Teaching Engineering Process Management to Graduate Students in an Engineering Management Program

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Dr Sangaappillai Sivaloganathan – Siva is a Srilankan by birth and a citizen of the United Kingdom. His experience in Sri-lanka started with an year’s post-graduate apprenticeship in the manufacturing shops of the Government Railway and nine years in the Cement Industry. He graduated as a Mechanical Engineer from University of Sri Lanka, and obtained his Masters from the University of Aston and PhD from City University of London, both in the UK. He started his career in the UK as the Senior Research Assistant at the SERC Engineering Design Centre. He joined Brunel University in 1995 where he worked for 18 years before joining United Arab Emirates University in August 2011. During his stay at Brunel he has worked with many British industries. Dr Sivaloganathan is a keen researcher in Design and was the Convenor for the International Engineering Design Conferences in 1998 and 2000. He has been a regular participant of the ASEE annual conference during the past few years. He has published more than 85 papers in reputed journals and conferences.

Dr. Essam K. Zaneldin P.E., United Arab Emirates University

Dr Essam Zaneldin earned his PhD in 2000 from the University of Waterloo in the area of Construction Engineering and Management. Dr Zaneldin is a professional engineer currently working as an associate professor of Construction Engineering and Management at the Department of Civil and Environmental Engineering, United Arab Emirates University. Dr Zaneldin is also the head of the College of Engineering Requirements Unit and the Director of the Master of Engineering Management Program at the United Arab Emirates University. In addition to his experience in the academia, Dr Zaneldin has more than thirteen years of work experience in areas related to design, construction supervision, and project management of mega size projects in North America and the Middle East. He has authored and co-authored several journal and conference publications in topics related to engineering education and course management, design coordination, change management, site layout planning, constructability, claims and disputes, and simulation of design and construction operations.

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Sarah S. Sedra, a telecommunication engineer currently working at Etisalat UAE as mobile access planning engineer. Worked previously for two years as an low voltage electrical engineer in AECOM middle east. Graduated in 2013 from Communication & electronics department in faculty of engineering Cairo university. After working for almost 4 years now I just started the master’s degree in Engineering management at UAE university which is the top University in UAE. This study was done in our first workshop in engineering process management.

Miss khawla Mousa Alrayssi, UAEU

Miss Khawla Alrayssi graduated as a Mechanical Engineer from UAE University in Jun 2010 and started her career in September 2010 at STRATA manufacturing in UAE. After being in the job as manufacturing engineer in aerospace field for 1 year she underwent training in material & process engineering & Non-destruction tests for aircraft parts t in Alenia Aermacchi in Italy for 7 months. On returning she joined the Quality team in STRATA as Non-destructive test engineer and works there for the past 4 years. She has achieved NDT UT /RT Level 3 Certifications and carries the honor to be recognized as the first Emirati female engineer to obtain this important qualification in the aerospace field. She is a student in the Master of Engineering Management program at the UAEU and has interest in Engineering Processes and their Management.

Ms. Riham Mohamed Surkatti Ms, Graduate Student

Ms. Surkatti Riham started her graduate studies and work as research assistant in Chemical Engineering department UAE University in 2010. During her masters studies she gathered enormous amounts of
experience in the areas of wastewater treatment using biological methods. Her research study resulted in 3 published papers in well-known journals and more than 5 conference papers. She completed her work as research assistant in another project from until 2016. The research project was collaboration between chemical and mechanical Engineering departments in the area of the application of the nanotechnology in solar panel coatings. Recently, she started her Ph.D. studies in the chemical engineering in UAE University, UAE.

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Haya Al Nuaimi graduated as a mechanical engineer from UAE University in February 2012. She started her career in June 2012 at Nimr Automotive in UAE (Manufacturer of Soft and armored vehicles, the first armored vehicle manufacturer in UAE). Her first position at Nimr was a production engineer, which she held for 3 years. During this time she handled the production planning and manufacturing of soft skin & armored vehicle variants. Recently, she is assigned to be a project engineer where she manages projects from the concept to completion of products (Customer requirements, concept, designing, ordering parts, build up the vehicle) and make sure the customer requirements are satisfied. She is student in the Master of Engineering Management program at United Arab Emirates University where she studied Engineering Process Management.
Teaching Engineering Process Management to Graduate Students in an Engineering Management Program

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Abstract:
Work systems are combinations of workers, machines and information to perform useful work and, knowledge on how to define specific work systems for their use will greatly enhance engineering managers. Competence in method study and work measurement will greatly assist in carrying out or supervising method planning and work estimation. In order to enthuse students in learning traditional industrial engineering topics in work systems, method study, work measurement and workstation design, a three-stepped methodology was devised. In its first stage, the knowledge was introduced through lectures, assignments, and tutorials. In the second stage, a workshop involving a familiar device was given. This made students to become thorough with the theory. The lectures and workshop gave students sufficient confidence and competence they needed. They applied their knowledge in solving real-world problems in the third stage. This paper describes this methodology and its implementation.

1 Introduction

Graduate programs in Engineering Management enroll students who had undergraduate education in a variety of disciplines such as civil, mechanical, electrical, and architectural engineering and other science disciplines. Knowledge on how to define specific work systems, which are combinations of workers, machines and information, to perform useful work will greatly enhance engineering managers. In particular, competence in method study and work measurement will greatly assist them to carry out or supervise method planning and work estimation and because of this, work system is often included in the curriculum. The Master of Engineering Management program, at United Arab Emirates University enrolls graduates from any science or engineering discipline. The traditional industrial engineering areas such as method study, time measurement, line-balancing, and micro-motion study formed part of the topics in the syllabus for the Engineering Process Management course. Past students found the theoretical instruction too dry. Instruction can be either topic-centered or problem-centered. In topic-centered instruction, components of the task are taught in isolation. To the contrary, in problem-centered instruction, students learn about a subject through the experience of solving an open-ended problem given in the trigger material. In order to enthuse students, an instructional design combining both approaches was devised and implemented where: (a) the theory was taught, (b) a workshop with a hands-on experience (the trigger material) was held, and (c) instructor-designed and/or industry-based projects were carried out, in sequence. This paper describes the instructional design, its implementation, and evaluation in detail. For easy comprehension of the paper, it is worth noting that sections 2 and 3 describe the literature survey and the methodology.
for the design of the delivery, while sections 4 and 5 describe the implementation of the methodology in the delivery.

2 Literature Review

This section identifies and summarizes some relevant literature that was used in devising the methodology. Instruction is the intentional facilitation of learning towards identified learning goals. Instructional Design, on the other hand, is the systematic and reflective process of translating principles of learning and instruction into plans for, instructional materials, activities, information resources, and evaluation [1]. Teaching refers to the learning experiences that are facilitated by a human being. Smith and Ragan [1] identifies three steps in instructional design in the following way:

a. Identifying the Goals through Analysis – This involves consideration of the learning outcomes to be achieved, background of students and the nature of the teaching activity such as lecture, workshop, and lab work.

b. Development of an Instructional Strategy – This is the planning of how the instruction will take place. It is the defining of how the material is presented, what activities the students will experience, and in what sequence they will experience them, in order to achieve the goals.

c. Evaluation – Evaluation is the process of assessing the level of attainment of the students and the effectiveness of the instructional method. This needs the knowledge of (a) the indications showing that the goals have been achieved and (b) the different levels of achievement.

In topic-centered instruction, students learn components in isolation. To the contrary in problem-centered instruction, students learn about a subject through the experience of solving an open-ended problem given in the trigger material. Problem-centered learning has four phases: (a) activation of prior experience, (b) demonstration of skills, (c) application of skills, and (d) integration of these skills into real-world problems [2]. Investigating the instructional design theories, Merrill [2] identified five prescriptive design principles, which state that learning is promoted when:

a. Learners are engaged in solving real-world problems

b. Existing knowledge is activated as a foundation for new knowledge

c. New knowledge is demonstrated to the learner

d. New knowledge is applied by the learner and

e. New knowledge is integrated into the learner’s world.

Reigeluth [3] elaborates on these task-centeredness, activation, demonstration, application, and integration in the following way:

i. With respect to task-centeredness, instruction should use (a) a task-centered instructional strategy and (b) a progression of increasingly complex whole tasks.

ii. With respect to activation, instruction should (a) activate relevant cognitive structures in learners by having them recall, describe, or demonstrate relevant prior knowledge or
experience, (b) have learners share previous experience with each other, and (c) have learners recall or acquire a structure for organizing new knowledge.

iii. With respect to demonstration, instruction should (a) be consistent with the type of component skill: kinds-of, how-to, and what-happens, (b) provide guidance that relates the demonstration to generalities, (c) engage learners in peer-discussion and peer-demonstration, and (d) allow learners to observe the demonstration through media that are appropriate to the content.

iv. With respect to application, instruction should: (a) have the learner apply learning, consistent with the type of component skill, (b) provide intrinsic or corrective feedback, (c) provide coaching, which should be gradually withdrawn to enhance application, and (d) engage learners in peer-collaboration.

v. With respect to integration, instruction should: (a) integrate new knowledge into learners’ cognitive structures by having them reflect on, discuss, or defend new knowledge or skills, (b) engage learners in peer-critique, (c) have learners create, invent, or explore personal ways to use their new knowledge or skill, and (d) have learners publicly demonstrate their new knowledge or skill.

Another approach to instruction design is called the ADDIE model, which consists of five stages: Analyze, Design, Develop, Implement, and Evaluate. It was created by the Center for Educational Technology at Florida State University for the U.S. army in the 70’s, and then quickly adopted by all the U.S. armed forces.

Pedagogy can be defined as the study of the methods and activities of teaching. Schneider [4] refers to a listing of 20 methods (called Khan’s list of methods) and activities, which are reproduced here in Table 1. The designer can choose one or several of these methods when designing the lessons.

<table>
<thead>
<tr>
<th>Table 1: Khan’s List of Methods and Strategies [4]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presentation</td>
</tr>
<tr>
<td>Demonstration</td>
</tr>
<tr>
<td>Tutorials</td>
</tr>
<tr>
<td>Story Telling</td>
</tr>
</tbody>
</table>

With respect to strategies and methods, Westbrook et al [5] identified the following six effective teaching practices, although not all are needed to be simultaneously present:

i. Flexible use of whole-class, group, and pair work where students discuss a shared task
ii. Frequent and relevant use of learning materials beyond the textbook
iii. Open and closed questioning, expanding responses, and encouraging student questioning
iv. Demonstration and explanation, drawn on sound pedagogical content knowledge
v. Use of local languages and code switching
vi. Planning and varying lesson sequences
3 Methodology

This section summarizes the methodology in three steps (Figure 1): 1) lectures covering the theoretical parts, 2) workshop giving hands-on experience, and 3) project application on a real-world problem. The three steps are explained in the following subsections.

3.1 Lectures Covering the Theoretical Parts

In this part of the instruction, students learn the components and their fundamental concepts. This may include the definitions, processes, modeling methods, analysis strategies and other similar materials that form the body of knowledge. The main task of the instructor is to input the necessary knowledge content. Selective use of the practices identified by Westbrook et al [5] can be very useful at this stage, in order to have the constant attention of students. This essentially is a topic-centered approach to instruction.

![Figure 1: Methodology Steps](image)

3.2 Workshop Giving Hands-on Experience

Merriam Webster dictionary defines workshop as ‘a usually brief intensive educational program for a relatively small group of people that focuses especially on techniques and skills in a particular field’. From this point onwards, problem-oriented instruction is followed. The challenging part of the instructional design is to find a manageable, simple and open-ended problem that spans across all the material covered in the theory. This should be given as the trigger material for students to solve in small groups in the class. A well-developed workshop reinforces the theory taught in step 1 and prepares students to handle real-world projects.

3.3 Project Application on a Real-World Problem

This is the first opportunity for students to apply what they have learnt on a real-world problem and showcase the benefits. They have to learn the method or process of carrying out the task
thoroughly so that they would not miss any task element. Any such missing task element is catastrophic, as it will give a false estimate of the total time for the task.

4. Implementation

This section describes the use of the above methodology. As the model shows, it started with a series of lectures followed by a workshop in the assembling of a three pin-plug. The workshop part is described in detail here. Two of the projects that followed are described here to demonstrate the relevance.

4.1 Teaching of the Theoretical Part

The relevant learning outcomes from this part of the syllabus are the abilities to: (a) carry out a systematic method study to facilitate productivity improvement and (b) carry out a work element analysis of a given task and estimate cycle time using a predetermined time system. Theoretical part started with the introduction of work systems where the concepts of normal time, cycle time and standard time were introduced. The concepts of personal, fatigue and delay allowances and productivity were also introduced. These were followed by instruction of, principles of work, method study and work measurement and, micro-motion study and ‘Therbligs’ as introduced by Frank and Lillian Gilbreth [6]. Predetermined Motion Time Systems were taught at the end. The Maynard Operation Sequence Technique (MOST) is a high-level predetermined motion time system. MOST is in wide use and has several additions. However in this course, students were taught with the basic MOST, which has three activity sequences namely general move, controlled move, and tool use. These were the activity models students used later in the workshop and in the real-world applications. The teaching was further enhanced with tutorials and assessed through quizzes and homework assignments. Most of the six effective teaching practices identified by Westbrook et al [5] in section 2 were used in the teaching of the Engineering Process Management course.

4.2 Workshop with Hands-on-Experience

The workshop was to use the contents studied in the theoretical part in the assembling of a three-pin plug. In order to get the students familiar with the components, each student was given a plug and was asked to dismantle the plug to component level and to reassemble them at least five times so that they are familiar with the components and the process. This pre-workshop task is aimed at ‘activation of prior experience’ and bringing all team members to similar levels of prior knowledge. Each student was asked to produce and submit a list of the work elements, once they are familiar with the components and the process. In order to maintain consistency, the name-list was given to all students as shown in Figure 2.
The workshop was designed to consist the following tasks:

Task 1 (prior to the workshop) - Repeat the process of dismantling and assembling the plug many times (at least 5 times) to get complete familiarity with its 14 parts, their names and the process. Once familiar, write down the steps or process in chronological order for assembling the plug from the constituent piece parts. The students have to submit the list before the workshop class. (Submission item 1)

Task 2 (First task in the Workshop) – Go through the list produced by each of the group members and agree on an improved list. Now produce an outline process flowchart. (Submission items 2 and 3)

Task 3 (Second task in the Workshop) – Assuming that only screw-drivers and the components are available, plan and draw a two hand process flowchart. Figure 5 later shows this flowchart. (Submission item 4)

Task 4 (Third task in the Workshop) – Perform the tasks as described in the two-hand process flowchart several times. Ensure that the chart is a true description of the activities by each hand. Measure the times with a stop watch for each work element and enter them in the two-hand process flowchart. (Submission item 5)
Task 5 (Fourth task in the Workshop) – The work-holding device shown in Figure 3 is given at this stage along with the screwdrivers and components. The task is to produce a two-hand process flowchart and measure and enter the times as in task 4. (Submission item 6)

![Figure 3: Work-Holding Device](image)

Task 6 (Fifth task in the Workshop) – Design of a workstation, using the classification of the use of human body, is introduced in this task assuming that the components are available in appropriate containers. The task is to design the workstation using the low-level motions in Table 2 and take a picture and measurements. (Submission item 7)

**Table 2: Classification of the Use of Human Body**

<table>
<thead>
<tr>
<th>Classification</th>
<th>Defined as</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Finger motion only</td>
</tr>
<tr>
<td>2</td>
<td>Finger and wrist motion only</td>
</tr>
<tr>
<td>3</td>
<td>Finger, wrist and forearm only</td>
</tr>
<tr>
<td>4</td>
<td>Finger, wrist, forearm and upper arm only</td>
</tr>
<tr>
<td>5</td>
<td>Finger, wrist, forearm and upper arm and shoulder motions</td>
</tr>
</tbody>
</table>

Task 7 (Sixth task in the Workshop) – Plan and draw a two-hand process flowchart for the assembling process using the workstation designed in task 6. Measure the times with a stop watch for each work element and enter it in the two-hand process chart. (Submission item 8)

Task 8 (After the Workshop) – Estimate the times for the work elements in the two-hand process chart in Task 7 using the predetermined motion time system MOST. (Submission item 9)
Task 9 (After the Workshop) – Complete the assignment with additional sections on introduction, learning experience and conclusions together with the nine submission items.

4.3 Typical Work by Students

This section presents samples of the outputs produced by the students.

4.3.1 List of Work Elements

Students brought their individual lists and discussed them in the group and agreed on the following 17 work elements as the constituents of the assembling process.

1. Pick up the Plastic base and hold it with the left hand (LH)
2. Pick up the assembled neutral pin and place it on the Plastic base
3. Pick up the live pin and place it on the Plastic base
4. Pick up the assembled live outlet and place it on the Plastic base
5. Pick up the assembled earth pin and place it on the plastic base
6. Fix the fuse to fit in the live outlet and live pin
7. Pick up the cable grip and place it on the plastic base
8. Hold the cable grip with plastic base
9. Pick up the first cable grip screw and insert it to fix it on the cable grip
10. Pick up the second cable grip screw and insert it to fix it on the cable grip
11. Fix the plastic top cover onto the plastic base and flip the plug
12. Pick up the screwdriver
13. Tighten the first cable grip screw
14. Tighten the second cable grip screw
15. Tighten the closing screw
16. Leave the screw driver
17. Pick up the paper and place it on the top of plastic base from the pins side

4.3.2 Outline Process Chart

An outline process chart gives an overall view of a process by recording only the main operations and sequences in proper sequence. The chart shows all parts and their turn to join the main assembly process forming the finished part. Figure 4 summarizes the process.
4.3.3 Two-Hand Flowchart and Times with Screwdriver Only

This chart shows the activities performed by the left and right hands in a sequential order. Figure 5 presents the two-hand flowchart and the times taken, with the use of a screwdriver only. In this chart, the LH is underutilized for holding the base.
4.3.4 Two-Hand Flowchart and the Times with the Fixture

The introduction of the fixture frees both hands to act freely. This reduced the cycle time and made the process easy. Figure 6 shows the two-hand flowchart and the times with the fixture.
4.3.5 Workstation Design

Figure 7 shows the workstation design to assemble the three-pin plug. The location for each element container was chosen to assemble the plug with minimum motion and hence less time. It has been designed with due consideration for the right handed person in this case. The scale used
is in cm and the coordinates (X, Y) for each element are measured from the reference point (0,0) to the center of the element.

Figure 7: Workstation Design

The names of the components of the workstation are shown in Table 3.

Table 3: Workstation Components

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fixture</td>
</tr>
<tr>
<td>2</td>
<td>Fuse</td>
</tr>
<tr>
<td>3</td>
<td>Cable grip screw</td>
</tr>
<tr>
<td>4</td>
<td>Neutral pin</td>
</tr>
<tr>
<td>5</td>
<td>Plastic base</td>
</tr>
<tr>
<td>6</td>
<td>Hummer</td>
</tr>
<tr>
<td>7</td>
<td>Screw driver</td>
</tr>
<tr>
<td>8</td>
<td>Earth pin</td>
</tr>
<tr>
<td>9</td>
<td>Top cover</td>
</tr>
<tr>
<td>10</td>
<td>Live outlet</td>
</tr>
<tr>
<td>11</td>
<td>Live pin</td>
</tr>
<tr>
<td>12</td>
<td>Cable grip</td>
</tr>
<tr>
<td>13</td>
<td>Cover paper</td>
</tr>
</tbody>
</table>
4.3.6 Two-Hand Flowchart and Times with the Fixture in the Workstation

In this process, the time is expected to be minimum because of the workstation design, which ensures minimal motion for the limbs. The chart and the time taken for the processes are illustrated in Figure 8.

### Figure 8: Two-Hand Process Chart when the Fixture is in the Designed Workstation

4.3.7 Time Estimation with MOST

The time was estimated for all work elements using the ‘MOST’ concept. Table 4 shows the activity sequence model and the time estimated for each element. The detailed time estimating for assembling the live outlet and fuse using RH and LH is explained below:
Getting the Object – By using both hands pick up the ‘Live outlet’ from the right hand (RH) side, and ‘Fuse’ from LH side. They are close to the fixture and hence the index for A is 0. B involves no body motion and hence the index is 0. G involves grasping light object using both hands independently and hence the index is 1. The activity sequence component is \(A_0B_0G_1\).

Put or move the object – placing the ‘Live outlet’ and ‘Fuse’ onto ‘Plastic Base’ one by one (RH & LH) respectively involves very small motion and hence the index for A is 0. For B, there is no body motion and hence the index is 0. P for placing the ‘live outlet’ is considered as ‘lay aside/loose fit’ object, and for placing the ‘fuse’ is considered as object with adjustment and light pressure. The indexes for P, therefore are 1 & 3, respectively (for the RH & LH). The activity sequence component is \(A_0B_0P_1 A_0B_0P_3\).

End the sequence – The hand moves free and hence A has a 0 index. The activity sequence component is \(A_0\).

The full activity sequence model \(A_0B_0G_1 A_0B_0P_1 A_0B_0P_2 A_0\) The sum of the indexes is \((0+0+1+0+0+1+0+3+0) = 5\).

Hence the time is \(5 \times 10 = 50\text{ TMUs} = 50 \times 0.036 = 1.8\text{ secs}\)

### Table 4: Process Time Calculation Using MOST

<table>
<thead>
<tr>
<th>Element</th>
<th>Process/ hand</th>
<th>Activity sequence model</th>
<th>Estimated Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic base</td>
<td>Pick up &amp; place/RH</td>
<td>(A_3B_0G_1 A_3B_0P_3 A_3)</td>
<td>4.68 secs</td>
</tr>
<tr>
<td>Earth pin</td>
<td>Pick up &amp; place/RH</td>
<td>(A_3B_0G_1 A_1B_0P_6 A_1)</td>
<td>4.32 secs</td>
</tr>
<tr>
<td>Live pin</td>
<td>Pick up &amp; place/RH</td>
<td>(A_1B_0G_1 2xA_1B_0P_6 A_0)</td>
<td>5.76 secs</td>
</tr>
<tr>
<td>Neutral pin</td>
<td>Pick up &amp; place/LH</td>
<td>(A_1B_0G_1 2xA_1B_0P_6 A_0)</td>
<td>5.76 secs</td>
</tr>
<tr>
<td>Live outlet</td>
<td>Pick up &amp; place/RH</td>
<td>(A_0B_0G_1 A_0B_0P_1 A_0B_0P_3 A_0)</td>
<td>1.8 secs</td>
</tr>
<tr>
<td>Fuse</td>
<td>Pick up &amp; place/LH</td>
<td>(A_0B_0G_1 A_0B_0P_1 A_0B_0P_3 A_0)</td>
<td>1.8 secs</td>
</tr>
<tr>
<td>Cable grip</td>
<td>Pick up &amp; place/RH</td>
<td>(A_0B_0G_1 A_0B_0P_1 A_0)</td>
<td>0.7 secs</td>
</tr>
<tr>
<td>Cable grip</td>
<td>Pick up &amp; place/RH</td>
<td>(A_0B_0G_1 2xA_0B_0P_6 A_3)</td>
<td>5.76 secs</td>
</tr>
<tr>
<td>Plastic cover</td>
<td>Pick up &amp; place/RH</td>
<td>(A_3B_0G_1 A_3B_0P_3 A_0)</td>
<td>3.6 secs</td>
</tr>
<tr>
<td>Three pin plug</td>
<td>Pick up &amp; place/LH</td>
<td>(A_0B_0G_1 A_0B_0P_6 A_3)</td>
<td>3.6 secs</td>
</tr>
<tr>
<td>Screwdriver</td>
<td>Pick up &amp; place/RH</td>
<td>(A_3B_0G_1)</td>
<td>1.44 secs</td>
</tr>
<tr>
<td>Cable grip</td>
<td>Tight/ RH</td>
<td>(A_0B_0P_6 A_0)</td>
<td>2.16 secs</td>
</tr>
<tr>
<td>Closing</td>
<td>Tight/ RH</td>
<td>(A_0B_0P_6A_3)</td>
<td>3.24 secs</td>
</tr>
<tr>
<td>Paper</td>
<td>Pick up &amp; place/RH</td>
<td>(A_3B_0G_1 A_3B_0P_1 A_0)</td>
<td>2.88 secs</td>
</tr>
</tbody>
</table>
The total time to complete the process is 50.1 seconds. The total time to complete the process increases to 53.7 seconds when the inspection of each “earth pin, neutral pin and live pin” is included together with the use of hammer if necessary.

**Table 5: Comparison of Times Taken by Different Methods**

<table>
<thead>
<tr>
<th>Process type</th>
<th>Time (Sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two hand process (task 4)</td>
<td>106.84</td>
</tr>
<tr>
<td>Two hand process+ fixture (task 5)</td>
<td>66.38</td>
</tr>
<tr>
<td>Two hand process+ fixture + design (task 7)</td>
<td>63.78</td>
</tr>
<tr>
<td>Calculated using MOST</td>
<td>50.1</td>
</tr>
<tr>
<td></td>
<td>(53.7)*inspection</td>
</tr>
</tbody>
</table>

Table 5 shows that the use of one hand to hold the base for assembly took the longest time. The use of fixture reduced the time substantially and this is due to the use of both hands. The workstation design has made only marginal savings. This may be due to the lack of experience and familiarity to the work. The use of MOST to estimate time gave a result of 50.1 seconds. With familiarity, the time taken in to complete the element in practice may approach this time.

The reduction in time reinforces the fundamental concept in workstation design for manual repetitive tasks: ‘*Keep both hands free to work and don’t use one hand as the work holding device*’. The fixture was designed by one of the previous groups of students and later another group improved the entry points. It is a very effective piece and saves substantial amount of time. Also it makes the work, as a whole, more easy. This highlights the concept that *properly designed fixtures can reduce cycle time and make the work easier*. The workstation design structured the process and all students sat down in the allocated seat before engaging in the assembling process. This made the work ergonomically simpler. The workshop was designed with continuous refining of the task that highlighted the benefit from each refinement. On the whole the exercise and the analysis gave the students a comprehensive insight into work design of manual repetitive tasks.

### 5.0 Learning Experience and Students’ Feedback

Learning four subject topics namely, understanding (a) method study, (b) work element analysis, (c) workstation design, and (d) predetermined motion time systems (PMTS) was aimed through this workshop. Students are expected to gain confidence and competence in these four topics by attending this workshop. Table 6 divides these learning elements into eight learning outcomes as shown.

**Table 6: Evaluation of Learning Outcomes of the Workshop**

<table>
<thead>
<tr>
<th>Indicator Variable</th>
<th>Evaluation Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Rate the contribution to your level of understanding of Method study by the workshop</td>
</tr>
<tr>
<td></td>
<td>Rate your confidence to plan a method study in your Own</td>
</tr>
</tbody>
</table>
At the end of the workshop, students were asked to rate the achievements of the eight learning outcomes on a 1 to 5 scale as shown in Table 5. The results of the ratings are averaged and shown in Figure 9. All learning outcomes scored between 4.2 and 4.4 excepting confidence in work element analysis, which scored 4.07. Even this is above 4, indicating a high level of confidence. In fact, many students commented that they understood the entire process of method study and work measurement clearly after the workshop.

**Figure 9: Results of Students-Rating of the Attainment of Learning Outcomes**

### 6.0 Application in Real-World Projects

This section gives a brief description of two projects undertaken by students from the course. In the first project [7], students identified an assembly process and evaluated it and suggested a new method for the assembly process. These units are made in large batches. In the second project, the packaging of selected high quality dates as VIP packages in a large factory was analyzed.
The packaging section employed twenty workers in addition to the staff who deliver unpacked dates and pick the completed packages.

6.1 Multipurpose Junction Box

This product is made up of a frame, a door and five panels fitted in place by 22 bolts. Figure 10 shows the component panels and the assembled product while Table 7 shows the quantities. The frame is fabricated from 25 mm thick strips on which 1.5 mm plates are assembled in all five sides. The sixth side has the door.

![Figure 10: Details of the Junction Box](image)

Table 7: Quantities of the Various Parts in a Junction Box

<table>
<thead>
<tr>
<th>No.</th>
<th>Part Name and Description</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Frame</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Front Door Assembly</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Back Panel</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Side Panel</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Top and bottom plates</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>40 mm bolts side &amp; back panels</td>
<td>12</td>
</tr>
<tr>
<td>7</td>
<td>15 mm bolts for top and bottom plates</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>10 mm bolts for door hinges</td>
<td>2</td>
</tr>
</tbody>
</table>

The students made several site visits to learn the current process. Their work can be broadly classified into the following groups:

a. Understand the product design and establishing the current process map
b. Decide upon the tools and the work elements
c. Carry out a Workstation Design
d. Establish an improved process map
e. Produce a time estimate using MOST Predetermined Method Time System and validate with stop watch measurements

The major weakness identified by the students was in the process or the method. When the process is not properly thought out, lot of time, labor, and space would be wasted, and this study
identified that. The workstation design conducted by the students, not only resulted in improved usage working space and labor, but also made the working less tiresome for the worker. The students reported about 27% savings of labor time.

6.2 Making VIP Packages of High Quality Dates

Unlike the previous project, this one involves picking and placing high quality dates, a relatively light object. The seeds of the dates are removed and are replaced with nuts. Some of these are then coated with chocolates of various kinds. These processes are carried out in another department and the processed dates are delivered for packaging. The activities essentially consist of picking empty boxes with plastic trays and placing the processed dates, one by one, in an orderly fashion in the trays, and closing and sealing the boxes once the filling is complete. Some boxes contain 12 dates, as shown in Figure 11, while some other packages contain 24 or 48 dates.

Figure 11: Typical Date and VIP Package of High Quality Dates

Students made several site visits to learn the current process. Their work can be broadly classified into the following groups:

a. Understand the product design and establishing the current process map
b. Carry out a Workstation Design
c. Establish an improved process design
d. Verify and confirm the fitness of the method

Here again, the major weakness identified by the students was in the process or the method. The process was not thought out properly, and the method was not set out as a standard procedure. This was the main cause for the loss in efficiency. The students’ study itself has prompted the management to act.

7.0 Discussion and Conclusion

The main aim of teaching is to create a learning experience that gives the necessary knowledge in a subject, skills in the efficient use of the knowledge and competence in applying the knowledge and skill to solve real-world problems. Instructional design is aimed at providing
these three elements in the learning experience. As Merrill identified, the experience should be such that: (a) learners are engaged in solving real-world problems, (b) existing knowledge is activated as a foundation for new knowledge, (c) new knowledge is demonstrated to the learner, (d) new knowledge is applied by the learner, and (e) new knowledge is integrated into the learner’s world. In the theory classes, new knowledge is explained and their application and skills are enhanced with tutorials. The workshop activated the existing skills and knowledge and provided an opportunity to integrate the new knowledge with the existing one. It made students confident in their ability to apply the newly acquired skills and knowledge to solve real-world problems. The survey conducted after the workshop indicates this. The workshop lasted for nearly five hours, but no group wanted to leave without completing the task to the full.

As conclusions the following can be said:
- Teaching the theory and solving tutorial problems to build theoretical knowledge increased the understanding of the concept.
- The workshop inspired students, and the hands-on experience made them understand the concept well. They also learned the use of various practical skills to solve a problem.
- The workshop gave students a thorough understanding of the subject and its applications and they felt that they are competent enough to solve real-world problems. However, the right choice of trigger material has to be made and all logistic arrangements should be done prior to the class.
- The three-step methodology proposed here has resulted in satisfactory conclusions.

References