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Impact of Online Learning on Stress and Fatigue Using GSR and SOFI Measurements

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ABSTRACT IN ENGLISH

The early days of university are often a period of great change and stress for freshman students. Freshman and sophomore students in the Industrial Engineering bachelor's degree program at University X are adapting to a more flexible learning environment, running two different learning methods, namely synchronous and asynchronous learning methods. This study was conducted to analyze the classification of stress and fatigue levels of undergraduates in the Bachelor Program in Industrial Engineering at University X. Industrial Engineering bachelor's degree program of University X when undergoing lectures. Stress levels were measured objectively using Galvanic Skin Response (GSR) with a gel electrode type. In contrast, fatigue levels were assessed subjectively through the Swedish Occupational Fatigue Inventory (SOFI) questionnaire. The analysis revealed that the stress levels of students during learning, whether through synchronous or asynchronous methods, were categorized as high, with a higher mean value observed in the synchronous learning method. Conversely, fatigue was classified as mild. Based on these findings, this study proposes implementing structured break schedules during synchronous learning sessions and optimizing asynchronous methods by integrating interactive yet less demanding activities to reduce stress and improve student well-being. Additionally, further ergonomic adjustments to the learning setup and duration are recommended to minimize fatigue.

1. INTRODUCTION

Entering the world of lectures can be a situation full of change and stress for some freshmen [1]. Stress manifests in many aspects of daily life, making it a complex topic for research, particularly in terms of categorizing stress exposure and identifying appropriate methods for its study [2]. The transition from high school to university is often marked by a significant shift in responsibilities and expectations. First-year students must adapt to a more independent learning environment, manage their time effectively, and navigate new social dynamics, all of which can contribute to heightened stress levels.

At University X, freshman students often encounter unique challenges as they begin their academic journey in a flexible learning environment that combines synchronous and asynchronous methods. While this approach offers greater freedom in learning, it also introduces new stressors and the need for significant adjustments. These online learning environments, characterized by a mix of real-time synchronous sessions and asynchronous self-study, have become integral to the student experience. Freshman and sophomore students, particularly those from the classes of 2021 and 2020, face additional difficulties adapting to a learning model that minimizes face-to-face interaction with peers and the campus community.

Entering the world of lectures can be a challenging experience for freshman students, particularly in the context of flexible learning environments. Along with adaptation to college, student stress levels will slowly decrease, leading to better social, academic, and emotional adjustments for students [3]. This adjustment period often brings changes in the social, academic, and emotional aspects of students' lives. To support their adaptation, universities typically hold orientation programs that introduce students to the academic environment and campus culture. However, with the development of more flexible learning methods, the way students adapt is also changing.

Given this situation, the stress reduction that typically occurs during the transition to university may have been delayed or altered for students. Moreover, the stress experienced can lead to mental fatigue, which can have an impact on their overall well-being. This study aims to explore how flexible learning methods, particularly the combination of synchronous and asynchronous learning, influence stress and fatigue levels in both freshman and sophomore students at University X. Therefore, it is important to understand how this new learning method affects stress and fatigue levels, especially for students who are just starting their academic journey. This is crucial to support their adaptation process during the continuation of their studies over the next few years.

At University X, the bachelor's degree program implemented two types of distance learning methods, namely synchronous and asynchronous, which further challenged students to find their balance in managing time and responsibilities. Synchronous is a learning method in which lecturers convey material directly by sharing screens through online media such as Zoom, Google Meetings, Discord, and others during lecture hours. Asynchronous is a learning method in which the lecturer provides recordings of lecture material in the form of suitable PowerPoint slides or videos before lecture hours take place, and during lecture hours, there will be online discussions [4]. In the asynchronous learning method, students must study the material earlier so that all students can discuss the day's material during lecture hours. With a busy class schedule, students need to arrange additional time to study the lecture material that day. Thus, the actual amount of student study time with the asynchronous learning method is more than the synchronous learning method.

With the limitations of orientation activities and the application of two different learning methods, this will likely cause an increase in the stress level of freshman students, which should decrease along with their adaptation to the world of lectures. Stress is the body's reaction to changes that require physical, psychological, and emotional responses, regulation, and adaptation [5]. Lumban Gaol [6]also said that stress cannot be separated from the body's reaction to existing stressors, so it can be concluded that stress is the body's physical reaction to existing stressors or stimuli that attack the body. Following the definition of stress, stress levels can be measured objectively according to the changes that occur in the body.

Research on stress and fatigue has been conducted among students and professionals. One study identified stress levels among teachers in Jordan's Ministry of Education, finding that gender significantly influenced stress [7]. Another study reviewed the effectiveness of prevention programs for depression, anxiety, and stress among students, showing significant symptom reduction[8]. Additionally, research on academy stress management using Rational Emotive Behavior Therapy (REBT) demonstrated effectiveness in improving academic adjustment and reducing stress among Industrial Engineering students in Enugu state Nigeria [9]. A literature review highlighted the potential of wearable devices for stress management [10]. Moreover, studies on medical students employed cross-sectional designs to indicate significant relationships between stress and fatigue [11], as well as the impact of online learning during the COVID-19 pandemic on student well-being [12]. Future research could explore the application of Galvanic Skin Response (GSR)

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and Subjective Occupational Fatigue Inventory (SOFI) to better understand stress and fatigue among Industrial Engineering students in the Indonesia area.

The activity of the sweat glands is determined by the autonomic nervous system, which contains two main subsystems: the parasympathetic and sympathetic nervous systems. The sweat glands on the skin are regulated only by the sympathetic nervous system; therefore, the activity of the sweat glands is a good indicator of inner tension and stress [13]. There is one tool that can detect minor changes in the activity of the skin's sweat glands, namely the Galvanic Skin Response (GSR). In English, GSR, also known as electrodermal response, measures the electrical properties of the skin to assess its response. ([14]. Previous studies have used the GSR, a measurement of continuous fluctuations in the electrical conductance of the skin, as an objective indicator of stress [15], [16], [17]. Additionally, GSR readings have been utilized to identify psychological or physiological arousal [18], [19], [20], [21], and the effect of emotions [22]. The GSR signals were significantly affected by both trust and cognitive load [23], comparing the skin's extreme sensitivity to the environment.

In addition, the stress felt by freshman students can also have an impact on their fatigue, especially mental fatigue. Stress and emotions can affect fatigue because when stressed or in other emotional conditions, a person needs energy; therefore, energy that should be used for work is wasted. Stress can reduce the ability to think rationally, increase emotions, and interfere with decision-making [24]. The negative results of word-related weariness include increased human errors, memory impairment, diminished decision-making and reasoning control, an increased risk of depression and anxiety, decreased productivity, and incapacity. Hence, exhaustion leads to decreased performance and reduced ability to perform physical and mental work [25], [26], [27], [28], [29], [30], [31].

There are several methods for measuring subjective levels of physical and mental fatigue, including the Pittsburgh Sleep Quality Index (PSQI), the Fatigue Severity Scale (FSS), the Multidimensional Fatigue Inventory (MFI), and the Profile of Mood States (POMS). Among these, the Swedish Occupational Fatigue Index (SOFI) questionnaire is specifically designed to identify the causes of fatigue during work activities. Developed by Ahsberg in 1998, SOFI comprises five dimensions: lack of energy, physical exertion, physical discomfort, lack of motivation, and drowsiness [32]. SOFI is an easy-to-use tool in ergonomics and serves as a self-report instrument for assessing fatigue, having been utilized in various settings over the past fifteen years. [33]. SOFI focuses on environmental and transient side effects in the here and now to look at momentary status or short-term indications of fatigue rather than significant causes or outcomes [34].

2. METHOD

The participants in this study were freshman students from the 2021 batch and sophomore students from the 2020 batch in the Industrial Engineering Bachelor's degree Program at University X, who experienced synchronous and asynchronous learning methods during the 2021-2022 Odd Semester. The total number of participants for this research was 11, comprising 3 students from the class of 2020 and 8 students from the class of 2021. The technique used was purposive sampling by selecting students who met the research criteria, namely those who attended synchronous and asynchronous lectures. This selection considered time constraints as well as the criteria for eligible participants. This approach aimed to gain relevant insights into the relationship between stress and fatigue levels on students' experiences. By focusing on the right participants, analyses can be conducted in-depth, despite the relatively small sample size used. This ensures that the research results remain relevant and meaningful, making a significant contribution to the understanding of the phenomenon under study.

Measurements were taken for mathematics courses in the Bachelor Program in Industrial Engineering at University X. The mathematics courses with the synchronous method attended by the class of 2020 for measurement included courses in Cost Analysis, Engineering Economics, Production Planning and Control (Response), and Statistical Data Analysis. The mathematics courses with the synchronous method followed by the class of 2021 for measurement were Industrial Statistics 2, Industrial Statistics 2 (Response), Basic Mathematics, Primary Mathematics (Response), Physics 2, and Physics 2 (Response). The mathematics courses with the asynchronous method followed for measurement were Engineering Economics (class of 2020) and Industrial Statistics 2 (class of 2021). Stress levels were measured objectively using GSR connected to an Android mobile phone.

Figure 1 - Galvanic Skin Response

The design of this study utilized a within-subjects approach, in which each participant was assessed under different conditions to evaluate their levels of stress and fatigue. The electrode, as shown in Figure 1, is part of the GSR tool and will be installed on one of the participants' palms. The type of electrode used is a gel electrode. Participants will be measured using the GSR during lecture activities, and the results of stress level measurements can be viewed through an application on an Android mobile phone called Mindfield eSense-Biofeedback. Measuring the level of physical and mental fatigue of students was done subjectively using the SOFI questionnaire. Participants completed the SOFI questionnaire after lecture activities, with each dimension translated into five question points, resulting in a total of 25 questions. Participants were asked to assess their condition on a scale from 0 (not felt) to 6 (very much felt) [35]. Each score will be added to determine the participant's fatigue level. Each participant will be measured for the level of stress and fatigue for each learning method (Synchronous and Asynchronous). Figure 2 illustrates this process, including data collection, stress and fatigue measurements, and follow-up interviews to gather supporting information on participants' physical health, difficulties during college, and personal experiences of stress and mental fatigue. On the first day, data will be collected from the participants. After that, the participants' stress and fatigue levels will be measured while attending lectures using the synchronous learning method. On the second day, participants will again have their stress and fatigue levels measured during lectures conducted with the asynchronous learning method. Following this, the interview process will take place. This interview aims to obtain supporting information about the participants' physical health conditions before attending college, the difficulties and obstacles they faced during their studies, and their personal opinions regarding feelings of stress and mental fatigue experienced during college.

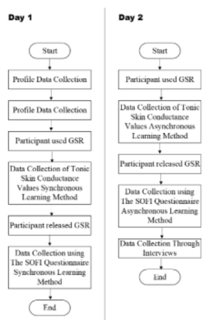

Figure 2 - Data Collection Process

The collected data will be tested for normality using the Shapiro-Wilk test to determine the distribution of the data. Moreover, comparisons between two groups of data will be made with the Wilcoxon test, which is one of the non-parametric tests used to determine the significance of differences between two paired data. The data tested using the Wilcoxon test is the average tonic conductance value obtained in synchronous and asynchronous learning methods. This test was also conducted using the SPSS program. The Spearman rank correlation coefficient test was used to assess the correlation between fatigue levels, measured by the total score of the SOFI questionnaire, and stress levels, determined by the average tonic conductance values of the students.

3. RESULT AND DISCUSSION

Most of the participants came from the class of 2021 who were taking semester two lectures. From the questionnaire results, it was also known that five participants preferred theoretical courses and six preferred quantitative courses. Participants who liked theoretical courses found it more challenging to attend quantitative lectures and vice versa. The average participant prefers the synchronous learning method and finds it more difficult to attend lectures.

The classification of stress levels among participants refers to the data presented in Table 1. This classification is essential for understanding how different learning methods impact student stress.

Table 1 - GSR Classification [36]

Condition	GSR (mS)	HP (bpm)	Blood Pressure (mmHg)
Relax	<2	60 – 70	100/70 – 110/75
Animated	2-4	70 – 90	100/75 – 120/85
Tense	4-6	90 – 100	120/90 – 130/110
Stressed	>6	>100	> 130/110

The Wilcoxon Signed-Rank Test was employed to examine the differences between the two methods. The findings revealed that the asymp.sig value was greater than 0.05, indicating no significant difference in stress levels between synchronous and asynchronous learning methods. Table 2 presents a comparison of tonic conductance values, lecture hours, sleep hours, and pre-lecture activities for participants engaged in the synchronous learning method. In contrast, Table 3 provides similar data for the asynchronous learning method.

The classification of GSR results indicates the following stress levels among participants:

- During synchronous learning, 55% of participants recorded stress levels that exceeded the threshold (exceeding 4 μS). This finding highlights the significant impact of real-time demands and structured schedules in synchronous learning, which can elevate stress due to the necessity for immediate participation.
- In the case of asynchronous learning, 45% of participants exhibited stress levels above the threshold (exceeding 4 μS). Although this figure is slightly lower than that observed in synchronous learning, it suggests that the flexibility offered by asynchronous methods does not completely alleviate stress. This is likely due to the cumulative workload and the responsibility students bear for their independent study.

The percentage data indicates that a majority of participants experience stress in both learning methods, with synchronous learning posing a slightly higher risk. This observation aligns with qualitative data suggesting that the structured and immediate nature of synchronous sessions creates cognitive pressure, particularly in quantitative courses.

Conversely, while the relative flexibility of asynchronous learning seems to reduce immediate stress, it does not eliminate it, as students still need to practice self-regulation and preparation. Consequently, students tend to experience more stress when using synchronous learning methods. One notable drawback of synchronous learning is its real-time nature, meaning that students cannot access learning materials outside of a predetermined schedule. This limitation can restrict the time available for participants to reflect and think critically, potentially contributing to increased stress levels associated with this learning method.

Table 2 - Comparison of Interview Data and Tonic Synchronous Conductance Values

No	Participant	Average Synchronous Tonic Conductance Value (Micro Siemens)	Class Time	Total Hours of Sleep	Activities Done Before Class
1	1	3,76	09.00 am - 10.40 am	3 hours	Take classes, make assignments
2	2	11,46	10.00 am - 11.40 am	6 hours 30 minutes	Take classes
3	3	2,28	07.00 am - 08.40 am	5 hours	-
4	4	9,81	07.00 am - 08.40 am	5 hours	Take classes, make assignments
5	5	1,71	09.00 am - 10.40 am	2 hours	Usual activities
6	6	25,41	03.00 pm - 04.40 pm	7 hours	Take classes
7	7	10,35	09.00 am - 11.30 am	7 hours	Usual activities
8	8	1,19	08.00 am -09.00 am	6 hours	Usual activities
9	9	5,07	03.00 pm - 04.40 pm	6 hours	Take classes
10	10	2,72	01.00 pm - 02.00 pm	4 hours	-
11	11	11,39	07.00 am - 08.40 am	8 hours	Take classes, make assignments

Table 3 - Comparison of Interview Data and Tonic Asynchronous Conductance Values

No	Participant	Average Asynchronous Tonic Conductance Value (Micro Siemens)	Class Time	Total Hours of Sleep	Activities Done Before Class
1	1	3,67	11.50 am - 12.30 pm	5 hours	Take classes, make assignments
2	2	11,87	09.00 am - 10.00 am	6 hours 30 minutes	Take classes
3	3	3,5	02.00 pm - 03.00 pm	6 hours	Take classes
4	4	13,9	01.00 pm - 01.30 pm	5 hours	Take classes, make assignments
5	5	2,52	01.00 pm - 01.30 pm	2 hours	Usual activities
6	6	12,04	02.00 pm - 03.00 pm	7 hours	Take classes
7	7	2,02	09.00 am - 10.00 am	7 hours	Usual activities
8	8	7,5	10.00 am - 11.00 am	6 hours	Usual activities
9	9	3,94	02.00 pm - 03.00 pm	6 hours	Take classes
10	10	2,21	11.00 am - 12.00 pm	4 hours	-
11	11	6,18	01.00 pm - 01.30 pm	3 hours	Take classes, make assignments

From Figure 3, the time of increase in stress experienced by each participant was different. This depends on the ability of each participant to take online lectures. The average time for increasing stress obtained in the synchronous learning method is in the 18th minute. The average time for increasing stress obtained in the asynchronous learning method is in the 13th minute.

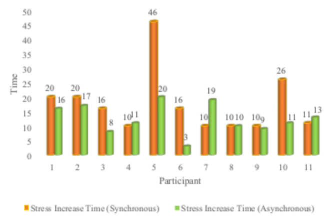

Figure 3 - Stress Increase Time Synchronous and Asynchronous Learning Methods

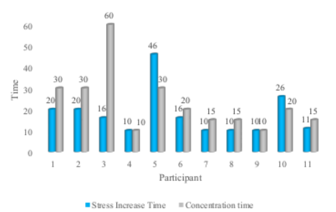

Figure 4 - Comparison of Stress Increase Time and Concentration Time (Synchronous)

Data collected from interviews provided insights into how long each participant was able to concentrate during synchronous learning sessions. This information was then compared with the time at which their stress levels began to increase, as measured by GSR recordings. Figure 4 illustrates that after the stress level starts to rise, participants often struggle to maintain their concentration. This correlation is evident in the concentration-time limits reported by the participants, which closely align with the moments when their stress levels increase. For instance, the first participant reported a concentration limit of 30 minutes at the beginning of the lecture, while their stress level began to rise at the 20th minute, as indicated by the GSR readings. Similarly, the second participant indicated a concentration limit of only 15 minutes, with their stress level rising at the 10th minute, as measured by the GSR device.

One of the symptoms of learning stress from an intellectual perspective is difficulty concentrating [37]. Research indicates that stress can lead to challenges in concentration, memory, and problem-solving skills [38]. This finding aligns with the results of the current study, where participants reported difficulties in concentrating as their stress levels increased. As demonstrated in this study, participants experienced significant challenges in maintaining focus after their stress levels began to rise. Therefore, the increase in student stress levels negatively impacts their ability to concentrate while engaging in synchronous learning.

The observed decrease in concentration coinciding with rising stress levels is also supported by Cohen's statement from 1980 [39], which asserts that individuals working under stressful conditions do not perform as effectively as those working under optimal conditions. As stress intensifies, students find it increasingly difficult to concentrate, which ultimately affects their performance during lectures.

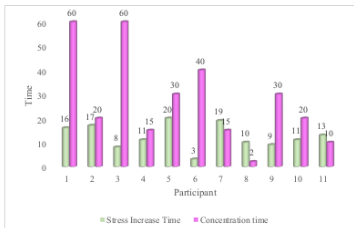

Figure 5 - Comparison of Stress Increase Time and Concentration Time (Asynchronous)

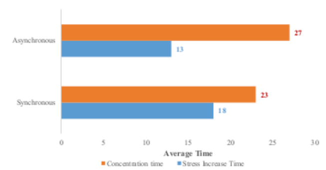

Figure 6 - Average Stress Increase and Concentration Time in Synchronous and Asynchronous Learning

The bachelor's Program at University X implements asynchronous learning methods exclusively for theoretical courses. As shown in Figure 6, during synchronous learning, the average time of stress increase reported by participants is greater than during asynchronous learning, while the concentration-time during asynchronous sessions is notably longer. For example, in Figure 5, participant 1 experienced a stress increase at the 16th minute but reported an impressive concentration duration of 1 hour. In contrast, during synchronous learning, many participants struggled to maintain focus as their stress levels rose; for instance, the concentration-time for participant 2 was only 20 minutes, with stress beginning to increase at the 17th minute.

These differences suggest that asynchronous learning formats can create a better environment for concentration, allowing students to manage their stress more effectively. The flexibility inherent in asynchronous learning allows students to engage with course material at their own pace, which can reduce the pressure associated with in-person participation and potentially improve focus and retention of information. In contrast, synchronous learning formats, which require immediate engagement and response, may increase stress levels, impairing concentration and overall performance.

Additionally, these findings highlight the importance of addressing students' emotional and psychological well-being in educational settings. The ability to concentrate well is critical to academic success, and the negative relationship between stress and concentration in synchronous learning suggests the need for strategies to reduce stress. Undergraduate programs may benefit from implementing stress management techniques, such as mindfulness practices or scheduling breaks during synchronous sessions, to help students cope with increased stress levels.

When examining the conductance values, it is noted that the number of participant breaks is minimal and does not significantly affect the detected tonic conductance values. The conductance value obtained by participants with a resting time of 2-4 hours is between 1-4 µS, which falls within the quiet category. This can also be influenced by the activities carried out by participants before entering college. Participants who slept only 2-4 hours did not engage in other activities before the measurement.

In terms of conductance values greater than 6 (indicating stress conditions) during both synchronous and asynchronous learning methods, it was observed that before attending college, participants participated in other activities such as attending other classes and completing assignments. Even with adequate sleep and a morning lecture schedule, the detected conductance values indicated high tension. Therefore, the activities conducted before college have a significant impact on stress levels compared to the participants' lecture hours and sleeping hours.

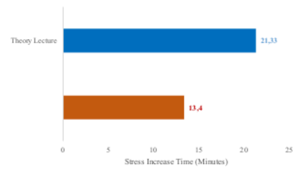

Figure 7 - Comparison of Increase in Stress Levels of Theory/Response Lectures

The average time to increase stress levels in response classes with synchronous learning methods was 21.33 minutes, longer than the theory classes which were only 13.4 minutes. Theoretical classes usually focus on the direct delivery of material by lecturers, where students only listen and take notes. This method tends to be more structured and formal. In contrast, response classes involve more active interaction between lecturers and students, or between students, where they are required to work on maths problems and actively discuss the material. While students may feel more comfortable interacting with peers during response lectures, this can lead to an increase in stress time.

Stress is the body's response to demands that are influenced by how an individual perceives a situation and the resources available. It involves interactions between environmental factors and personal perceptions and includes both physical and mental aspects[40]. Chronic stress can negatively impact an individual's decision-making, leading to negative behaviors. Currently, chronic stress is classified as a 'risk indicator' for periodontal disease. [41]. Stress can be understood as the body's response to various stimuli that affect individuals. The stress experienced by individuals can be seen as a result of a combination of various activities undertaken, including the academic demands faced The perception of stress is subjective and can vary significantly from person to person, influencing how individuals cope with stressors The results of measuring student fatigue levels using the SOFI questionnaire, conducted after measuring stress levels, showed that the average SOFI total score in synchronous learning was 43.7273, while the average total SOFI score for asynchronous learning was 43. Based on the SOFI total score classification in Table 4, a total score of 1-50 is categorized as mild fatigue. During synchronous lectures, students do not experience excessive fatigue, and similarly, students in asynchronous lectures also fall within the mild fatigue category. This shows that even though students face diverse academic demands, they are still able to manage their fatigue levels well subjectively.

Table 4 - Fatigue Classification [42]

Fatique Classification	Total Score
Mild Fatique	1-50
Moderate Fatique	51-100
Severe Fatique	101-150

The mean of conductance value and stress value were tested using the Wilcoxon signed rank test. The result showed asymp.sig value of 0.657 (> 0.05), which means there is no significant difference in students' stress levels between synchronous and asynchronous learning methods. However, for SOFI total score, asymp.sig value of 0.683 (> 0.05) indicates no significant difference in students' fatigue levels between both methods. This finding shows that neither synchronous nor asynchronous method has a significantly different impact on students' stress and fatigue, although other possible factors influence the result such as time management and learning strategy.

At the acute level, stressors trigger predictable psychological and physiological responses [43]. The correlation between stress levels and student fatigue levels was further analyzed using Spearman's rank correlation test. The results indicate a correlation between stress levels and student fatigue levels during synchronous learning, with a correlation coefficient of -0.513, indicating a moderate negative correlation. In contrast, the correlation coefficient for asynchronous learning was -0.198, indicating a very low negative correlation. This shows that stress has a greater influence on student fatigue in the context of synchronous learning compared to asynchronous learning.

The average participant was only able to concentrate for 27 minutes on asynchronous learning. However, stress levels began to increase at the 13th minute. Therefore, the duration of asynchronous learning should not exceed 27 minutes to maintain student concentration. The total time should be divided into two parts, with a maximum duration of one video of less than 13 minutes. This is important because after the 12th minute, students' stress levels increase, which can interfere with concentration. By breaking down the content, students can take a short break, suggested to be around 1-3 minutes, before continuing to the second video. This brief pause will help students reduce stress and regain focus, allowing for a more effective delivery of the lessons. An illustration of this suggestion can be seen in Figure 8.

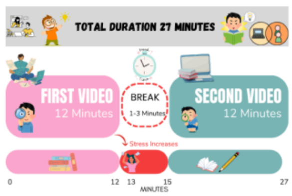

Figure 8 - Optimal Duration for Asynchronous Learning

The asynchronous learning method has several weaknesses, such as not all students accessing the learning videos, difficulties in asking questions directly to the lecturer, and the possibility of students forgetting to access the videos. To address this, the asynchronous learning system should be implemented with the following steps: First, students are required to access all learning videos, after which they must fill out an activity sheet. The system will notify the lecturer about students who have not accessed the videos, allowing the lecturer to remind them. If there are students who have never accessed the videos, this information will be forwarded to the academic advisor or the student's parents through email. Next, students must fill out the activity sheet, which consists of reflections and questions, where at least one section must be completed to continue accessing the learning materials. After that, students can access the course materials in the form of downloadable PowerPoint slides, which will serve as a reference during synchronous classes. Figure 9 illustrates the systematic approach to implementing the asynchronous learning system. With this system, it is hoped that student participation in asynchronous learning will increase.

Figure 9 - Proposed Systematic Steps for Asynchronous Learning Implementation

Participants who attend synchronous in the morning show lower stress levels compared to those who attend classes in the afternoon. Interview results also reveal that activities before class influence the increase in stress levels. Therefore, it is recommended that synchronous classes be scheduled in the morning between 7:00 AM and 10:00 AM, to prevent students from experiencing increased stress due to other activities.

The average increase in stress during theory classes occurs at minute 13,4, while in response classes it occurs at minute 21,33. Therefore, it is recommended to implement synchronous teaching methods in response classes for more optimal learning, as students can feel more relaxed during the learning process.

Based on the data obtained, students in the Industrial Engineering Bachelor's Program at University X showed an average concentration ability for 23 minutes at the beginning of the lecture, while the stress level increased at the 18th minute. Therefore, it is recommended that lectures both 2 credits (1 hour 40 minutes) and 3 credits (2 hours 30 minutes) are not carried out non-stop but are interspersed with breaks to maintain focus and reduce stress. For 2-credit lectures (see Figure 10), a total time of 100 minutes should be divided into three breaks. The first break should take place between the 18th to 23rd minutes to prevent excessive stress. Simple interactive activities, such as pairing questions with statements, word association, true/false questions, etc. can be done in breaks 1 and 3. In the middle of the lecture, it is recommended to stretch together to relax the muscles and reduce tension. For a 3-credit course (see Figure 11), the total time of 150 minutes should be divided into five breaks. Pauses 1 and 4 can be filled with interactive activities to recapture students' attention. Pauses 2 and 5 should be used for a short break without activity so that students can drink water and reduce stress. In the middle of the lecture, stretching together is also recommended to restore concentration. The break intervals can be adjusted according to the needs or preferences of the lecturer. With the right distribution of duration and activities, it is expected that students can be more focused and reduce stress levels during lectures.

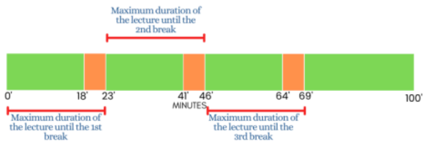

Figure 10 - Recommended Duration Distribution for 2 SKS Synchronous Lectures

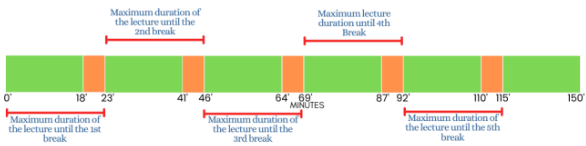

Figure 11 - Recommended Duration Distribution for 3 SKS Synchronous Lectures

4. CONCLUSION

The stress levels experienced by students using synchronous and asynchronous learning methods fall into the high-stress category, primarily influenced by pre-class activities. Increased stress during synchronous learning negatively impacts student concentration. In contrast, fatigue levels remain mild for both learning methods, with a weak relationship between stress and fatigue.

To address these findings, the study proposes introducing structured breaks during synchronous sessions to alleviate stress and prevent burnout. For asynchronous learning, integrating more interactive but less cognitively demanding tasks could enhance engagement while reducing stress. Moreover, ergonomic adjustments, such as improved seating and screen positioning, along with optimized session durations, are recommended to minimize fatigue and support long-term learning efficiency. Future research should explore the impact of these interventions and other factors such as lighting, noise levels, and individual learning preferences on student stress and fatigue.

These findings suggest that while synchronous learning presents challenges to student focus due to heightened stress, asynchronous learning offers a more flexible environment that supports academic success. To address these issues, practical strategies are recommended, including the implementation of structured breaks during synchronous sessions to alleviate stress and prevent burnout. Additionally, incorporating interactive yet less cognitively demanding tasks in asynchronous learning can enhance engagement while reducing stress levels.

Further, ergonomic improvements—such as better seating arrangements, optimized screen positioning, and adjusted session durations—are advised to minimize fatigue and promote long-term learning efficiency. Time management training and the use of adaptive learning technologies are also proposed to support students, particularly in mathematically intensive courses, and to improve their overall academic experiences.

Future research should investigate the long-term effects of these learning methods on student performance and well-being, as well as the impact of factors such as rest hours, pre-class activities, lighting, and noise levels on stress and concentration. These efforts aim to create a more supportive and effective learning environment for students in the Bachelor of Industrial Engineering Program.

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