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RESEARCH ARTICLE

Development of Remote Schooling Helper Application

Geonhun Lee
Bergen Catholic High School, 1040 Oradell Ave, Oradell, New Jersey, 07649, USA; geonhun.kevin.lee@gmail.com

ABSTRACT: This paper attempts to solve the issue of teachers' inability to monitor students' attention effectively in the virtual classroom setting which was changed by COVID-19. To solve this issue, this research designs and implements software that can monitor students' postures by using gyroscope sensors and detect students' presence in the class by using webcams. The gyroscope sensor and the webcam send sampled data to the web server where the attention is categorized (as "Out of class," "Present," "Concentrating," "Participating") using the algorithm based on the inclination of the upper body and the location and size of the face detected on the camera. The categorized conjectured attention is shown on the teacher's monitor via a website. After the design and the implementation, this paper runs a mock virtual class with the use of the developed application to verify its effectiveness of the developed application. The results show that an application like this can be used to track students' conjectured attention in a virtual classroom setting and assist teachers in the virtual setting.

KEYWORDS: Systems software; Application; Remote Schooling; Face detection; Posture Monitor; Python.

Introduction

A. Background:

COVID-19 has been the single most impactful event in the 21st century. With the new social distancing policies, people had to quarantine themselves in their respective places. Thus, workplaces and schools were forcibly moved to the remote environment in the comfort of people's rooms. Even as the pandemic lengthens and the policy gets more lenient, some people still stay at home and conduct their activities virtually.

And this is the same for the students. According to the study by Burbio, 52 percent of students in the USA planned to do virtual classes, 19 percent are doing hybrid, and only 25 percent plan to do offline lessons in the fall semester of 2020 with the assumption that the situation will be constantly changing.[1] With 2022 approaching, many students are still taking classes online from the comfort of their rooms and the situation will not change for many for some time.

Even though remote activities were inevitable for many students around the nation, they came with their own set of problems, especially for both the students and teachers in the remote class setting. Some problems for students include bad posture and losing focus in the remote class setting while teachers cannot notice and manage students losing focus in the class along with bad posture.

Indeed, one of the problems that students face is bad posture resulting from prolonged sitting. Even before the pandemic, students on average spent 10 hours in a chair.[2] However, with the lockdown caused by COVID-19, students were expected to spend even longer times in chairs. With prolonged sitting in chairs, students are bound to acquire bad posture that negatively affects their health. According to Ma, even if a person sits in a correct position, in the beginning, most people soon revert to a position where the center of mass is shifted to one side of the body within seconds.[2] The position in which the center of mass is shifted to one side can affect one's health negatively by changing the shape of the spine from an S-shape to a C-shape. The C-shape may press the nerves in the back and cause a herniated disc.[2] Not only the back can be affected but also the cervical spine can be affected by the neck pressing it due to VDT syndrome from the prolonged problematic posture.[3] As such, bad posture has a negative influence on health. Yet, this problem is exacerbated by students' prolonged sitting on chairs in a remote class setting.

Poor posture caused by using a computer for a prolonged time promotes the poor performance of the users as well. According to Straker, when the shoulder flexion is greater than 30 degrees, which means that the shoulder is leaning forward 30 degrees, subjects showed poorer performance on visual display unit work. Along with poorer performance, there was greater muscle discomfort for the subjects.[4] Therefore, students will eventually lose their good posture from prolonged sitting at a computer every day and thus perform poorly in their academic careers due to discomfort and muscle fatigue.

In addition, students can lose focus on important tasks of the day due to a phenomenon called "zoom fatigue." Zoom fatigue is an arising phenomenon among the virtual platform users that describes, "the tiredness, worry, or burnout associated with overusing virtual platforms of communication."[5] As many students are overusing virtual platforms every day, many students are feeling burnout from video calling with their teachers, friends, and more. According to Harvard Business Review, virtual platforms are more taxing than physical activities due to a few reasons: more factors of distraction, lack of points of focus, and temptation of multitasking.[6] These factors make remote students put more energy into focusing on remote classes; therefore, remote classes exhaust the students at the end of the day more than face-to-face classes do. With greater fatigue every day, students may lose focus on their academic work. Thus, students can perform even worse in their virtual school than they would have done in the physical school.

For people who must use computers for multiple hours a day, these problems are inevitable, yet it is hard to fix since no one can directly notice these problems and tell the person over the screen. Normally, fixing students' posture and guiding them back into focus on the lesson would be the teacher's job. Normally, teachers can usually scan the classroom and immediately find who is not focusing and can guide them back to the lesson of the day. However, this job is much harder now. The average number of students in a class in the US is 24.3.[7] In a virtual class, the teacher must scroll through small windows of students while they are teaching to ensure that the students are participating in the class. In addition, the teacher cannot tell exactly if a student is focusing on the class or just doing something else on the computer. If the teacher cannot monitor students effectively as they do physically, students' postures will eventually become poorer students, and they will lose concentration and perform poorly, academically.[8] Consequently, if teachers were to be able to monitor students better, they would be able to emulate their immediate scanning of students in the live classroom and prevent students from performing poorly.

B. Research Question

Based on the discussion above, the following question can be asked: "Is there a way for a teacher to effectively monitor students' attentions in a virtual classroom setting?"

C. Background Research

Students' attention in virtual classrooms is an understudied topic. Yet, there is a need in allowing teachers to observe the status of all students all at once on a single display to replicate the teacher's scanning of the class.

The student's attention in the class can be measured through blinking eyes, eye movement, brain waves[9], and screen gaze.[10] However, these data alone cannot determine what kind of attention these indicators show.[11] Thus, we believe that measuring sitting posture and analyzing the data to determine whether the student is watching a virtual class will be more useful value for monitoring the student's attention.[11] To develop such a system, the researcher has considered previous literature on how students' attentions and posture can be monitored using camera screens and sensors in the new virtual setting.

One way to monitor student posture in a virtual setting is through a gyroscope sensor. According to the literature, there have been experiments that involve fixing posture using gyroscope sensors, accelerometers, or pressure sensors. According to Hong, gyroscope sensors can be used to determine the neck's inclination for cervical hyperlordosis.[3] According to Ma, an accelerometer, which is very similar to gyroscope sensors, can be put adjacent to cervical vertebrae to determine the change in the vertebrae as the posture changes. There also have been experiments using pressure sensors to log the change in the weight distribution when a person is sitting as posture changes.[2,12]

Since this study needs to monitor students' screen gaze, the degree of bowing the neck should be evaluated. Thus, gyroscope sensors[13], which is a useful tool to measure the inclination of the neck, are optimal to be used.

Another important tool used to monitor students is image processing algorithms. Because a camera is often a requirement in a virtual classroom, facial recognition algorithms[14] can be used to determine if the person is within the camera's sight during the virtual class. Nowadays, there are many facial recognition algorithms available.

Methods

A. System Design:

a. System Overview

The system that I develop includes the following items: MPU6050 gyroscope sensor, Logitech C920 Webcam, Raspberry Pi 4 B, an application developed using Python, and a website and monitoring server based on Python, HTML, and JavaScript. In this paper, this system will only be tested on me at my home during a mock virtual class setting (Figures 1- 2).

Figure 1: The completed image of the system developed.

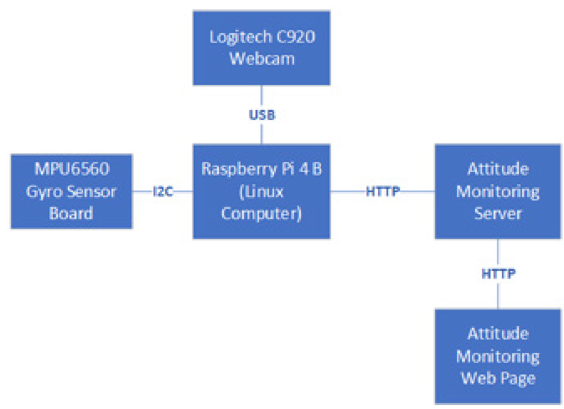

Figure 2: The diagram of the system planned to be developed.

b. Face detection Module Design

The first major component of the system is the facial detection module to identify the student's face during the virtual class. This system uses a separate web camera (Logitech C920 webcam) on the computer since Zoom prioritizes the use of the built-in camera for its use so this system could not access the camera while the Zoom class was functioning. The face detection software was programmed as a Raspberry Pi[15] that receives the image from the camera and computes the coordinates in the camera's FOV of the person's face by using OpenCV Image Processing Library's Face Detection Algorithm.[16]

To appropriately evaluate the student's attention, I have done the following experiments. The experiment consisted of determining the location of the face concerning the camera's field of view, horizontal (Figures 3-4) and vertical angle (Figures 5-6) that the camera and the face look out on, and the distance of the face (Figure 7) that can be detected from the camera using the face detection algorithm. These experiments set basic standards for the algorithm that determines good behavior

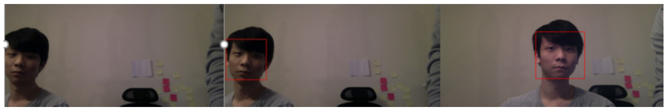

Figure 3: Various Cases of Facial Detection in the horizontal direction at the front-facing position.

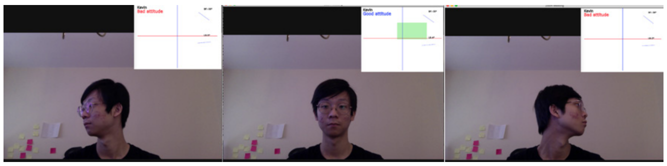

Figure 4: Various Cases of Facial Detection at different horizontal angles of facing positions.

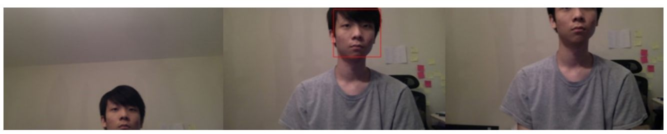

Figure 5: Various Cases of Facial Detection in the vertical direction at the front-facing position.

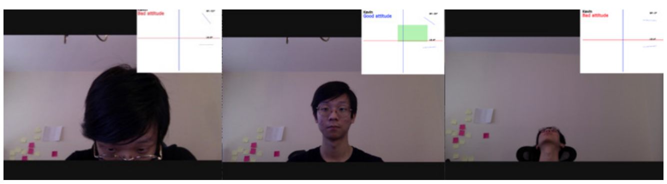

Figure 6: Various Cases of Facial Detection at different vertical angles of facing positions.

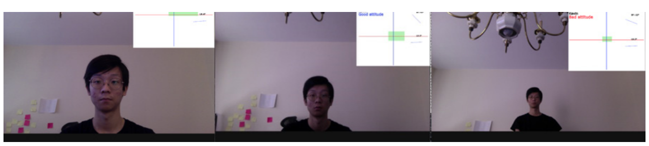

Figure 7: Various Cases of Facial Detection at different distances from the camera (50 cm, 1 m, and 2 m from the camera respectively).

c. Posture Monitor Module Design:

The second major component of the system is the 3-axis MPU6050 gyroscope sensor attached to the student's body to compute the orientation of the upper body (Figure 8). It is attached between numbers 5 and 6 of the cervical spines based on previous literature.[3] The BF-axis of the gyroscope faces the student's screen while the IR axis faces perpendicular to the screen. Because the sensor is small, it doesn't impact the student's posture and doesn't give discomfort. Raspberry Pi receives the computed value from the gyroscope sensor.

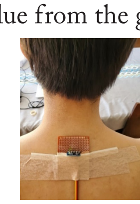

Figure 8: Gyroscope sensor attached to the student's body.

Because there was no data related to healthy posture based on the measurements from the gyroscope, the researcher has conducted experiments to determine the measurements of posture using the gyroscope. For this experiment, the researcher has defined eight postures using three standards based on the gyroscope's measurable range, healthy posture, and facial detection within the field of view of the camera.

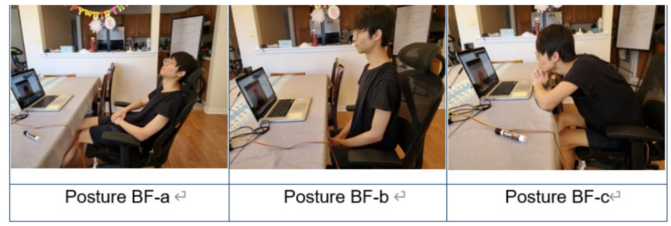

Figure 9: Various backward and forward (BF) inclining postures when the student looks onto the camera.

Figure 9 shows various backward and forwards (BF) inclining postures when the student looks into the camera. The inclination of the posture is measured by the BF-axis of the gyroscope. The range of accepted inclination for the BF-axis is determined by the maximum range in which the face detection program detects the student's face. In posture BF-a, the student faces the front and leans backward. In posture BF-c, the student faces the front and leans forward. In posture BF-b, the student faces the front and does not lean forward at all.

Figure 10: Five different postures when the student is leaning either right or left (LR) while facing front.

Figure 10 shows five different postures when the student is leaning either right or left (LR) while facing the front. These postures are all determined by the inclination on the LR-axis of the gyroscope. The maximum/minimum inclination is determined by the inclination when the student puts his/her head down on either side of the desk, when the student rests his/her chin on their hand, and when the student does not lean at all. Based on these standards, in posture LR-a, the student puts their head down on the right side of the desk. In posture LR-b, the student rests on the chin on the right hand. In posture LR-c, the student does not lead anywhere. In posture LR-d, the student rests their chin on the left hand. In posture LR-e, the student puts their head down on the left side of the desk.

d. Alghorithm Implementation

Using the data from the design process of the modules, I have implemented an algorithm to compute the attention of a student based on the posture for a prolonged time.

B. Software Impelementation:

Figure 11 shows the comprehensive configuration of the developed software using the modules and algorithms design-

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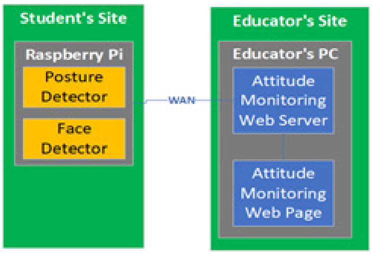


Figure 11: Diagram of software.

ed in earlier steps. On the student's side, Raspberry Pi runs the posture monitor and the face detector. These modules gather images and detect values from the sensors and convert them to use information such as the student's current posture and the face's coordinates in the camera's FOV (Field of view) and send the data out to the Attention Monitoring Server. In the Attention Monitoring Server, the program computes the student's attention using the quantified data on the student's posture and face using its evaluation algorithm and displays the result on its web page. The teacher can directly see the algorithm's evaluation of the student's current attention on the Attention Monitoring Web Page.

C. Application Testing:

The developed application is tested in a mock virtual class setting to ensure that the application properly collects data, computes results, and sends the result to the teacher's webpage. The application is also designed to ensure that various postures are categorized as intended and sends that data to the teacher's webpage. This simulation method verifies the results by comparing the recorded class and the result sent to the teacher.

The simulation consists of a 34-minute virtual Zoom class between the student (researcher) and the teacher (advisor). For the test, the application described in Figure 11 was set up. During the mock class, the application monitors and evaluates students' attention and provides the result to the teacher. All the evaluated attention scores and the mock virtual class are recorded cumulatively. After the mock virtual class, the researcher compared and verified the students' posture recorded on Zoom and the evaluated attention score.

■ Results and Discussion

A. Computation of Reference Value:

The reference value to evaluate students' current attention has been computed using the following method.

a. Face Detection:

The conditions for facial detection are as follows. The camera needs to see the major features of the face and thus the face detection algorithm detects the face within the field of view of the camera. In addition, the detected image size needs to be composed of more than 11.5 percent of the total size of the image since the face detection algorithm can detect the student's face up to 10m from the camera as the student may abuse that feature. The percentage is calculated using the field of view of the camera. Assuming that the student can maximally sit 1m from the camera and the field of view of the camera is 90 degrees, the researcher was able to find the perimeter that the web camera views is π/2m horizontally. Then the researcher calculated the ratio of the perimeter and the average width of a person's face, 0.18m. This results in 0.115, which shows that the face should occupy at least 11.5 percent of the screen width to assume that the student is within 1m from the camera.

b. Range of Inclination of Good Posture:

The following Figure 12 is the result of the experiment to acquire reference values for inclinations of good posture on a vertical axis (axis facing the camera's FOV). In posture BF-a, the furthest the student can lean backward is 45° degrees. In posture BF -b, the student sitting without any leaning on either side produces a value of about -25°~15°. In posture BF -c, the furthest the student can be forward is about -55°.

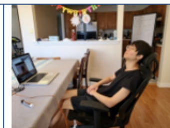
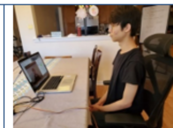
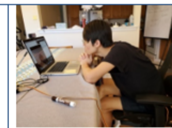
Posture			
Value	45° ~ higher	-25° ~ 15°	-55° ~ lower
type	Posture BF-a	Posture BF-b	Posture BF-c

Figure 12: The result of the experiment to acquire reference values for inclinations of good posture on a vertical axis (axis facing the camera).

The following Figure 13 is the result of the experiment to acquire reference values for the inclination of good posture on the horizontal axis (axis parallel to the camera's FOV). In posture LR-a, the inclination of the student lying on the left side of the table on the arm is lower than -30°. In posture LR-b, the inclination of the student having their chin on the right hand is -30°~-15°. In posture LR-c, the inclination of the student sitting straight is -15°~ 15°. In posture LR-d, the inclination of the student having their chin on the left hand is 15°~ 30°. In posture LR-e, the inclination of the student lying on the right side of the table on their arm is higher than 30°. Based on the result, the reference range of good posture on the vertical axis is set as -30° ~ 30°.

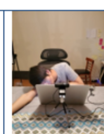
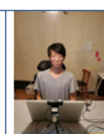
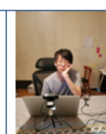
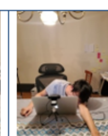
Image of Posture					
Inclination	-30°~ lower	-30°~ -15°	-15°~ 15°	15°~ 30°	30°~ higher
Type	Posture LR-a	Posture LR-b	Posture LR-c	Posture LR-d	Posture LR-e

Figure 13: The result of the experiment to acquire reference values for the inclination of good posture on the horizontal axis (axis parallel to the camera's FOV).

The reference range for both axes is shown in the following chart. The good range of inclination for the vertical axis is -50°~30°and the good range of inclination for the horizontal axis is -30°~30° (Table 1)

Table 1: Reference "Participating" range.

	vertical axis (°)	horizontal axis (°)
Reference "Participating" range	-55 ~ 30	-30 ~ 30

B. Algorithm Based on Reference Value:

Based on the reference values that were computed in the above section, an algorithm has been built to determine a student's current attention status in four levels: "Out of class", "Present", "Concentrating", and "Participating." The algorithm runs based on a scoring system over a prolonged time. The algorithm takes account of time because a person's posture is constantly changing. For example, a student may drop their pencil or must look behind because someone calls the person. These actions do not necessarily mean that the student is not paying attention but may be deemed as bad conjectured attention consequently. The student starts with a score of thirty at the beginning of monitoring. Then, the sensors sample the student's face location and the angle of the gyroscope. These values are used to compute the student's attention status.

If the posture determined is within the range mentioned in Table 1, the student gets one point. If the student's face is detected and the size of the detection is more than 11.5 percent of the camera's screen, the student gets another point. Every second, the student's facial detection and posture are evaluated and given points from zero to two. The given point is recorded for thirty seconds and is updated every second. The score from the last thirty seconds is used to determine the four levels of student's attention status using the following variables:

CS: Current Status (0~3, 4 levels of status)

SWS: Short-term window size, 5 seconds

LWS: Long-term window size, 30 seconds

SS: Short-term score, 0 ~ 10 points, cumulative score for the last 5 seconds

LS: Long-term score, 0 ~ 60points, cumulative score for the last 30 seconds

SC: Short term criteria, SWS x 2 = 10 points

LC: Long term criteria, LWS + 1 = 31 points

Then, the score is used to determine the four levels of attention as listed in the following:

Level 3: Participating (CS = 3)

Level 2: Concentrating (CS = 2)

Level 1: Present (CS = 1)

Level 0: Out of Class (CS = 0)

The following Figure 14 is the algorithm that uses the variables listed above to compute the student's attention. It was made using Python.

C. Application Testing by Mock Virtual Class Simulation:

```
MINIMUM_FACEWIDTH = 11.5        # minimum face width percent
BF_POSTURERANGE = [-55, 30]     # posture range bf-angle
LR_POSTURERANGE = [-30, 30]     # posture range lr-angle
scoreArr =[1]*30 #: Recent 30 seconds score array
CS = 0          #: Current Score
SWS = 5         #: 5 seconds, Short term window size
LWS = 30        #: 30 seconds, Long term window size
SS = 0          #: 0, Short term Score
LS = 0          #: 0, Long term Score
SC = SWS * 2    #: 5 * 2, Short term Criteria
LC = LWS + 1    #: 30 + 1, Long term Criteria
ATTI = ["Out of Class","Present","Concentrating","Participating"]

while True:
    current = face_detect() + posture_detect()  # 0 or 1 or 2
    scoreArr.push_tail(current)
    scoreArr.pop_front()
    LS=SS=0

    for s in scoreArr:  # long term score accumulation
        LS = LS + s
    for s in scoreArr[-1:(-1 - SWS):-1]:    # short term score acumulation
        SS = SS + s

    if SS == SC:    # perfect during recent 5 seconds
        CS = 3
        # if recent SWS score(SS) is perfect but past 30 seconds record is not good,
        # recover past LWS ~ SWS second data as 1
        if LS < LS:
            for s in range(len(scoreArr) - SWS):
                scoreArr[s] = 1
    elif LS > LC:   # long term score is high
        if SS > SWS:
            CS = 3
        else:
            CS = 2
    elif LS <= LC:  # long term score is low
        if LS >= 5:
            CS = 1
        else:
            CS = 0
    update_ui(ATTI[CS])
```

Figure 14: Pseudocode of the algorithm.

The developed application collected monitoring data for thirty-four minutes of a mock virtual class. The following Figure 15 shows the change in students' attention scores over 34 minutes on the top with the bottom figure zoomed in to show 5 minutes.

Figure 16 shows the image of the student around thirty-one

Figure 15: Change of Attention Score over time for 34 minutes of the mock virtual class.

minutes from the beginning of the class (Box B in Figure 15 lower part) which the graph shows as Level 0: "Out of class" attention level. As shown in the image, the student's major facial features were out of the camera's FOV, so the face detection module failed to detect the face and the posture inclination was not within the reference "participating" range (see Table 1).

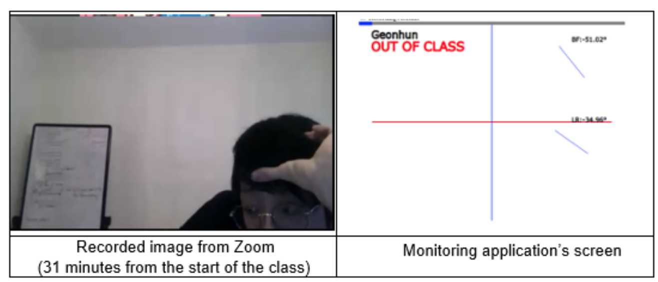


Figure 16: The student's posture and recorded image when the application determined the attention as "Out of Class."

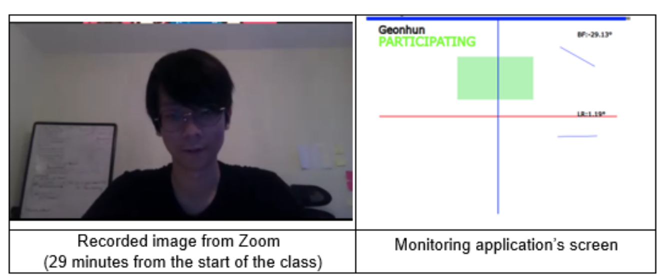


Figure 17: The student's posture and recorded image when the application determined the attention as "Out of Class."

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Conclusion

In this paper, an application that uses data from a gyroscope sensor module and an image processing module has been developed to assist educators in evaluating students' attention. In addition, a mock virtual class has been conducted to verify that meaningful data can be collected and sent to the educator.

If the developed application is applied in a real virtual class setting, teachers will be able to use less time and effort on monitoring students and thus will be able to focus more on teaching. Moreover, the teacher can give feedback to students based on the developed application so the students can take virtual classes more effectively. In doing so, this application can be proved to be a convenient tool for both students and teachers and promote quality of education in a virtual class setting.

The current research has multiple problems. Therefore, in future studies, we will do the following.

To begin with, a current indication of engagement is not direct or a clear reflection of student engagement. Thus, in the follow-up study, to secure representativeness of the reference value, more trials of the experiment with a greater number of subjects will be performed, deriving the reference value.

Second, although the focus of the study was to promote student attention in the virtual classroom setting, it only succeeded in evaluating student attention and not fully achieving promoting student participation. In future studies, beyond providing one-way information to inform teachers of the students' attention status, the system will be modified and developed so the application can give automatic feedback which will induce students' attention. Also, a two-way information exchange system that enables interaction with teachers will be added to facilitate the teacher's management of students.

Thirdly, it is true that evaluation of a student's attention is only based on face detection and posture detection can be ambiguous. Thus, in future studies, more criteria, such as the movement of eyeballs and perspective, the vibration of heartbeat, and more will be added to make the evaluation of student attention in a virtual classroom even more clear.

Last, of all, the posture monitor module used in this paper did not produce the most accurate evaluation of the student's posture because of a lack of ergonomic research. Therefore, a module that can accurately evaluate one's posture must be developed in future studies.

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Author

The author of the research paper, Geonhun Lee, is currently a student at Bergen Catholic High School. He is interested in Computational biology, the combined application of math, statistics, and computer science to solve problems regarding biology. Researching in this field, he will move forward to achieve his dream.