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Comparative Analysis of Mental Workload in Industrial Engineering Laboratory Assistants Using the NASA-TLX Method

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A B S T R A C T

The education system at Telkom University Surabaya (TEL-U SBY) is not only in the form of theory but also practicum material, one of which is like the activities in the Industrial Engineering Stdui Program at Telkom University Surabaya. In this Study Program has a laboratory unit as a means of practicum activities, which includes 5 laboratories. The practicum activities involve the role of active students who are responsible as laboratory assistants in the implementation of practicum. This makes them have two roles that can lead to the potential for increased mental workload (MW). So, in this study, a comparative measurement of the mental workload of laboratory assistants was carried out to help identify the level of workload experienced, as well as increase efficiency and productivity. The method used as an approach in measuring the mental workload of laboratory assistants is through the NASA-TLX method. The results obtained from this study, it is known that the Engineering Management laboratory has the highest mean score of 65.42 and the second highest is the Optimization and System Modeling laboratory of 60.56. The most dominant indicators as the cause of the mental workload of laboratory assistants are the effort and temporal demand indicators. Recommendations for improvement include task and time management, work appreciation, and improving adequate practicum facilities, for the comfort and satisfaction of laboratory assistant members.

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1. INTRODUCTION

In the current digital and information technology era, the education industry is undergoing a massive transformation in teaching methods, accessibility, and learning experience (Dewi, 2022). One example is Telkom University Surabaya (TEL-U SBY), a leading private university in Surabaya that offers education under the Telkom Education Foundation. TEL-U SBY carries an education system that not only focuses on theory but also provides practicum material to develop students' motor competencies. In this context, laboratory assistants play a role as students who are selected through selection to assist lecturers in guiding practitioners during practicum

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activities (Kusnadi & Santoso, 2016). Telkom University Surabaya, especially in the Industrial Engineering Study Program, has the most 5 laboratories that provide facilities for practicum activities. 5 laboratories include, Lab. Optimization & System Modeling, Lab. Logistics & Supply Chain Engineering, Lab. Manufacturing System, Lab. Engineering Management, and Lab. Ergonomics & Innovation Design.

As a member of the laboratory assistants, not only has the responsibility as a student activist but also as a supervisor of practitioners. In fact, when someone has a double job, it is not only due to the amount of work that must be completed, but also to the level of attention required so that this is what increases their workload (Wulanyani, 2013). The burden of a double job is not only related to the number of tasks, but also to the level of attention that must be given, which can increase stress and workload (Wulanyani, 2013). Although double jobs provide opportunities for experience and career opportunities, they also carry the risk of stress and increased workload (Inspigo, n.d.). Workload can be divided into two categories, namely physical and mental workload (Okitasari & Pujotomo, 2016). In laboratory assistant jobs, mental workload tends to be a greater concern because it involves multiple tasks, namely as an active student and an assistant performing cognitive tasks. Therefore, measuring mental workload is important to ensure the well-being, safety and professional development of laboratory assistants.

One method used as an approach in measuring mental workload is using the National Aeronautics and Space Administration Task Load Index (NASA-TLX) method. This method has a high level of sensitivity and involves six main indicators namely Mental Demand (MD), Physical Demand (PD), Temporal Demand (TD), Performance (OP), effort (EF), and Frustration Level (FR). The six indicators aim to analyze and address the high level of mental workload experienced by Industrial Engineering laboratory assistants at TEL-U SBY. The level of sensitivity, comprehensiveness, validity, reliability, and subjective assessment that NASA-TLX possesses provides an effective way to analyze mental workload and enables performance evaluation and comparison. Therefore, this study aims to analyze the comparison of mental workload experienced by laboratory assistants of Industrial Engineering at TEL-U SBY using the NASA-TLX method. This is an effort to reduce high levels of mental workload, as well as consider subjective criteria in improving the welfare and productivity of laboratory assistants.

2. LITERATURE REVIEW

Ergonomics

Ergonomics is the science of optimal design of work and work environment by considering the comfort, safety, and health of workers. The integration of disciplines such as engineering, mathematics, statistics, anatomy, physiology, psychology, and sociology helps improve working conditions, prevent injuries, and increase productivity (Lestari, 2019). Ergonomics in the enterprise involves optimizing work systems, job designs, and work environments according to the psychological and sociological needs of workers. Problems that arise, such as low productivity, work incidents, poor work quality, work barriers, high absenteeism, worker turnover, and excessive overtime, need to be addressed immediately to maintain the achievement of the company's vision. An important principle of ergonomics is to ensure workers' workload is always within their capacity (Iridiastadi et al., 2014).

Workload

The workload is divided into physical and mental, both of which have a significant impact on productivity. An imbalance between worker capacity and job demands can lead to a decrease in productivity (Okitasari & Pujotomo, 2016). Workload arises from the disparity between individual abilities and job demands, which can lead to feelings of boredom or excessive fatigue (Widyanti & Johnson, 2010). Factors influencing workload include external factors (tasks, work organization, work environment) and internal factors (somatic and psychological elements) (Koesomowidjojo, 2017).

Mental Workload

The mismatch between job requirements and workforce capabilities can result in mental workload, especially in information management. Mental workload analysis is important to understand the extent to which job requirements match worker capabilities, as well as to optimize training systems and programs (Wulanyani, 2013). Evaluation of mental workload in ergonomics is done by quantitatively measuring the level of workload, as non-optimal mental workload conditions have the potential to cause errors, increased task time, and decreased performance (Wulanyani, 2013). Mental workload is related to the level of attention in cognitive tasks, and this is also relevant in learning activities in higher education (Wulanyani, 2013). Students, during their studies in higher education, face a variety of activities with potential mental and physical workload (Lestari, 2019).

NASA-TLX

NASA-TLX (National Aeronautics and Space Administration Task Load Index) was developed by Sandra G. Hart from NASA-Ames Research Center and Lowell E. Staveland from San Jose State University in 1981. This method aims to measure subjectivity through 6 subscales, such as mental demand (MD), physical demand (PD), temporal demand (TD), effort (EF), frustration level (FR), and performance (OP).

Table 1. Mental workload indicators

No	Indicator Weighting		
1	Mental demand	(or)	Physical demand
2	Mental demand	(or)	Temporal demand
3	Mental demand	(or)	Effort
4	Mental demand	(or)	Frustration level
5	Mental demand	(or)	Performance
6	Physical demand	(or)	Temporal demand
7	Physical demand	(or)	Effort
8	Physical demand	(or)	Frustration level
9	Physical demand	(or)	Performance
10	Temporal demnad	(or)	Effort
11	Temporal demand	(or)	Frustration level
12	Temporal demand	(or)	Performance
13	Effort	(or)	Frustration level
14	Effort	(or)	Performance
15	Frustration level	(or)	Performance

To measure mental workload with the NASA-TLX method, Hart & Staveland (1988) recommend the following steps (Hart & Staveland, 1988): (1) Weighting: at the weighting stage, respondents are expected to choose one of the two dimensions that are considered dominant in affecting the occurrence of mental workload mental workload. The questionnaire contains 15 pairwise comparisons. Table 1 is a questionnaire table for retrieval of weight values. (2) Rating: at the rating stage respondents are expected to be able to provide an assessment of the six dimensions of mental workload. The rating given is subjective and according to the level of mental workload felt by the respondent. The rating sheet will be shown in Figure 1.

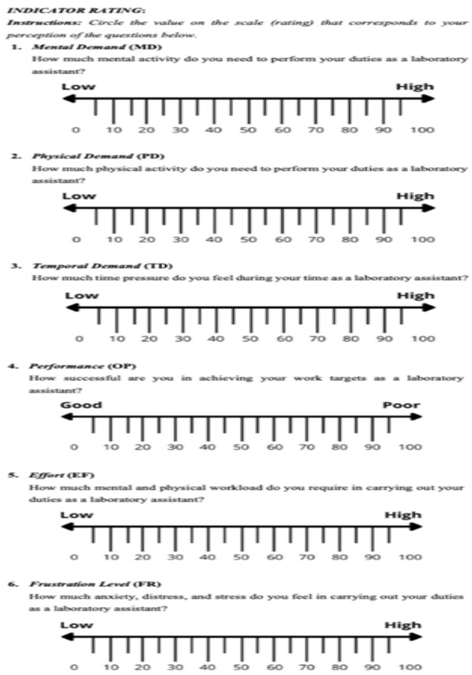


Figure 1. Rating sheet

Hart & Staveland (1988) state that the data from rating is needed to calculate the mean weighted workload (Hart & Staveland, 1988).

Calculating the Product

The product is obtained by multiplying the weight and rating of six mental workload indicators, namely mental demand, physical demand, temporal demand, effort, frustration level and performance.

Product = work weight x rating

Calculating Weighted Workload (WWL)

Weighted Workload (WWL) is obtained from the sum of the six product values.

$$WWL = \Sigma \text{ Products}$$

Calculating the Average WWL

The Average Weighted Workload (WWL) is calculated by dividing the total WWL by the number of pairwise comparisons of the six

NASA-TLX indicators, each of which is worth 15.

Score = (Σ Products)/15

The results obtained can be written on the Weighted Workload (WWL) Worksheet.

Score Value Interpretation

Hart & Staveland (1988) explained in the NASA-TLX theory, the workload score obtained can be interpreted as follows (Hart & Staveland, 1988): (1) Score 0-9 states low workload (low), (2) Score 10-29 states medium workload (medium), (3) score 30-49 states a somewhat high workload (somewhat high), (4) Score 50-79 states high workload (high), (5) Score 80-100 states that the workload is (very high). In summary, although research using the NASA-TLX method for workload assessment already exists, there is a gap in the literature regarding comparative analysis of mental workload among various industrial engineering laboratories and identification of customized solutions. This suggests that further empirical investigation is needed to delve deeper into this aspect. By examining and comparing the mental workload experienced by laboratory assistants across different industrial engineering laboratories, researchers can gain valuable insights into the specific challenges and factors faced by laboratory assistants in various contexts. Moreover, this comparative analysis can pave the way for the development of targeted interventions and strategies according to the needs of each laboratory environment. Ultimately, empirical investigations can contribute significantly to improving the well-being and productivity of laboratory assistants in industrial engineering department.

3. RESEARCH METHOD

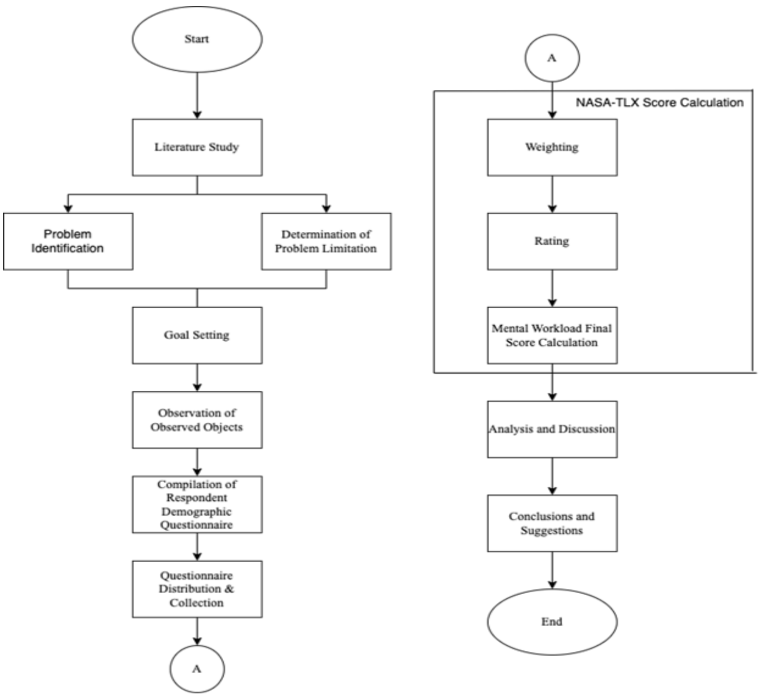


Figure 2. Research flowchart

This research examines the Comparative Analysis of Mental Workload in Industrial Engineering Laboratory Assistants Using the NASA-TLX Method, to compare mental workload classifications and provide recommendations for improvement. This method was developed based on the need to measure subjective aspects consisting of nine sub-scale factors, including task difficulty, time pressure, type of activity, physical effort, mental effort, performance, frustration, stress, and fatigue (Terranova, 2014). The systematics of the research that has been compiled can be seen in the Figure 4.

Preliminary Stage

Literature Study

This method is also used in knowing the object of research directly and finding problems through discussions with supervisors, as well as industrial engineering laboratory assistants Telkom University Surabaya (TEL-U SBY) as a step to analyze the problems that will be focused on this research topic. Then identify problems and determine problem boundaries.

Goal Setting

Based on the background description and problem formulation that has been described. This stage aims to provide a clear framework, so that the data collection that has been determined in the study can be processed properly and correctly (Fauzi, 2017).

Data Collection Stage

Observation of Object of Observation

The initial stage of data collection is to observe the object of observation on the laboratory assistant of industrial engineering TEL-U SBY. This observation aims to gain an understanding of the factors that cause the mental workload of laboratory assistants such as stress levels, work environment, or other factors (Salmi, 2020). Observation of the object of observation can be done directly by Focus Group Discussion (FGD) and distributing questionnaires to related objects (Pradhana & Suliantoro, 2018).

Compilation of Respondent Demographic Questionnaire

The questionnaire method is a set of questionnaires related to all the information needed (Salmi, 2020). Information collection to obtain data can be done directly (face-to-face) or indirectly (mail) (Soewardi & Putra, 2018). The list of questionnaire questions is part of the process of developing an instrument for measuring the mental workload experienced by SBY TEL-U industrial engineering laboratory assistants using the NASA-TLX method. The following are the steps of the preparation of the respondent demographic questionnaire. (1) Determining Respondent Identity: Determining the identity of the respondent is a way to find out who can help in filling out the research questionnaire. The identity of the respondent is the assistant laboratory of industrial engineering TEL-U SBY. The data needed is as follows (Putri et. al., 2018): (a) Name, (b) Gender (M/F), (c) Age, (d) Force, (e) Laboratory Assistant, (f) Laboratory Assistant Position, (g) Total practitioners taught (include Study Program and batch). (2) Identifying Workload Dimensions: The dimensions or factors of the workload to be measured must be identified. NASA-TLX usually takes into account aspects such as mental demand, physical demand, temporal demand, effort level, frustration level, and performance (Nofri et al., 2017). Identifying these workload dimensions is important for formulating appropriate questions in the questionnaire (Afifah et. al., 2021). (3) Formulating Questions: Once the dimensions of workload are established, specific questions that reflect each of these dimensions should be formulated (Soewardi & Putra, 2018). These questions should be clear, concrete, and easy to understand, by the respondents. Questions can refer to the level of mental fatigue, level of task difficulty, level of physical strain, and other aspects relevant to the workload to be measured (Hart & Staveland, 1988). (4) Creating a Rating Scale. The NASA-TLX questionnaire uses a Likert rating scale that is used to measure the level of workload on each dimension (Putrisani et al., 2023). The rating scale ranges from 0 to 100, with higher numbers indicating higher levels of workload. Each question in the questionnaire is given a corresponding rating scale to allow respondents to give their responses (Hart & Staveland, 1988).

Questionnaire Distribution and Collection

The researchers sought to collect data directly by actively engaging in the research project and using Focus Group Discussion (FGD) methods to obtain data as well as through distributing questionnaires (Prabaswari et al., 2019). (5) FGD, this activity is carried out to obtain research data by asking questions directly to the respondents concerned. In this research, FGD was conducted to laboratory assistants of industrial engineering TEL-U SBY regarding what they feel related to lecture activities as students and laboratory assistants experienced so far, knowing what factors cause the level of mental workload experienced, and how the efforts they make during lecture activities take place simultaneously. Questionnaires, this research was conducted by distributing NASA-TLX questionnaires to industrial engineering laboratory assistants of TEL-U SBY based on indicators that have been determined when preparing the questionnaire. The distribution was carried out to 36 members of all TEL-U SBY industrial engineering laboratory assistants for the 2023/2024 period because these students were active students who were selected to undergo two roles of responsibility in lecture activities and practicum teaching activities.

Data Processing Stage

This research was conducted to measure the mental workload of laboratory assistants by comparing five industrial engineering laboratories of TEL-U SBY. The measurement of mental workload is done by NASA-TLX method on six sub-scale dimensions.

NASA-TLX Score Calculation

In this study, respondents are expected to provide an assessment of the level of mental workload they feel when carrying out lecture activities and teaching practicum through filling out the NASA-TLX questionnaire. After obtaining data results from distributing questionnaires to related respondents, the next stage is to process the data using the NASA-TLX method. The following are the stages used for processing mental workload data with the NASA-TLX method: (1) Weighting: At this stage, weighting was carried out using a pairwise comparison questionnaire of fifteen pairwise comparisons. Respondents were instructed to choose one of two pairwise comparisons involving six indicators while performing work. The weight of each mental workload indicator was calculated based on the sum of the tally counts of the indicators considered most dominant in causing mental workload. (2) Rating: In this step, respondents were asked to rate the six NASA-TLX indicators using a 0-100 rating scale. Furthermore, the level of mental workload felt by the respondents during the task was subjectively converted using a rating scale. (3) Mental Workload Final Score Calculation: After knowing the weight and rating of each indicator, the next step is to calculate the average Weighted Workload (WWL). This is important because it aims to calculate the final score of the NASA-TLX method data processing. The final NASA-TLX mental workload score is obtained from the results of multiplying the weight and rating and then summing and dividing by 15 (number of pairwise comparisons). Then the score value is interpreted, whether the perceived workload is high or low (Nur I et al., 2020).

Analysis and Conclusion Stage

This stage is an important part of the research process. Where the data obtained is arranged systematically to be analyzed to produce research findings and conclusions to achieve research objectives (Putrisani et al., 2023). The following are the things done at the analysis and conclusion stage.

Analysis and Discussion

After obtaining the final score through the NASA-TLX method, the next step involves interpreting the score. The results of subjective workload measurements will then be analyzed descriptively, both through descriptions and graphs, as well as calculations to obtain the average subjective workload of industrial engineering laboratory assistants at TEL-U SBY. Furthermore, the results of statistical tests are used in assessing whether the mental workload experienced by students selected as laboratory assistants, in carrying out these two roles of responsibility, can be considered high or low. The analysis also includes an explanation related to which factors from the NASA-TLX dimensions cause mental workload in laboratory assistants. This information is important because it will be the basis for providing recommendations to minimize the excessive mental workload experienced by these laboratory assistants. This entire analysis aims to provide a more comprehensive view of the mental workload experience of students as laboratory assistants in the Industrial Engineering environment of TEL-U SBY.

Conclusions and Suggestions

In the conclusion section will contain points that answer the formulation of the problem that has been determined (Rahmawanti, 2023). And the suggestions given are things related to providing input to the industrial engineering laboratory assistant of TEL-U SBY in implementing recommendations to minimize excessive mental workload on industrial engineering laboratory assistants.

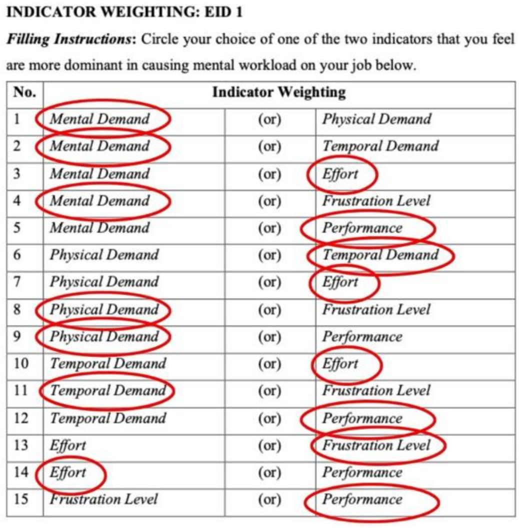
4. RESULT AND DISCUSSION

In the results and discussion section, the findings of the research conducted related to the measurement of the mental workload of

Industrial Engineering laboratory assistants at Telkom University Surabaya (TEL-U SBY) will be described. This research focuses on comparing mental workload classifications in an effort to avoid a high percentage of excessive mental workload, and the analysis is made with the National Aeronautics and Space Administration Task Load Index (NASA-TLX) method. This data collection was conducted directly through Focus Group Discussion (FGD) on 36 members of industrial engineering laboratory assistant TEL-U SBY period 2023/2024. This data collection aims to determine the gender, age, generation, laboratory assistant respondents, and gain an understanding of the factors that cause the mental workload of laboratory assistants such as stress levels, work environment, or other factors. Further data collection was carried out by distributing NASA-TLX questionnaires related to the measurement of the mental workload of SBY TEL-U industrial engineering laboratory assistants for the 2023/2024 period, based on predetermined indicators. The questionnaire was distributed to 10 members of the lab assistant. Ergonomics and Innovation Design, 10 members of the lab assistant. Manufacturing System, 8 members of the lab assistant. Engineering Management, 5 members of the lab assistant. Logistics and Supply Chain Engineering, and 3 members of the lab assistant. Optimization and System Modeling. The questionnaire distribution was carried out from the 2nd to the 4th week of October 2023, in the Ergonomics Laboratory room (KTT1.32) Telkom University Surabaya (left side) and through a zoom meeting (right side).

Indicator Weighting

At the weighting stage, respondents were asked to choose one of two pairwise comparisons totaling 15 pairwise comparisons involving six NASA-TLX indicators One example of filling out the indicator weighting questionnaire for respondent EID 1, can be seen in Figure 3.


INDICATOR WEIGHTING: EID 1

Filling Instructions: Circle your choice of one of the two indicators that you feel are more dominant in causing mental workload on your job below.

No.	Indicator Weighting		
1	*Mental Demand*	(or)	*Physical Demand*
2	*Mental Demand*	(or)	*Temporal Demand*
3	*Mental Demand*	(or)	*Effort*
4	*Mental Demand*	(or)	*Frustration Level*
5	*Mental Demand*	(or)	*Performance*
6	*Physical Demand*	(or)	*Temporal Demand*
7	*Physical Demand*	(or)	*Effort*
8	*Physical Demand*	(or)	*Frustration Level*
9	*Physical Demand*	(or)	*Performance*
10	*Temporal Demand*	(or)	*Effort*
11	*Temporal Demand*	(or)	*Frustration Level*
12	*Temporal Demand*	(or)	*Performance*
13	*Effort*	(or)	*Frustration Level*
14	*Effort*	(or)	*Performance*
15	*Frustration Level*	(or)	*Performance*

Figure 3. Example of questionnaire filling

Indicator Weighting Based on Figure 3 above, the options chosen by respondents are indicators that are considered the most dominant in influencing the mental workload felt when carrying out work as a laboratory assistant. For example, the mental demand indicator (MD) obtained 3 weighting results, and so on to the frustration level (FR) indicator. Furthermore, the results of the weighting of each respondent's indicators are recapitulated into one indicator weighting table which can be seen in Table 2. Based on Table 2, it can be seen that respondents EID 4, EID 5, and MS 8 have the lowest total rating value of 150, while respondent EM 3 has the highest total rating of 440. The overall total rating and average for each indicator are as follows, the mental demand (MD) indicator has an overall total rating of 2260 with an average of 62.8, the physical demand (PD) indicator has an overall total rating of 2030 with an average of 56.4, the temporal demand (TD) indicator has an overall total rating of 2270 with an average of 63.1, the performance indicator (OP) has an overall total rating of 915 with an average of 25.4, the effort indicator (EF) has an overall total rating of 2320 with an average of 64.4, and the frustration level indicator (FR) has an overall total rating of 2005 with an average of 55.7.

Table 2. NASA-TLX indicator rating results

Indicator Rating Results NASA-TLX

Laboratory	MD	PD	TD	OP	EF	FR	Total
***Ergonomics and Innovation Design* (EID)**							
EID 1	65	70	60	30	80	40	345
EID 2	90	90	70	10	80	60	400
EID 3	90	100	90	20	80	40	420
EID 4	40	20	20	20	30	20	150
EID 5	30	10	30	50	30	0	150
EID 6	70	60	50	20	70	50	320
EID 7	60	55	70	5	50	60	300
EID 8	20	50	55	5	45	45	220
EID 9	60	45	70	10	60	60	305
EID 10	75	60	70	10	90	65	370
***Manufacturing System* (MS)**							
MS 1	70	60	40	30	60	70	330
MS 2	80	20	50	20	40	90	300
MS 3	80	70	80	30	50	70	380
MS 4	50	50	50	80	80	30	340
MS 5	50	60	80	40	60	50	340
MS 6	40	90	90	20	70	60	370
MS 7	60	60	70	30	70	70	360
MS 8	20	50	10	20	20	30	150
MS 9	50	60	40	20	60	20	250
MS 10	65	70	80	15	75	55	360
***Engineering Management* (EM)**							
EM 1	70	30	70	30	80	60	340
EM 2	80	40	70	30	80	90	390
EM 3	90	40	90	40	80	100	440
EM 4	80	90	70	20	70	60	390
EM 5	70	10	70	50	60	60	320
EM 6	70	70	80	10	80	40	350
EM 7	60	70	80	20	50	50	330
EM 8	70	80	60	30	80	50	370
***Logistics & Supply Chain Engineering* (LSCE)**							
LSCE 1	70	60	50	30	70	60	340
LSCE 2	70	60	70	30	50	60	340
LSCE 3	70	50	70	20	60	70	340
LSCE 4	80	60	60	20	70	70	360
LSCE 5	35	85	55	30	70	80	355
***Optimization and System Modeling* (OSM)**							
OSM 1	80	30	60	20	70	60	320
OSM 2	50	60	60	30	70	50	320
OSM 3	50	45	80	20	80	60	335
Average	**62,8**	**56,4**	**63,1**	**25,4**	**64,4**	**55,7**	**327,8**
Total	**2260**	**2030**	**2270**	**915**	**2320**	**2005**	**11800**

Data Processing

Data processing is obtained from the results of collecting NASA-TLX questionnaire data on industrial engineering laboratory assistants. An example of a weighted workload (WWL) worksheet can be seen in Table 3.

Table 3. Example of WWL worksheet

Item	Remark		
Name	EID 1		
Gender	Male		
Age	22 years old		
Force	2020		
Laboratory Assistants :	*Ergonomics and Innovation Design*		
(Offline)			
MW Indicator	*Weight*	*Rating*	*Product*
MD	3	65	195
PD	2	70	140
TD	2	60	120
OP	3	30	90
EF	4	80	320
FR	1	40	40
Total			**905**
***Weight* (Total)**			**15**
Mean WWL *Score*			60

Based on Table 3, there is a column of respondent demographics, a column of six NASA-TLX indicators, a column of weights, ratings, a column of products resulting from multiplying weights and ratings, a column of total products, and a column of mean WWL score resulting from dividing total and weight (total). The following is an example of calculating the NASA-TLX mental workload score (Rahmawanti, 2023):

Calculating Product

Product = work weight x rating

MD = 3 x 65 = 195

PD = 2 x 70 = 140

TD = 2 x 60 = 120

OP = 3 x 30 = 90

EF = 4 x 80 = 320

FR = 1 x 40 = 40

Calculating Weighted workload (WWL)

WWL = Σ Products

= 195 + 140 + 120 + 90 + 320 + 40 = 905

Calculating WWL Average

$$\text{Score} = \frac{\sum \text{Product}}{15} = \frac{905}{15} = 60$$

Calculation of WWL Value

The results of the WWL calculation can be seen in the following tables in each industrial engineering laboratory.

Table 4. Summary of WWL calculation results

Lab. Name	MD	PD	TD	OP	EF	FR	Total
EID	1270	1285	1985	765	2080	100	7485
MS	825	1540	2030	855	1880	1280	8410
EM	1600	580	1410	500	2140	1620	7850
LSCE	695	280	900	630	1160	200	3865
OSM	570	75	640	170	800	470	2725

From the overall results of the weighted workload (WWL) value, it can be seen that the Manufacturing System laboratory has the highest WWL value of 8410, while the Optimization and System Modeling (OSM) laboratory has the lowest total WWL of 2725.

Calculation of Average Weighted workload

At this stage, the results obtained from weighted workload (WWL) are used to calculate the average mental workload score obtained from dividing the total product by weight (total) which amounts to 15. The results of the average weighted workload (WWL) can be seen in the following tables in each industrial engineering laboratory.

Table 5. Average WWL results

Lab. Name	Total (Product)	Mean Score (Product / 15)
EID	7485	49,90
MS	8410	56,07
EM	7850	65,42
LSCE	3865	51,53
OSM	2725	60,56

From the overall average WWL results, it can be seen that the Ergonomics and Innovation Design laboratory has the lowest mean score of 49.90, while the Engineering Management laboratory has the highest total mean score of 65.42.

Comparative Analysis of Mental Workload Indicators

Table 6. Recapitulation of NASA-TLX score comparison results

Lab. Name	Indicator						Total	*Mean (Score)*	Interpretation
	MD	PD	TD	OP	EF	FR			
EID	1270	1285	1985	765	2080	100	7485	49,90	*Somewhat High*
MS	825	1540	2030	855	1880	1280	8410	56,07	*High*
EM	1600	580	1410	500	2140	1620	7850	65,42	*High*
LSCE	695	280	900	630	1160	200	3865	51,53	*High*
OSM	570	75	640	170	800	470	2725	60,56	*High*

Based on Table 6, the indicator column shows that the highest mental demand (MD) of 1600 is obtained by the Engineering Management (EM) laboratory, because the EM laboratory assistant feels that the practitioners who are taught are difficult to manage and do not understand the delivery of material, internal miscommunication in the EM aslab, and work beyond their abilities so as to cause various aspects of cognitive, emotional, and social interactions that are quite complex. The highest physical demand (PD) indicator of 1540 was felt by the Manufacturing System (MS) laboratory because manufacturing practicum activities require a lot of energy, as well as work tools that are continuously used so that they require routine maintenance, besides that the distance from the assistant's house to the campus also affects physical demands. The highest temporal demand (TD) indicator of 2030 was felt by the MS lab because of the short time demands in preparing the practicum timeline and time competing with other activities.

The highest performance indicator (OP) of 855 was also felt by the MS lab, because it had not yet achieved maximum performance satisfaction and experienced obstacles, as well as the delivery of complex material such as Computer Numerical Control (CNC) practicum so that the MS lab required extra performance while working. The highest effort indicator (EF) of 2140 was obtained by the Engineering Management (EM) laboratory because it conducted a software training program as an additional activity, and the EM lab also felt that the lecturer did not provide a specific explanation of the material, mentally the lab was more burdened in learning the material presented previously. Therefore, aslab EM needs to maintain performance with greater effort. The last indicator, namely frustration level (FR) with the highest score of 1620, was felt by the EM laboratory. EM assistants experience increased frustration due to the lack of responsiveness of practitioners during learning, as well as sudden assistance schedules that make the assistants have to provide more time for assistance, even outside working hours. The mean score column and interpretation are depicted in Figure 4.

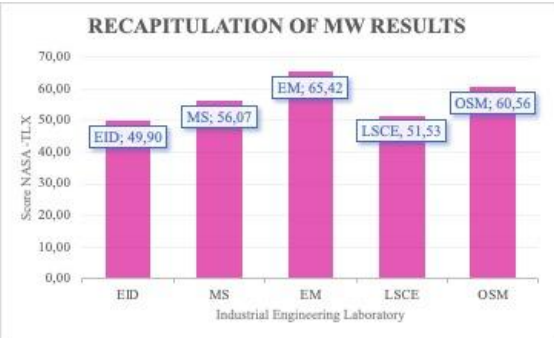


Figure 4. Recapitulation of mean (score) results

Based on the results of laboratory recapitulation in the field of Industrial Engineering, the Engineering Management (EM) laboratory has the highest mean score of 65.42, indicating a high level of workload. The effort indicator (EF) in this laboratory also has a fairly high score, indicating the complexity of tasks involving management, training, and communication. Frustration level (FR) and mental demand (MD) also reached high scores, indicating a lack of communication and unfavorable environmental conditions. The Optimization and System Modeling (OSM) laboratory has the second highest mean score of 60.56. The effort (EF) and temporal demand (TD) indicators achieved high scores, indicating the pressure in assessing practitioners and the density of activities. Although the performance indicator (OP) achieved a high score, the assistant was not satisfied with the results achieved. The Manufacturing System (MS) laboratory ranked third with a mean score of 56.07. Temporal demand (TD) is the highest indicator, indicating the demands in preparing the practicum timeline. The effort indicator (EF) also reached a high score, indicating the effort required in checking the details of the practicum assignment.

The Logistics and Supply Chain Engineering (LSCE) laboratory ranked fourth with a mean score of 51.53. The effort indicator (EF) achieved the highest score, indicating the effort required in reviewing and adjusting the material. Temporal demand (TD) also reached a high score, indicating the pressure of making modules and running two practicums at once. The Ergonomics and Innovation Design (EID) laboratory has a rather high mean score of 49.90. The effort (EF) and temporal demand (TD) indicators achieved the highest scores, indicating work demands outside of laboratory activities that require extra effort and high flexibility. The performance indicator (OP) achieved a lower score, indicating a lack of satisfaction with the preparation of teaching materials. In general, the results show that laboratory assistants in all areas require high effort and time to complete their tasks, some laboratory assistants experience different levels of frustration and dissatisfaction. The results of the comparative analysis of mental workload in industrial engineering laboratory assistants with causal factors, and the proposed improvement recommendations, laboratory assistants can optimize performance, improve laboratory conditions, and increase overall operational efficiency.

Suggestions that can be given to future researchers, it is expected that the object of research is expanded not only the scope of laboratory assistants of the Industrial Engineering study program, but all laboratory assistants of study programs at TEL-U SBY. Also, not only measuring and analyzing mental workload, but also physical workload using the Cardiovascular Load (CVL) method or other relevant methods.

5. CONCLUSION

Based on the results of data processing and analysis of the Final Project research by measuring the mental workload of Industrial Engineering Laboratory Assistants at Telkom University Surabaya for the 2023/2024 period, it can be concluded as follows: (1) The results of the interpretation of the mental workload score experienced by industrial engineering laboratory assistants, show a classification with a high workload category in the Engineering Management (EM), Optimization and System Modeling (OSM), Manufacturing System (MS), and Logistics and Supply Chain Engineering (LSCE) laboratories from a score scale of 50 to 79. While in the Ergonomics and Innovation Design (EID) laboratory, with a somewhat high workload category from a score scale of 30 to 49. The order of mental workload indicators that are dominantly felt by laboratory assistants is the indicator of effort (EF), temporal demand (TD), mental demand (MD), physical demand (PD), performance (OP), and frustration level (FR). (2) The results of the calculation of the average Weighted workload (WWL) show that, there is a comparison of the classification of mental workload experienced by industrial engineering laboratory assistants. The Engineering Management (EM) laboratory has the highest mean score of 65.42, while the Ergonomics and Innovation Design (EID) laboratory has the lowest mean score of 49.90. The method used as a comparison of mental workload indicators from these laboratories is the National Aeronautics and Space Administration Task Load Index (NASA-TLX) method, in order to evaluate the performance of industrial engineering laboratories. The Engineering Management (EM) laboratory has the highest value in the effort indicator (EF), while the Ergonomics and Innovation Design (EID) laboratory has the lowest value in the frustration level (FR) indicator. The results of this comparative analysis can be used to identify areas of improvement with the aim of reducing mental workload and improving welfare and productivity in carrying out duties as laboratory assistants.

Recommendations that can be given to mitigate the mental workload of industrial engineering laboratory assistants, from the overall results of the six NASA-TLX indicators include improving structured task and time management strategies, reducing and balancing additional workload, and giving appreciation to laboratory assistants as a form of motivation in the form of fees and certificates. In addition, it is necessary to increase the availability of adequate laboratory facilities, especially for those who do not have a private laboratory in order to increase job satisfaction. Support in preparing teaching materials also needs to be improved to reduce physical and mental workload, and increase work comfort for laboratory assistants.

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