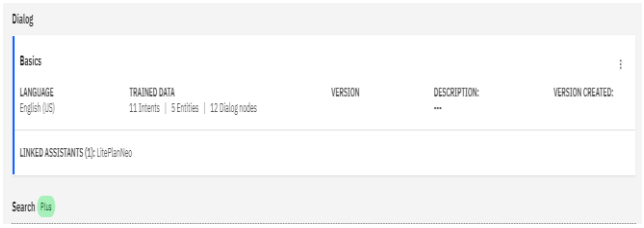

Figure 6. IBM Watson instance details

C. *Emotion Monitoring Technique*

A webcam video is given as a contribution to the framework to perform consideration observation as displayed. An accuracy of around 75% can be obtained here by the data set used. The camera detects the face-loaded mark when it is open, and it is shown in Figure 7. Then to detect the emotions displayed on the face and the student's face are displayed as shown in Figure 8. In the meantime, if the face is not seen by the camera, the emotion detection stops and as shown in Figure 9.

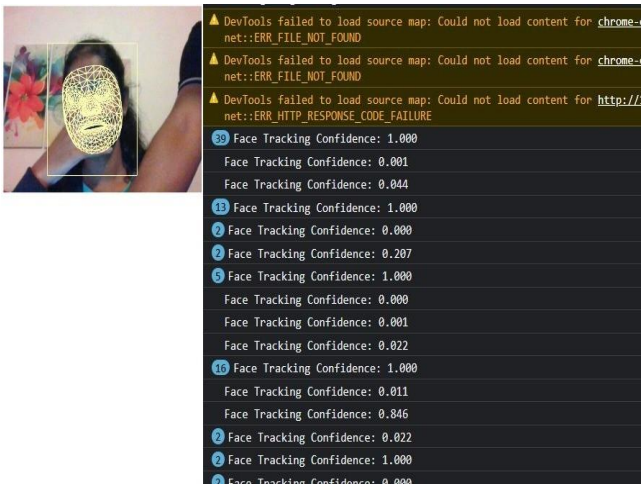

Figure 7. Landmark detection

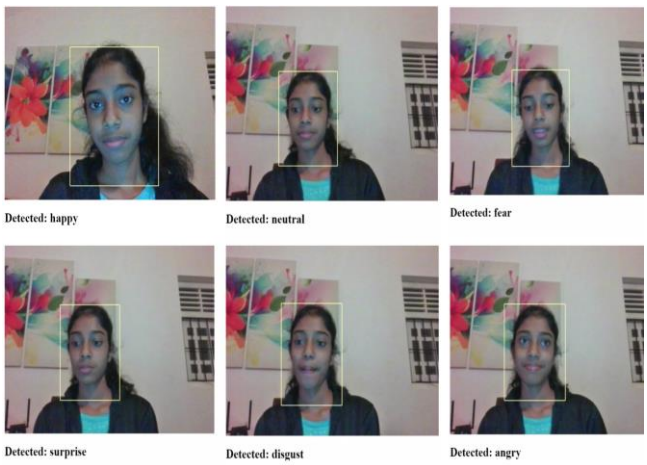

Figure 8. Detected emotions

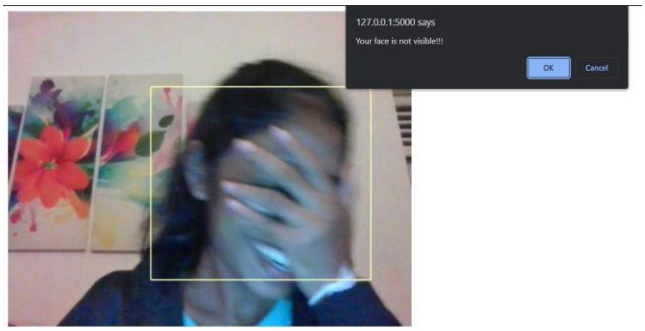

Figure 9. Pausing the emotion detection

But there is some confusion about this emotion detection. This is because the database system use can be obtained from the association. In some cases, it produces similar emotions and is more effective in generating emotions like "sad," "fear," etc. Also, in some cases, the "disgust" emotion also shows the "anger" (e.g., Figure 10) emotion.

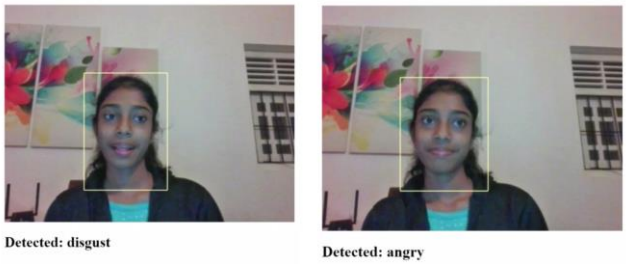

Figure 10. Confusion of emotions

D. *Dynamic Web-Based Game With Questions*

The final output of this part can be seen in three parts. In the first part of this, after clicking on the gaming object in the game, it will be possible to go to certain places in the game object bar. It is shown in section A before moving to the positions, and section B shows how it has moved to the correct positions. In the second part of this, after 10 seconds, the hint will be displayed, and when the hint is clicked, the question will be displayed as the second result. The stage before the hint and question box is shown in section C, and the way after it is displayed is also shown in section D (e.g., Figure 11).

Figure 11. Object moment, Question box, and hints

In the third part of this, after selecting the correct answer related to the question in the question box, you can see that the object spins. It is shown in Figure 12.

Figure 12. Game object moment

V. Conclusion and Future Scope

This research work has been developed primarily for Ordinary Level students in Sri Lanka because of the high annual number of students failing Ordinary Level mathematics. The application presents teaching materials, monitors student attention during lessons, has a voice assistant specifically designed to get help for the learning process, and has a web-based game component for students to participate in when student attention drifts away from mathematics related comprehensive online learning.

Enhancing the MCQ generation, voice identification, and emotion capturing can be considered code-level improvements. Adding more game worlds and scenarios could be identified as future work to enhance the play and learn the concept within the NeoApp. To achieve this, it needs to optimize the data sets and fine-tune the algorithms.

Acknowledgment

We would like to thank the authors of the research papers we have referred to in writing this paper.

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