The root cause of ability and inability to assemble and install components using written manual with or without diagrams among non-native English speakers: Root cause analysis

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Abstract. Documentation errors and human errors are often claimed to be the contributory factors for aircraft maintenance mistakes. This paper highlights the preliminary results of the third phase of a four-phased research on communication media that are utilised in an aircraft maintenance organisation. The second phase has looked into the probability of success and failure in completing a task by 60 subjects while in this third phase, the same subjects have been interviewed immediately after completing the task by using Root Cause Analysis (RCA) method. It is discovered that the root cause of their inability to finish the task while using only written manual is the absence of diagrams. However, haste is identified to be the root cause for the incompletion of the task when both manual and diagram are given to the participants. It is observed that those who are able to complete the task is due to their reference to both manual and diagram, simultaneously.

1. Introduction

Communication plays the pivotal role in conveying the critical information in any aircraft maintenance organisation. Many previously conducted researches suggest that human mistakes and documentation errors have contributed to the aircraft delays, incidents and accidents [1-11]. Human errors are related to poor language proficiency, inexperience, lack of knowledge, misunderstood or unused information and time constraint. In the meantime, documentation errors can be attributed to incorrect, insufficient or unavailable information. Written media such as manuals, emails and software have a higher risk in conveying critical information in an aircraft maintenance organisation compared to verbal media [12]. Misunderstanding transpires from written information that has been transferred between departments could affect the aircraft’s safety and efficiency. This is supported by the argument that the richness of information through written media is lacking, thus it creates ambiguity [13, 14]. The vagueness of the message in written media can have serious effects when maintenance personnel perform their task by referring to these task cards and maintenance manuals that contain unclear, incorrect and insufficient information. With this notion in mind, this study looks into the root cause of the ability and inability to assemble and install the components by referring to manual with or without diagram.
2. Methodology
As mentioned, the main purpose of this study is to investigate the root cause of the ability and inability of assembling and installing components with or without diagram among non-native English speakers through the approach of Root Cause Analysis (RCA). RCA is widely used in investigating incidents and accidents, not only in aviation industries but also in other critical safety management systems such as railway, healthcare, road transport, military strategy, constructions and many more [15]. There are six different methods of RCA and interview is one of the ways to obtain valuable insights from those involved in the incidents by reflection of their personal experiences during the event. In this study, the interviews are conducted immediately after the subjects have completed two experimental situational tasks using Lego mini aircraft. The Experiment Condition 1 (EC1) involves assembling and installing components by referring to a written manual only whereas Experiment Condition 2 (EC2) involves the similar type of tasks but by referring to both the written manual and diagrams. The overall research methodology flowchart is illustrated in Figure 1.

![Figure 1: Research flowchart](image)

This research utilised qualitative research methodology where 15 interview questions are designed and self-administered. These questions cover both contents of the written manual given to the subjects and their experiences in assembling and installing the Lego mini aircraft within 15 minutes. Based on the results, they can provide some insights on the root causes of aircraft maintenance errors, whether documentation errors or human mistakes. The recruitment of the subjects for this study involved 60 semester six Bachelor degree students, aged 18 and above at the Universiti Kuala Lumpur - Malaysian Institute of Aviation Technology (UniKL-MIAT). The students are chosen as they have been exposed to theoretical and practical knowledge of aircraft engineering technology in mechanical and avionics, and their learning at the technical university has exposed them in assembling and installing aircraft components in reference to aircraft maintenance manuals during their hands-on lessons in workshops and hangar. Since these experiments are taken to simulate the real maintenance activities: maintaining, repairing and overhauling aircraft, which involve referring to the written manuals and diagrams, their selection as the subjects in this study seems highly practical.

The interview answers are coded and classified into themes, which are later inserted into Statistical Package of Social Science (SPSS). The interview data is first regarded as continuous data, which later is converted into categorical data as the answers are categorised thematically, and the correlation coefficient test has been conducted. To obtain adequate estimate of the group average exposure for observation, the minimum sample size of 15 to 25 is acceptable.

3. Results and Discussion
The experiments are divided into two categories: EC1 and EC2. Several variables are of interest in this study and they are the subjects’ O level/GCSE English language results, time constraint, experiment condition, experience in assembly and install of components, and their feedback on the causes of their
success and failure in the experiments. Relationship of these variables with the experiment outcomes is identified to find out whether or not they have significant association with the outcomes.

Total number of semester six students at the institution during the study was 159: 119 mechanical engineering students and 40 avionics students. All seven classes have been approached and invited to take part in the experiment. However, only 60 students agreed to volunteer while the others declined for reasons of the clash of class schedule and/or lack of interest. Table 1 tabulates the breakdown of the subjects for both EC1 and EC2 experiments with regards to their gender, age, language proficiency and program of the study, with total number of subjects, \( n = 60 \).

| Characteristics      | EC1          | EC2          |
|----------------------|--------------|--------------|
| Gender               |              |              |
|   Male               | 27 (90%)     | 27 (90%)     |
|   Female             | 3 (10%)      | 3 (10%)      |
| Age                  |              |              |
|   18 – 24            | 28 (93%)     | 27 (90%)     |
|   25 – 34            | 2 (7%)       | 3 (10%)      |
| Second Language Speaker | 20 (100%) | 20 (100%) |
| Degree Program       |              |              |
|   Mechanical         | 27 (90%)     | 25 (83%)     |
|   Avionics           | 3 (10%)      | 5 (17%)      |

The outcomes of the experiments have revealed 100% incompletion of assembly and installation of components by written manual while 40% by written manual and diagrams. The results presented in Figure 2 shows all 30 subjects in EC1 were unable to complete the experiment within the given time. This includes 16 (36%) subjects, who obtained above 85% (exceptional) in the English proficiency O level/GCSE result. On contrary, as for EC2 shown in Figure 3, it is unexpected to see seven (50%) out of 14 subjects who failed in EC2 are those who obtained an exceptional result of English Language proficiency. Only five (31%) of the subjects who have above 85% (exceptional) in English proficiency O level/GCSE result was able to successfully complete the task. However, it is discovered that there is no relationship between the students’ O Level English language results with the success and failure of both experiments with \( p = 0.982 \). This shows that one’s level of English language is not the root cause one’s ability or inability to complete a task that involves assembly and installation of components.

Figure 2: Distribution of O Level English language results in EC1

![Figure 2](image)

Figure 3: Distribution of O Level English language results in EC2

![Figure 3](image)

Figure 4 indicates time spent by those who were unable to complete the experiment. All 30 (100%) subjects in EC1 took the full 15 minutes for the tasks while, for subjects in EC2, five (36%) of them spent eight minutes, three (21%) took 15 minutes, three (21%) took 10 minutes, three (21%) spent 15 minutes and one (7%) took seven minutes. Figure 5, on the other hand, shows those who were able to
complete, which are all in EC2 experiments. Only five (31%) spent a full 15 minutes, four (25%) spent eight minutes, three (21%) spent 10 minutes, another two (14%) subjects spent nine minutes and only one (7%) took seven minutes, respectively, in completing the tasks. The findings highlight that there is a significant relationship between the duration of time given in both experiments with the results of those experiments with $p = 0.002$.

Both the experiment condition and duration have significant associations with the outcomes of the experiment. Figure 5 has indicated that all 30 (100%) EC1 subjects spent 15 minutes in completing the task whereas the majority of EC2 subjects (30%) spent eight minutes assembling the Lego. For EC2, eight subjects spent 15 minutes, six subjects spent 10 minutes, four subjects spent nine minutes and three subjects spent seven minutes of the given time. The results also show that there is a significant relationship between the two variables with $p = 0.000$ as shown in Figure 6. Furthermore, in Figure 7, it is found that that 13 (43%) subjects who were unable to complete EC1 had previous experience in Lego building whereas 17 (57%) did not have any prior experience with Lego. As for those who were unsuccessful in EC2, it is discovered that 11 (79%) did have experience in Lego building while only three (21%) did not. However, there is no significant relationship between having experience in Lego building with the results of both experiments with $p = 0.386$.

![Figure 4: Time spent to complete EC1 and EC2 (unsuccessful outcome)](image)

![Figure 5: Time spent in EC2 (successful outcome)](image)

![Figure 6: Experiment condition and experiment duration](image)

![Figure 7: Experience in building Lego (unsuccessful outcome)](image)

After the completion of each experiment, the subjects are interviewed to find out reasons for their success or failure in the given task as indicated in Figure 8. With EC1, it has been discovered that all 30 (100%) subjects were unable to complete the task given within fifteen minutes. 22 (73%) of them mentioned that their inability to understand the written manual contributed to their failure while 11 (37%) said that they were not familiar with the components of Lego, five (17%) claimed that there was no diagram provided to help them and another two (7%) thought that the time given was not enough.
The results concur with previous findings that “information not understandable” and “information not available” and “written documents” have contributed to maintenance errors [1-3].

On the other hand, in EC2, only 16 subjects managed to complete the experiment successfully in 15 minutes. The reasons for their success, as illustrated in Figure 9, are because five (31%) of the subjects referred to both written manual and diagram simultaneously while another six (38%) claimed that they referred to the diagram without reading the manual. Another five (31%) claimed that they referred the diagram more than they read the manual. Although the outcome is successful, the act of referring to diagram alone would be considered as “routine violation” in aircraft maintenance industry [11]. This is because it is clearly stated in the experiment instruction that the subjects have to refer to both manual and diagrams during the experiment. It is observed that the participants did not put in an extra effort in reading the written manual as they pushed it aside and focused on the diagram, aiming to complete the experiment before the fifteen minutes ended.

Figure 8: Reasons given for inability to complete EC1 and EC2

Figure 9: Abilities to complete EC2

4. Conclusion
The interview findings present a new discovery in searching for the root cause of success and failure among non-native English speakers in carrying out aircraft maintenance tasks, which include assembly and installation of components by referring to written manual with or without the presence of diagram. The first phase of this study suggests that written media namely software, E-mail and documentation pose a higher risk of misunderstanding critical information. This is due to incorrect, insufficient and unavailable information of which, if not detected or corrected, will result in maintenance errors and aircraft delay. The second and third phases of the study unveil detailed account on the potentially high
risk of misunderstanding of written manual based on two conditions: documentation errors and human errors. Though the Lego written instructions that simulate Aircraft Maintenance Manual are validated and verified as complete, correct and clear manual, the results show that they are not comprehended by all 30 participants in EC1. The language ability of the subjects nor their inexperience did not have any significant relationship with the outcome in both experimental conditions. It is concluded that the root cause of their failure in EC1 is unavailability of information (i.e. the absence of diagram). This led to the misunderstanding of vocabulary, sentence structure, unfamiliarity of components, wrong selection of components and time constraints. They took more time to repeatedly read the instructions in order to understand the meaning of the critical information to complete the task. Meanwhile, the root cause of the failures in completing EC2 is observed as haste. The consequences of being hasty, wanting to finish the task quickly, led the participants to ignore reading the written instructions. Instead, they spent more time digesting information from only the diagrams. This creates a chain reaction where they skipped a step that led to wrong assembly of the components. From analysing the contributory factors of failure, the findings suggest that the success factor among non-native English speakers in completing a maintenance task is to have comprehensive critical information in the documents and to simultaneously refer to both manual and diagram while performing maintenance tasks. This is vital such that each step of the instructions is carefully read and the labeled diagram is accurately followed in order to select the right components and place them in the precise position with the condition that the personnel is not in a state of a hurry to complete the task. It is also important to always read the instructions again and inspecting the product to confirm the completion of work done.

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