Training Performance Measurement with Schema and Mental Rotation Test

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Abstract. Training was a crucial technique for skill development and basic foundation of learning in manufacturing while the traditional way of training selection was to trial-and-error those training methods to see its performance which take cost and time. The purpose of present study was to preliminary investigate the training performance measurement using cognitive schema and mental rotation test in camera assembly tasks with basic training and physical training condition for production staffs. 180 novice participants performed in this study. Results revealed that both cognitive schema and mental rotation test could significantly distinguish training performance between basic and physical training condition in the same direction. The implication of this study was on the measurement that could shorten the time and reduce cost in estimating the performance of each training method which could be used to support decision making. Discussion was provided.

Keywords: Training, Assembly, Mental Rotation, Schema, Cognition, Skill acquisition.

1. Introduction

In the manufacturing, training was a crucial technique for skill development and basic foundation of learning in organizations [1-2], since it could improve productivity, increase job performance, and reduce the cost of manufacturing process [3]. Besides, it also helped employee acquire new knowledge, skills, attitude and behaviors [4]. Hence, training becomes a mandatory process for newly hired employees/workers in various position in many organizations [5].

There were various methods of training available to use such as on-the-job-training, lecture-based training, and simulation training etc., while the traditional way of selection was to trial-and-error those training methods to see its performance that fit most with the context of working condition with acceptable training cost. This would take a period of time (weeks or months) to reveal the training performance in term of productivity [6], cost and time [7], and the quantity of defect and its effectiveness [3]. Thus, it would be worth to investigate the possible training performance measurement to overcome the traditional trial-and-error method to save cost and time for support manager decision making.

The schema script measurement was found to correlate with memory performance [8], and its accuracy could measure learning performance of people (e.g. Kraiger, et al. [9]). It is a framework developed in people’s mind to solve a problem, organize knowledge, and support future instruction and learning [10]. The schema script usually represents people’s understanding of the orderly step of any processes such as the working process [11]. Accordingly, schema test might be able to distinguish training performance since it relates to human learning.
The mental rotation ability was also found to be an essential ability that helps people integrate and understand cognition process from multiple viewpoints after training [12]. It is the ability to make the mental image of a given 2D or 3D object turning in space [13], and it could be improved by training [14]. This ability would be important in skill-based training such as in the manufacturing tasks. The mental rotation test (MRT) could be used as the paper-and-pencil based test which people must match 20 rotated figures to target figures [15]. Therefore, MRT might be able to distinguish skill-based training performance, especially in manufacturing.

Both schema test and MRT were used for measuring training performance in several areas. For example, Moreau & Clerc [16] investigated gender differences in sports training performance by measuring MRT. Stransky & Wilcox [12] revealed that students who received surgical training program had higher MRT scores which lead to better skill acquisition. Arthur [17] also used schema test to compare its similarity between trainees and expert. He found that it had a correlation with skill acquisition and could be used for prediction of skill retention and transfer. To the best of our knowledge, there was no research apply schema test and MRT in manufacturing context of training performance measurement.

Thus, in this study, we separated training conditions into basic training and physical training in camera assembly tasks. According to Bloom taxonomy [18], the basic training was focusing on remembering and understanding by lecture-based with the demonstration, while the physical training was recognized as a higher level of training than those basic ones by focusing on remembering, understanding, and applying. The physical training used VDO training together with real simulation on real work. Both training condition had 1 hours in each condition. According to literature reviews [1, 18, 19], the physical training condition would provide better skill acquisition than basic training condition.

The purpose of present study was to preliminary investigate the training performance measurement using schema and mental rotation test in camera assembly tasks with basic training and physical training condition for production staffs. The results of this study could support for the future study of using schema and MRT to estimate the effect size from each training condition to support decision making in training selection if schema test and MRT could clearly differentiate the work skill acquisition from the different level of training condition.

2. Methods

2.1. Participants
Participants performed in this experiment were 180 Thai associate degree students trainee (Male = 51, Female = 129) and with no previous experiences in assembly tasks. The age ranged between 17 and 22 years (M = 19.16, SD = 1.39).

2.2. Stimulus Materials

2.2.1. Basic training materials. The hard copies with color printed of work instructions were provided to each participant to read follow the process while listening to supervisors during explain and demonstrate each step of assembly tasks at the workstation. This work instruction had specified caution-point into work instruction.

2.2.2. Physical training materials. The VDO clip of the procedure was provided with a standard with high resolutions (1920x1080) and the average length of 66 seconds. All steps in VDO were demonstrated with captions and had no sound. Participants could stop and replay any time. Moreover, the real parts (5 sets) for assembly were provided for participants to practice follow the VDO instruction at the workstation.
2.3. **Apparatus**
The places for training were conducted at the digital camera assembly workstation. It was equipped with all tools used for assembly such as Tweezers, Bit-torque, Screw-driver, Electric-driver, Jig, Fixture etc. The computer systems were installed at all stations of use for the training with monitor screen 16-inch. Finally, closed-circuit television (CCTV) and stopwatch were used for recording time in this study.

2.4. **Task**
The camera assembly process was divided into 9 different tasks according to the standard procedure of assembly line to achieve its task’s standard time (66 seconds) from parts to finish goods. All participants were randomly assigned to only one task, between-subject condition.

2.5. **Measurement**

2.5.1. **Schema test**. This test consisted of 6 assembly steps of their own task to ask participants to reorder these steps into the correct work order. The score was only counted if the order was correct and continue sequenced with the max score of 6.

2.5.2. **Mental Rotation Test**. Participants were given the 3 color-printed pictures in the different visual angle of work-in-process regarding their task to answer whether it was right or wrong in assembly task at their station within 5 minutes. The correct answer would be scored as 2 points for each picture. The scores would range from 0 to 6.

2.6. **Procedure**
Prior to beginning the experiment, participants were given a brief explanation of objective of the research and sign a consent form. See Figure 1. Participants were then randomly assigned one training condition (Basic training or Physical training) to acquired assembly skill. The experiments were designed to random assignment with both training conditions and tasks. In each training condition, participants were received the one-hour training. During the training period, all the process and equipment were observed and controlled by the certificated training skilled supervisor from Technical Training Center of the company case study. After training, participants were asked to complete schema test and MRT, respectively. Then, they were thanked and dismissed.

![Figure 1. Overview of study design and random assignment](image-url)
3. Results

The descriptive statistics of basic and physical training condition on schema and MRT scores were shown in Table 1. A multivariate analysis of variance (One-way MANOVA) was conducted to assess if there were differences between the two training condition (basic training and physical training) on schema and mental rotation test scores.

The results revealed the significant difference between the training condition (Wilk's $\Lambda = .79$, $F(2, 177) = 23.51$, $p = .00$, $\eta^2 = .21$). Examination of the coefficients for the linear combinations distinguishing training methods indicated that schema and mental rotation scores contributed most to distinguish the method training. The analysis of variance (ANOVA) indicated that participants with physical training condition got higher schema test score than those with basic training condition ($F(1, 178) = 35.175$, $p < .05$). In the same direction, participants with physical training condition also got higher MRT score than those with basic training condition ($F(1, 178) = 10.770$, $p < .05$). Games-Howell post hoc tests revealed that, of the schema test with the basic training did seem to be associated with differences in physical training ($p<.01$), also of the mental rotation test with the basic training did seem to be associated with differences in the physical training ($p<.01$) as shown in Figure 2.

Table 1. Means and standard deviations of basic and physical training condition on schema and mental rotation test

| Training Conditions | N  | Schema Test | Mental Rotation Test |
|---------------------|----|-------------|----------------------|
|                     |    | M           | SD                   |
| Basic training      | 90 | 3.34        | 1.49                 |
|                     |    | 3.11        | 1.50                 |
| Physical training   | 90 | 4.07        | 1.47                 |
|                     |    | 4.40        | 1.41                 |

Figure 2. The interaction plot of mean and standard deviation of basic and physical training condition on schema and mental rotation test scores.
4. Discussions and Conclusions
The purpose of present study was to preliminary investigate the training performance measurement using cognitive schema and mental rotation test in camera assembly tasks with basic training and physical training condition. The experiments with 180 participants were conducted. The results test revealed that both MRT and schema test could differentiate the performance of two types of training in the same direction. People who received physical training condition got the significantly higher scores from both schema test and MRT.

The results of this study showed that schema test and MRT could be used to level performance of the training condition instead of conduct full trial-and-error as the traditional method in the manufacturing context. However, future study should investigate the effect size as well as the accuracy of using these two measurements and conduct the real experiment in order to calibrate these measurements and its validity. Since human cognition schema and MRT are both individual assessment level, while some type of manufacturing such as continuous assembly line may require measuring performance as a group-based performance. This would be worth investigating in the further study whether the individual performance measurement remains valid in those group-based contexts of manufacturing.

Finally, the schema and mental rotation test might be another method that could help the manager in making the decision in training condition of manufacturing context. This could shorten the time and cost comparing to conduct trial and error. While the future study may consider investigating its sensitivity of these measurements whether it applies to all types of training.

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