Jurnal Sistem dan Manajemen Industri Vol 5 No 1 June 2021, 35-42

Available online at: http://e-jurnal.lppmunsera.org/index.php/JSMI

Jurnal Sistem dan Manajemen Industri

ISSN (Print) 2580-2887 ISSN (Online) 2580-2895

Calculation of mental load from e-learning student with NASA TLX and SOFI method

Anastasia Febiyani, Atik Febriani*, Jauhar Ma'Sum

Department of Industrial Engineering, Institut Teknologi Telkom Purwokerto, Jl. DI. Panjaitan no. 128 South Purwokerto, Central Java 53147, Indonesia

ARTICLE INFORMATION

Article history:

Received: November 28, 2020
Revised: June 22, 2021
Accepted: June 26, 2021

Keywords:

Mental workload
E-learning
NASA-TLX
SOFI

A B S T R A C T

The learning process between students and lecturers usually occurs face-to-face in class. Technological developments and a continuous pandemic change the learning process to be a face-to-face e-learning process. The mental load during face-to-face learning is very different from learning in e-learning. This study was built using ergonomic thinking that is integrated with the use of e-learning. Cognitive ergonomics see from the point of view of students' comfort in cognitive thinking processes when doing e-learning. Data processing and testing will use a questionnaire derived from the NASA-TLX method. The results obtained from this study are the mental load calculations of each NASA TLX calculation. NASA TLX calculations show that efforts with a value of 267.29 dominate students. It could indicate that in e-learning lectures, students need more effort in conducting lectures. In addition, students experience fatigue while participating in online learning. It can be seen from the average SOFI measurement, which is only 1.26.

*Corresponding Author

Atik Febriani
E-mail: atik@ittelkom-pwt.ac.id

1. INTRODUCTION

The use of information and communication technology (ICT) in recent decades for educational purposes has increased. The role of ICT in education supports the visualization of ideas that can facilitate the learning system, understand the material, and allow positive interactions between teachers and students. The spread of network technology has caused the practice of e-learning to develop significantly [1].

Students as the object of e-learning learning will determine the success or failure of learning. The abilities and competencies obtained by students can measure The success of e-learning. Students are required to know technology, be able to use computers, and be able to access the internet. E-learning has two types of methods: the synchronous method and the asynchronous method. Second, the application of this e-learning method requires students or lecturers to access the internet [2].

The concept of e-learning is often complained by students and lecturers as a new burden in education. Lecturers must make the content as attractive as possible and then upload it to the Learning Management System (LMS). Students can then access the material in the LMS and immediately carry out existing assignments. Lecturers are always pressed for time to create content, and students are pressed for time to complete stacked

assignments. The pile of tasks coupled with students who often postpone work and underestimate e-learning learning also causes fatigue.

Workload increases when someone is doing activities using the user interface [3]. The workload is an essential factor in activities, so measuring workload is very important. The workload definition can be interpreted in several ways: the ability or workers associated with the work to be carried out [4]. The workload consists of two types, namely physical and mental [5]. Excessive physical and/or mental workload can cause distraction due to improper work posture.

Measurement of the mental workload of workers can do using a variety of methods, both subjective and objective. However, objective measurements are rarely used because they are expensive and are not comparable to inaccurate results. Therefore, another alternative has been developed by measuring and using subjective methods. The workload measurement method that is popularly used is the NASA-TLX (NASA Task Load Index) method. Sandra G. Hart developed this method (of the Aerospace Human Factors Research Division, NASA Ames Research Center, Moffett Field, California) and Lowell E. Staveland (from San Jose State University) in 1988 [6], [7]. Initially, NASA-TLX consists of two parts: the total workload divide into six subjective subjects represented on a single page, serving as one part of the mental questionnaire requests, physical requests, temporal requests, performance, effort, and level of support [6]. There is a description for each of these subscales that subjects should read before ranking. They are graded for each task within a 100-point range with a 5-point step. These ratings are then aggregated into the duty load index. Each description provides an overview to help respondents answer more accurately [8].

The application of the NASA-TLX method for measuring or analyzing workloads is found in several research results. Some of which were found in research [5], [9]–[14]. Measurement of workload using the NASA-TLX method carried out using a questionnaire that collects data on workload requirements on mental worker activities. The use of a questionnaire regarding the measurement of workload is found in [11], [15]–[17].

One of the symptoms of health problems that arise from overwork is suffering. Fatigue is a significant problem that needs to be appropriately addressed because it can cause various problems such as decreased productivity, health capacity, and the body's ability to survive. It causes work accidents—fatigue directly from work stress, environmental conflicts, and work capacity [18]. Fatigue with the weakening of the workforce in doing work or activities will increase errors in doing work [19]. The instrument used in this study to measure students was the Swedish Occupational Fatigue Index (SOFI) questionnaire. The Swedish Occupational Fatigue Index contains 23 questions about lack of energy, five questions about physical activity, four questions about physical discomfort, four questions about lack of motivation, and five questions about drowsiness [20].

This study aims to determine the mental workload experienced by students while participating in online learning during the Pandemic. Mental workload is defined as evaluating the increase in a person's capacity when performing certain mental activities [4]. The problem of suffering from work mental load when taking online lectures will then be used as study material in this study. NASA TLX, followed by measuring the SOFI method, is used as a cognitive ergonomics testing tool. Cognitive ergonomics research on asynchronous and synchronous e-learning is expected to be a preliminary study to design and streamline e-learning.

2. RESEARCH METHODS

Respondents involved in this research were students who took online lectures. Students have different backgrounds and majors from the Telkom Purwokerto Institute of Technology. The total population of students who take e-learning is 2790 students. The sampling method in this study was the purposive random sampling method. Sampling was done randomly for students.

$$n = \frac{N}{1+Ne^2} \quad (1)$$

Based on the calculation of Slovin, there is a minimum number as a sample of e-learning students, namely 97. As for the adequacy of data, 200 data is determined. Students who then filled out this questionnaire were students from the S1 Industrial Engineering study program, S1 Software Engineering, and S1 DKV from semester one to semester six.

The data technique used a questionnaire survey method to respondents, namely students. How to plant a questionnaire is done online? Students can fill in the Google form that has been filled in and can be filled in according to the relevant conditions. The object of this research is

http://dx.doi.org/10.30656/jsmi.v5i1.2789

the Telkom Purwokerto Institute of Technology in the Telkom Education Area in April-November 2020.

The method used in studying the data in this study is to use primary data sources. Primary data sources are obtained directly from the data sources obtained. Primary data used in the form of the results of filling out questionnaires by students of Telkom Institute of Technology Purwokerto.

Table 1. The mental load indicator

Indicator	Rating	Description
Mental Demand (MD)	Low, High	How much Mental activity is required when taking online learning.
Physical Demand (PD)	Low, High	How much physical activity is required when taking online learning
Temporal Demand (TD)	Low, High	How much Time Pressure fulfilling the assignments is required when taking online learning
Own Performance (OP)	Low, High	How big is the Success Level in fulfilling the required assignments when taking online learning
Frustration level (FR)	Low, High	How much effort did you put in physically and mentally in fulfilling the required tasks while taking online learning
Effort (EF)	Low, High	How much Pressure Do You Feel To Feeling Unsafe, Discontinued, Offended, or Disturbed to fulfil the required assignments while taking online learning

The NASA-TLX scale [4] is the most popular subjective technique [6], and the scale has been used in a wide variety of domains [21], [22]. NASA-TLX consists of six subscales: mental demand, physical demand, temporal demand, performance, effort, and frustration level [6]. A common simplification to the original NASA-TLX procedure calculates an unweighted global score, often referred to as the raw TLX [22], [23]. The original NASA-TLX was developed for post-task application; however, to increase the sensitivity and diagnosticity, studies have applied the rating scales in scenario breaks [24] or simultaneously with task performance [25]. The mental workload indicator to be measured on the NASA-TLX is shown in Table 1.

Six dimensions used in NASA-TLX to assess mental workload are mental demand, physical demand, temporal demand, effort, and frustration. Each scale has a score from 0 to 100. A weighting procedure was used to combine the six individual scale ratings into a final score. This procedure requires a pairwise comparison between the two dimensions before assessing the workload. Pairwise comparisons require the respondent to select a more relevant dimension to the workload in all pairs of these six dimensions. The number of dimensions is selected as the more relevant weights to the scale dimensions for the assigned task for that respondent. Workload scores from 0 to 100 are obtained for each dimension score by multiplying the weight by the dimension scale score (rating), adding up all dimensions, and dividing by the total number of paired comparisons [26].

1. Mental Demand (MD) vs Physical Demand (PD)
2. Mental Demand (MD) vs Temporal Demand (TD)
3. Mental Demand (MD) vs Own Performance (OP)
4. Mental Demand (MD) vs Effort (EF)
5. Mental Demand (MD) vs Frustration (FR)
6. Physical Demand (PD) vs Temporal Demand (TD)
7. Physical Demand (PD) vs Own Performance (OP)
8. Physical Demand (PD) vs Effort (EF)
9. Physical Demand (PD) vs Frustration (FR)
10. Temporal Demand (TD) vs Own Performance (OP)
11. Temporal Demand (TD) vs Effort (EF)
12. Temporal Demand (TD) vs Frustration (FR)
13. Own Performance (OP) vs Effort (EF)
14. Own Performance (OP) vs Frustration (FR)
15. Effort (EF) vs Frustration (FR)

The first step to calculate the final score for NASA TLX is to calculate the total value of each aspect of mental load from the multiplication of the rating by weight. Then the total value of the mental load aspects is added up to get the WWL

value. The final score is obtained from the WWL (weighted workload) score divided by 15. The value 15 is obtained from the combination of the six pairs of mental load aspects. Workload classification based on NASA-TLX Score 0 – 20: very low; 21 - 40: low; 41 – 60: moderate; 61 – 80: high and 81 – 100: very high

$$WWL = MD + PD + TD + PO + FR + EF \quad (2)$$

$$NASA - TLX\ Score = \frac{WWL}{15} \quad (3)$$

Table 2. The dimension of SOFI

No.	Dimension	Indicator
1	Lack of energy	Overworked
		Worn out
		Exhausted
		Spent
		Drained
2	Physical Exertion	Sweaty
		Breathing heavily
		Palpitations
		Warm
		Out of Breath
3	Physical Discomfort	Tense muscles
		Stiff joints
		Numbness
		Hurting
		Aching
4	Lack of Motivation	Uninterested
		Passive
		Listless
		Indifferent
		Lack of Concern
5	Sleepiness	Sleepy
		Falling Asleep
		Drowsy
		Yawning
		Lazy

The next step is to use the Swedish Occupancy Fatigue Inventory (SOFI) Questionnaire. This questionnaire was used to measure occupational damage from a subjective side [18]. The SOFI questionnaire consists of 5 dimensions: lack of energy, physical energy, physical discomfort, lack of motivation, and drowsiness (Table 2). Of the five dimensions, there are 25 question indicators, with a scale from 0 - 6. A value of 0 indicates that the question is not felt at all. Meanwhile, the value of 6 shows that the respondent feels the question for each point that each dimension has.

3. RESULTS AND DISCUSSION

The results of the questionnaire that have been obtained, then data preprocessing is carried out to ensure that the data used is protected from being noisy and incomplete. A validity test was conducted to ensure the validity of the questionnaire. The data validity test was conducted on 30 respondents using SPSS software version 23. Testing the data validity is seen by comparing the results of the calculated R_{value} with the r_{table} value. The processing results show that the questionnaire is declared valid because the calculated R_{value} is more than the r_{table} value.

The next test is the reliability test used to determine the reliability of a questionnaire to show that respondents provide consistent answers. Testing is carried out with the assistance of SPSS software version 23. The questionnaire is said to be reliable based on the cronbach alpha coefficient. Test reliability with cronbach's alpha if less than 0.6 is said to be not good. If more than 0.7 is accepted, if more than 0.8, it is good [20]. The results of the reliability test with cronbach's alpha 0.63 so can be accepted.

The uniformity test was carried out to determine whether the data obtained were uniform and did not exceed the control limits and lower control limits. Data is uniform if it comes from the same system and is between the two control limits. Meanwhile, the data is non-uniform if it comes from different causes systems and outside the control limits. If the data uniformity is not uniform, the data is discarded. The results of the data uniformity test using SPSS showed that the research data used were uniform. It is shown on the control chart, where the data used does not exceed the control limit (Fig.1).

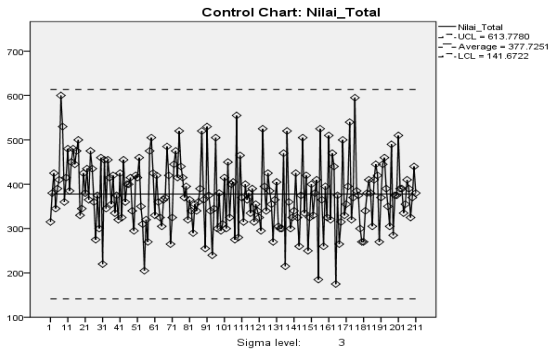

Fig. 1. Control chart of uniformity chart

http://dx.doi.org/10.30656/jsmi.v5i1.2789

After knowing the data used are uniform, the next step is the data sufficiency test. A data sufficiency test is needed to ensure that what has been collected and presented in the weighing report is sufficiently objective. Ideally, measurements should be carried out in large numbers, even up to an infinite number, so that the measurement data is suitable for use.

This data collection technique requires respondents to be asked several research-related questions. The questionnaire is in the form of questions related to research indicators on the mental load of students while taking online lectures using an ordinal scale of 0 – 100. Descriptive analysis is a technique in statistics used to describe research data in general. The descriptive statistical analysis aims to make it easier to explain the distribution of data. This analysis describes the characteristics of the respondents in the form of differences in age, gender, and work level.

Furthermore, it will explain the distribution of respondents' answers to the questionnaire regarding each research variable [20]. Respondents were asked to provide ratings with a range of 0-100 on six indicators of mental workload. The assessment given is subjective depending on the individual's perception of mental workload.

Table 3. Measurement of mental workload on all respondents

Indicator	WWL Score
MD	179.75
PD	153.28
TD	171.52
OP	200.49
FR	202.18
EF	267.29
Total WWL Score	1,174.51
Avg. WWL Score	78.30

Table 3 presents the results of mental load measurements for all respondents, and it can be seen that the NASA-TLX measurement score is 78.30. This score is included in the high category, so it can be concluded that students experience a high mental workload. The indicator that gives the highest portion is the effort of 267.29. This indicator is related to the efforts made by students in participating in online learning. This value shows students feel depressed during online learning, so they feel insecure, hopeless, and disturbed. The second highest order is the frustration indicator, with a score of 202.18. This value shows that the efforts made both physically and mentally are not too burdensome for students. The third place is occupied by own performance.

This indicator explains the success and satisfaction of students with the implementation of online lectures. The following sequence is mental demands, with a score of 179.75. It shows the mental activities that students do during online learning. The average student feels the mental demands they face. Temporal demands have a WWL score of 171.52. It explains the time demands that students feel in taking online lectures. Students feel burdened by the time spent during online lectures. In the sixth place, the indicator with the lowest portion is physical demand, with a WWL value of 153.28. This indicator shows the physical pressure felt by students in taking online lectures. This value implies that students tend to feel a bit of physical pressure, given that online learning places a lot of emphasis on mental effort.

The total average overall of the NASA TLX calculations is 78.30. Based on the weighting of the NASA TLX indicator, the number 78.30 is included in the high category. The SOFI questionnaire is a questionnaire used to determine the level of fatigue of the respondents. Table 4 shows the average measurement of 5 dimensions of SOFI (lack of energy, lack of motivation, physical discomfort, physical exertion, and sleepiness).

The fatigue felt by students when participating in online learning is in the medium category, seen from the average score of 1.26. The highest value is lack of energy of 1.79 (moderate). Lack of energy describes the energy reduction when attending online lectures. Next is the sleepiness dimension, with a value of 1.49 (moderate). In this study, most respondents had regular sleeping hours, but it was inversely proportional to the measurement results [5], [9], [11], [14]. Several factors cause this, including less conducive class schedules, unattractive course materials, or boring lecturers' delivery [16].

Table 4. Result of SOFI measurement

Dimension	Score
Physical Exertion	1.15
Lack of Energy	1.79
Physical Discomfort	0.68
Lack of motivation	1.17
Sleepiness	1.49
Average	1.26

The next dimension is the lack of motivation of 1.17 (moderate). The decrease in high enough motivation in students can be caused by the high level of sleepiness felt by students. The Physical Exertion dimension has a value of 1.15. Even though it is carried out online, online lectures still require physical activity and require physical exertion in its implementation. The last dimension is Physical Discomfort, with a value of 0.68. The slight physical discomfort for students is due to activities that are not only static but also dynamic [18], [27].

After obtaining NASA – TLX data and SOFI data, the next step is to determine whether there is a relationship between mental load and fatigue. Tests carried out to analyze the relationship using the ANOVA test. In the ANOVA test using the hypothesis:

H_0 : There is a relationship between the workload of e-learning lectures and the level of fatigue in e-learning users

H_1 : There is no relationship between the workload of e-learning lectures and the level of fatigue in e-learning

From testing the relationship between workload and student fatigue levels that have been carried out, it was found that F_{count} 0.593 < F_{table} 3.94, it was decided that H_0 was accepted (Fig. 2). The results of this study indicate that mental workload can affect the effectiveness of e-learning. Mental workload has a significantly higher value in e-learning than in face-to-face learning [27]. The challenge in e-learning can be felt in real terms is the unavailability of an appropriate curriculum in a sudden situation. The availability of inadequate facilities and infra-structure such as technology and internet networks and human resources' readiness. The current conditions require lecturers to be more adaptive and innovative. With more innovative learning, it is hoped that students will no longer feel physically burdened.

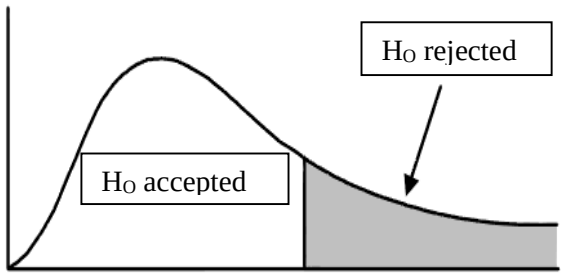

Fig. 2. Anova test acceptance area

4. CONCLUSION

The physical and psychological abilities possessed by each individual are different so that the limits of the workload that can be accepted also vary. Measurement of workload in online learning aims to see the limits of students' abilities to achieve learning objectives. In this study, students' workload at the Telkom Purwokerto Institute of Technology was carried out. Identification of the mental workload of students is made using the NASA TLX method. Calculations from NASA TLX were carried out by using questionnaires to student respondents. Questionnaires are obtained from 200 respondents. The indicators in the NASA TLX indicate six indicators which are then multiplied by 15 rating factors. The results of the weighting calculation get if the effort value is the highest value, which is equal to 267.29. It shows that to take e-learning lectures, students need more effort than when taking face-to-face lectures. In addition, students experience fatigue while participating in online learning. It can be seen from the average SOFI measurement, which is only 1.26 (0-6).

Analysis of the relationship between workload and the level of fatigue of students participating in e-learning was carried out using ANOVA testing. From the test, it was found that F_{count} 0.593 < F_{table} 3.94, it can be concluded that the workload received by students in participating in e-learning lectures is directly proportional to the level of fatigue during e-learning lectures. Future research plans are to add variables related to mental workload. This variable is used as a measure. The standard benchmark is an increase in student achievement in taking e-learning courses. With this benchmark, it is hoped that it can support e-learning in the future.

ACKNOWLEDGMENT

The author would like to thank you for the program of activities sponsored and funded by the Ministry of Research and Technology of Higher Education-Directorate General of Research Strengthening and Development-Research Grant Beginners (PDP) in 2020.

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