Using Phenomenological Approach to Identify Mathematical Competency in Engineering Workplace

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Abstract: Engineers are responsible for solving highly complex problems and, hence, some training to solve such problems, particularly real-life issues, are necessary. The Engineering Accreditation Council (EAC), Board of Engineering of Malaysia (BEM), emphasizes the important of engineering competencies in engineering Program Learning Outcome (PLO), such as the ability to identify, formulate, analyze, and apply mathematical knowledge to engineering problems. However, it was reported that students in university face more challenges in understanding engineering mathematics as they are not taught by instructors who specialize in the respective field. Thus, this study was conducted using a phenomenological approach to identify the mathematical competencies (MC) among practicing engineers at manufacturing workplaces in PDCA (Plan-Do-Check-Action) process workflow. Three respondent engineers were chosen as respondents for this study, but only one respondent reported in this study. Data was gathered through intensive interview sessions at the workplace. Data analysis technique of phenomenological reduction was primarily utilized in this study were Epoche, identify significant statement, Meaning Units, Textural Description of the Experience, Structural Descriptions of the Experience, and Textural-Structural Synthesis phenomenology. The method provides logical, systematic, and coherent design elements that lead to an essential description of the experience. The findings revealed that the MC elements frequently used at each stage of the PDCA process are thinking mathematically, problem handling, and mathematical communication. This study will inform instructors to develop mathematical competencies related to real-life problem-solving during teaching and learning in engineering activities and academic programs at their institutions.

Keywords: mathematics at workplace, mathematics in industry, PDCA, phenomenological method, mathematical competency

Introduction

In embracing industrial Revolution 4.0, engineers solve highly complex problems requiring practical training to solve real-life problems. Meanwhile, the engineering accreditation council board of engineering of Malaysia (EAC-BEM, 2015) emphasizes engineering competencies, such as having the ability to identify, formulate, analyze, and apply mathematical knowledge engineering problems in the undergraduate engineering curriculum.

However, it was reported that university students face more challenges in understanding engineering mathematics as they are not taught by instructors who specialize in the respective fields (ASCE, 2008). Although there are contradictory findings regarding the methods and approaches to how engineering mathematics should be taught, most researchers agreed that the teaching approaches between engineering and mathematics undergraduates must differ (ASCE, 2008).

Hence, engineering mathematics' teaching and learning approach may degrade students' understanding as they cannot relate the mathematical principles with real-life applications (Irish *Academy* of Engineering, 2004). Thus, there is a need to enhance the understanding of mathematics related to engineering tasks in this real environment. Therefore, it is rational to bring the practice's mathematical context from the engineering workplace and embed it constructively and systematically into the mathematics curriculum in engineering programs. Therefore, this study will consolidate mathematical competency for engineering program where practicing engineers' experiences are considered.

Phenomenology Approach

The phenomenology approach has been translated into a qualitative research method and is currently expounded by Moustakas (1994). This phenomenology approach was based on principles that Husserl introduced in 1931. Moustakas (1994) highlighted that in phenomenology, the researcher is more focused on describing participants' experiences than the researcher's interpretations.

This approach is helpful in "describing the common meaning for several individuals of their lived experiences of a concept or phenomenon (Creswell and Poth, 2018).

To capture engineers' experiences, this phenomenology approach has been selected as the appropriate research design for this study. According to Creswell and Poth (2018), phenomenological approach allows the researcher to capture detailed descriptions of the participants' experiences. A detailed description of participants' experiences is very useful for describing the phenomenon that has been experienced by participants' (Cordes, 2014). Husserl's concepts of epoche (or bracketing) have been used in this research to capture a good description of experiences from practicing engineers by "setting aside own experiences as much as possible to take a fresh viewpoint toward the phenomenon under investigation of this study" (Creswell and Poth, 2018).

Mathematical Competency (MC)

21st-century educational attributes for engineering graduates in higher education includes problem-solving ability to think mathematically. It is a valuable and powerful way of thinking about things in the world (W.A et al., 2002 and K.J et al., 2002). Moreover, mathematics is an important tool as it equips students with the ability to use mathematics in a single or multiple disciplines environments (K. Stacey, 2007).

Abstractly, teaching engineering mathematics may not help students understand as they cannot relate the mathematical principles with real-life applications, and students' anxiety about mathematics has been reported. Anxiety creates strong negative emotions and can hinder a person's cognitive, learning, and academic performance (Linde, 2001; Nor et al., 2016; Rahman et al., 2012; Zeynivandnezhad et al., 2016). Thus, there is a need to enhance their understanding of engineering practice at the workplace to narrow the gap between what is being taught in institutions and what engineers really do at the workplace. With this knowledge, instructors of engineering undergraduates can identify what matters to be focused on in teaching and learning activities to prepare engineering assessment program. According to Niss (2003), mathematical competency is the ability to understand, judge, do, and use mathematics in various intra- and extra-mathematical contexts and situations in which mathematics plays or could play a role. Niss listed eight mathematical competencies as below: -

1. Thinking mathematically
2. Reasoning mathematically
3. Posing and solving mathematical problems
4. Modeling mathematically
5. Representing mathematical entities
6. Handling mathematical symbols and formalism
7. Communicating in, with, and about mathematics
8. Making use of aids and tools

Engineers and PDCA

An engineer is a person whose job is to design or build machines, engines, or electrical equipment, or things such as roads, railways, or bridges, using scientific principles (Oxford English Dictionary, 2019). Meanwhile, engineering is defined as an application of science and mathematical application to tackle technical problems economically. Engineers' work depicts a relationship between scientific discoveries and commercial applications, which aim to serve the demand made by society and consumers (U.S. Department of Labor website., 2010).

Engineers' working fields do not range from only designing, developing, testing, and maintaining, but also extensively utilize computers to; i) produce and analyze designs; ii) simulate and test the operation of a machine, structure, or system; iii) generate specifications for parts; iv) monitor products' quality; and v) control the efficiency of processes (U.S. Department of Labor, 2010-11). Meanwhile, Wulf and Fisher (2002) mentioned that engineers are designing under constraint as their creativity is constrained by numerous elements, including nature, cost, safety concerns, environmental impact, ergonomics, reliability, manufacturability, maintainability, and others.

In 1996, the automotive vehicle company TOYOTA introduced the "LEAN Manufacturing" technique. the purpose of "LEAN Manufacturing" is to "determine value accurately according to a particular product, identify the value flow for each product, create an uninterrupted flow of value, let customers draw value from the manufacturer, and pursue perfection. '"In LEAN, there are 25 analysis methods, and One of the methods is Plan-Do-Check-Act (PDCA) cycle. The PDCA cycle is also known as the Deming or Shewhart Cycle (Strotmann, 2017).

In view of that, this study explored the PDCA management cycle in the manufacturing workplace to investigate how mathematics is applied during engineering tasks. The PDCA cycle is repeatedly implemented to improve performance so that the ultimate task goal is gradually achieved continuously, as described in Table 1.

Table 1: The PDCA cycle

Process/ Step	Description
PLAN	Establishing the objectives and processes necessary to produce the expected output
DO	Implementation of the plan
CHECK	Studying and analyzing the actual implementation results and comparing them with the expected ones,
ACTION	Corrective actions (including adjustments) to solve differences between actual and expected results or closing the loop.

Methodology

Figure 1 shows the overall flow chart details for this study's phenomenological methodology and analysis. Figure 1 also shows four steps to complete this study: background study, data collection, data analysis, and result. This study aims to identify the mathematical competency most commonly demonstrated in PDCA engineering tasks from the perspective of practicing engineers using phenomenological approach. A phenomenological approach to qualitative research was the focus of this study. The study focuses on detailed, textural descriptions, structural descriptions, and the study's essence (Creswell, 2013; Moustakas, 1994). Phenomenology helps describe the phenomenon using the participants' experiences, perceptions, and voices. According to Creswell (2013) and Moustakas (1994), the phenomenological reduction data analysis method was used to achieve a textural-structural synthesis and essence of the experience.

Selection engineer at the workplace

Purposive sampling strategy was applied to achieve representativeness and cover all practicing engineers regardless of their gender, level of achievement, and cultural background (Teddlie and Yu, 2007). Teddlie and Yu (2007) explained that this technique is used when the researcher wants to select a purposive sample representing a broader group of cases as closely as possible. The practicing engineers in this research were selected purposively utilizing a homogeneous sampling scheme (Patton, 2002; Teddlie and Yu, 2007; Creswell, 2012). Homogeneous sampling is individuals with similar traits or characteristics (Creswell, 2012, Onwuegbuzie and Collins, 2007). Patton (2002) states that homogeneous sampling aims to describe a subgroup in depth.

The initial stage was searching for a company registered with Federation of Malaysia Manufacturing (FFM) that manufacture certain product(s). An electronic manufacturing company located at Pasir Gudang, Johor, was selected for this investigation. This study has been done in the manufacturing department of the company where problem solving is critically performed by an experienced engineer in that field, who was selected as the sample for this investigation. The nature of work at the engineering department was consistent with the requirements of the intended study, which examine mathematical competencies among engineers at the workplace.

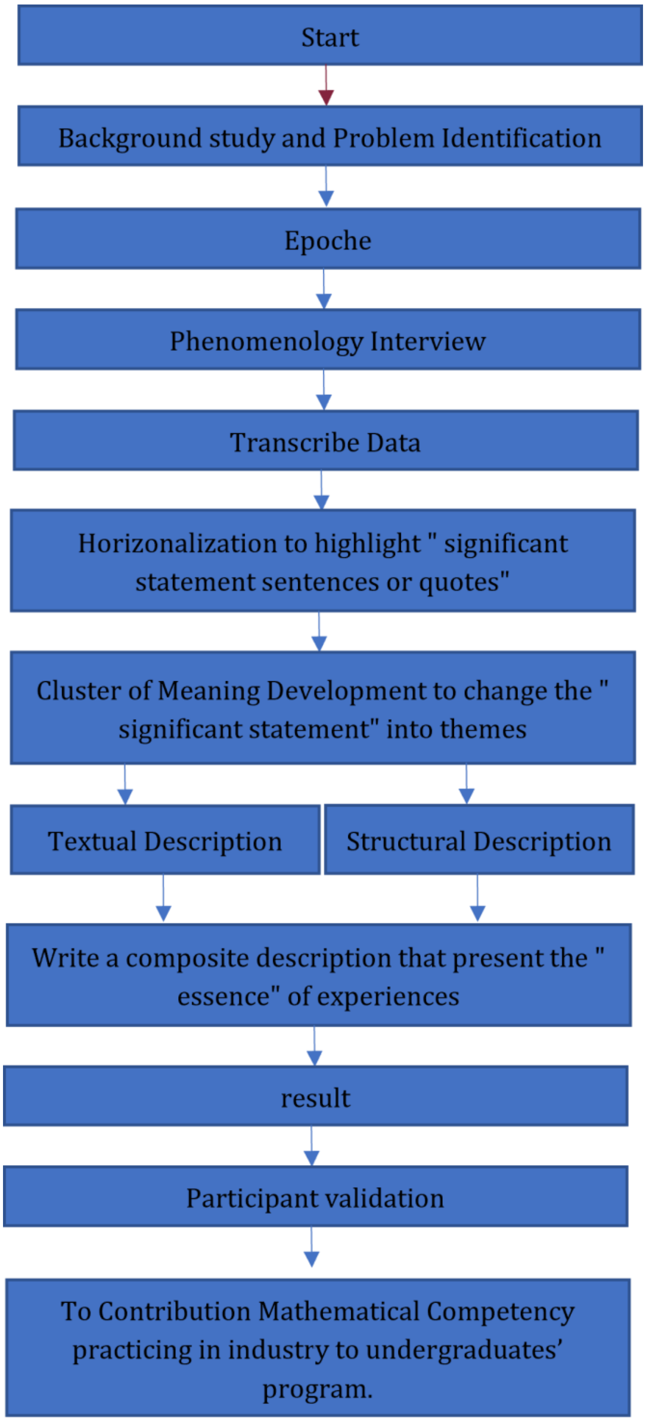

Figure 1. The Flow Chart for Phenomenological Methodology and Analysis

There are four main departments that involves engineers' expertise in the company (Table 2).

Table 2: Type of Engineers

No.	Department	Type of Engineers
1	Factory Engineering	Electrical R&D Engineer, Mechanical Engineers
2	Quality Control	Quality Control Engineers, Supplier Quality Engineer
3	SMT Production	SMT Production Engineer
4	Production Engineering	Production Engineer

The Factory Engineering Department includes Electrical R&D Engineer and Mechanical Engineers. Electrical R&D Engineers are responsible for planning, assembling, troubleshooting, repairing, and modifying prototype devices and fixtures with minimal supervision from engineers. They are also responsible in electronic prototypes assemblies, printed circuit board assemblies, electrical wiring, and cable assemblies. Mechanical engineers are responsible for designing, developing, building, and testing mechanical and thermal sensors and devices.

The Quality Department has two types of engineers. The first is Quality Control Engineer, and the second is Supplier Quality Engineer. Quality Control engineers are responsible for testing new products and determining whether they meet the business's reliability, durability, and functionality standards. A supplier quality engineer ensures all suppliers and the materials they provide comply with engineering and manufacturing specifications and company and government standards.

The production department has one type of engineer, which is the SMT Production Engineer. The SMT Production Engineer is responsible for the hands-on SMT manufacturing lines, including process development, scheduling, quality, and other SMT process logistics. The SMT Production Engineer will also work with the SMT Process Engineer to troubleshoot problems with production and implement corrective actions as required.

The Production Engineering department has Production Engineers. Production Engineers are responsible for supervising and improving production at plants and factories. They support engineering teams, draw up safety protocols, report issues to the manager, and develop strategies to improve efficiency and profit.

Table 3: Background of practicing engineers

Informants	Designation	Department	Experience in Engineering (Years)	Duration of interview (Minutes)
Engineer 1 (E1)	Senior Engineer	Production Engineering	15	82
Engineer 2 (E2)	Engineer	Quality Control	16	82
Engineer 3 (E3)	Senior Engineer	SMT Production	12	155

Table 3 shows the background of three practicing engineers as the samples of this study. The following is background and data for respondent (E1) to show how the data is analyzed. The first respondent (E1) is an SMT Process Engineer from the Surface Mount Technology (SMT) Production Department. SMT is affixed to the surface-mount components, soldered into the printed circuit board (PCB) provides the location on the circuit assembly technology's surface, used in the circuit board with responsibility unprincipled drilling. In particular, it is the first in the circuit PCB solder paste coating on the disk, and then surface mount components accurately coated with solder paste on the pad and the printed circuit board by heating until the solder paste melted.

Engineer E1 has been working as a company engineer for 15 years. The responsibility of the SMT Process Engineer is to manage and perform the necessary operations while running smoothly and orderly. The respondent also analyzes each problem, new process, equipment, and technology for suitability, application, and implementation. As an experienced engineer, he also needs to improve efficiency, maintenance, and performance in the SMT department by providing training and guidance to SMT partners and developing technologies in electronics and sub-installations.

Besides, the respondent has been applying LEAN for the analytical method to improve as imposed by the company using selected materials (solder paste, PCB/ stencil cleaning solution), and process optimization skills (time, quality, cost) based on specific data and formulas. Data programs were produced by the SMT engineers. The program is to move or direct SMT equipment (Paste Printer, select and Place, SPI, AOI), thermal profile, and calibration equipment. For all the performance-enhancing efforts to go smoothly, the respondent needs technical specifications from the R&D SMT Department and the Production Line for evaluation of electronic design, optional components, stencil order. Also, respondents need to manage engineering changes for significant electronic boards, such as spare parts/consumables for the equipment used.

Finally, the main task as an of SMT engineer is to prepare professional practical and systematic report, for record and further actions.

Methods of Data Collection

The researcher needs to identify the required types or methods for data collection to address all the research questions. The researcher has decided to use interviews to collect data in this study. This was due to the focus of the Phenomenology research study, typically on a single person, gathering data through the individual reporting experiences and discussing the meaning of those experiences. The following sections explain how these data collection methods were employed in this study are discussed.

Phenomenology Interview

This study used interviews for data generation, which involved the researchers directly accessing the data source. The selection of informants is intentional and focused on narrowing the theoretical sampling to allow the researcher to examine only informants that can contribute to the generation (Creswell, 2013).

The first round consisted of a phenomenology interview. The researcher's interventions were to be kept to a minimum not to affect the respondent's memories and speaking style (Lee, 2006).

In the second round, a semi-structured interview explored the practicing engineer's experiences in further detail. According to Cousin (2009), a semi-structured interview allows researchers to develop in-depth accounts of experiences and perceptions with individuals. A semi-structured interview facilitates the researcher to inquire more about manufacturing-related engineering tasks.

Before beginning the interview sessions, the researcher made an effort to get to know each of the participants by conversing with them during their free time, emailing them to see if they had any additional questions or concerns, and calling them to arrange an appointment before scheduling the interview sessions to ensure that the interview sessions did not interfere with their busy schedules. This strategy worked well because it enabled the researcher to develop a friendly, accessible, and flexible relationship with the study participants (Creswell and Guetterman, 2019).

Each of the two series of interviews had its own set of interview protocols. Each interview lasted around 60 and 120 minutes and included several questions. The lengths of the interviews differed greatly depending on the topics discussed. The researcher would move on to another subject if the participant had nothing to say. When gaps in the participants' data are discovered, the researcher will later contact them by email or phone to gain additional information to fill the gap. The time spent filling in the gaps was not included in the initial interview times. By filling in the gaps, the researcher could get a more in-depth look at the phenomenon (Moustakas, 1994).

Phenomenology was chosen as the appropriate methodology for this study as a researcher searched for an understanding of the meaning of these participants' experiences. Additionally, Moustakas's systemic procedures and detailed data analysis steps are suitable to assist less experienced researchers. the phenomenology approach using systemic procedures is consistent with our philosophical view of balancing both the objective and subjective approaches to knowledge and detailed, rigorous data analysis steps

Further, the researchers validated the storyline's flexibility and transferability among the informants and validated the credibility of the storyline and emergent substantive theory via expert.

Because the study focused on understanding the mathematical competency usage in the engineering manufacturing process in manufacturing engineering practice, the researcher was positioned as a social being whose experiences, ideas, and assumptions can contribute to understanding and interpreting the social processes studied. The finding was developed to understand better the main concerns encountered in its substantive area from the researchers' perspective. nevertheless, the substantive finding is considered transferable to contexts of other engineering processes that are comparable to the context

Data Analysis

Data Transcription (Phenomenology interviews)

In adopting Moustakas' (1994) phenomenological model using phenomenological reduction, the following step identifies significant statements, meaning units, textural description of the experience, structural descriptions of the experience, and textural-structural synthesis. The purpose is to identify a significant statement.

Horizonalization (Significant Statements Identification)

As shown in Table 4, Column 2, the researcher identified individual verbatim statements shared by the respondent (E1) depending on each PDCA step for purposely showing only for step *Plan* to show how to analyze at this step. These statements represent non-repetitive, non-overlapping significant statements. These statements reflected entire sentences and were a subjective extrapolation from the transcripts. No attempt was made to group these statements or order them in any way. In this analysis phase, the researcher wanted to learn how individuals viewed the term. Reading their statements provides details about how individuals experience reinvestment in others. These significant statements are gleaned from the transcripts and provided in Table 4 so that researcher can identify the range of perspectives about the phenomenon (Moustakas, 1994).

Table 4. Selected Significant Statements for PLAN Step

No.	Verbatim statements	Researcher interpretation
	PLAN	
1	I accept PCB quality issue out of spec above 2.6mm. We take ten pcs to sample before reflowing and found four pcs reject from ten pcs over 1.56, meaning 40% reject and after oven getting worse, at point a, b, c, d warpage making a lot. We have to check the size of all 10 points in the original state and after the oven process, besides whether the process causes component defects. Similarly, the SMT process is problematic or not; for example, solder printing is impractical; the PCB surface will crack when the PCB is pressed while testing is running and assembled within the cabinet, thus making components break,	Engineer Recognition of mathematical concepts Engineer investigating various problems (identifying, posing, and specifying) Engineer following and assessing chains of arguments put forward by others
2	As always, as practice, we will receive problems/problems from production or QC and solve problems. That is a fixed strategy.	Engineer investigating various problems (identifying, posing, and specifying)
3	When I get an email from QC, I will understand the real problem by understanding the symptoms of the reported issue. For example, there is information such as quantity reject, percentage reject, and a scene of rejection. That information will help me understand more and make initial guesses and hypotheses about the problem and why it is. It also helps me to explain to others the pain.	Engineer expressing oneself about mathematical contents Engineer investigating various problems (identifying, posing, and specifying) Engineer utilizing and understanding different representations of entities (decoding, interpreting, distinguishing between) Engineer understanding relations between different representations
4	It started with a data collection that would send an email to call several departments such as QC, Production, Warehouse, and Engineering.	Engineer Expressing oneself about mathematical contents
5	The purpose is to find the correct issue information and the rights situation, in which case we will also discuss some issues on the issue, such as how much quantity? How often? If interrupting efficiency/efficiency, for example, one hour too often, can result in lost time, we have to study. Is there a mechanical problem or RAW part problem? Identifies normal or abnormal. It involves several parties like in charger machines, storing the raw problem claims to PCB maker in charge. We will tell the inspector PCB maker and defective part and advise the issue that the warpage part cannot be high.	Engineer investigating various problems (identifying, posing, and specifying) Engineer utilizing and understanding different representations of entities (decoding, interpreting, distinguishing between) Engineer recognition of mathematical concepts Engineer expressing oneself about mathematical contents
6	The data involved is an email stating the problem, reject what? How many Quantities? What is the ratio?	Engineer recognition of mathematical concepts Engineer understands the scope/limitations of a given concept
7	YES. There are departments like QC, Production, warehouse, and Engineering department.	Engineer expressing oneself about mathematical contents

Table 5. The Cluster of Meaning Development for PLAN Step

Plan	Themes/ Meaning Units	Evidence in Engineer statement
	Thinking mathematically	I accept PCB quality issues out of spec above 2.6mm. We take ten pcs to sample before reflowing; he found four pcs rejected from 10PCs over 1.56, meaning 40% reject. After the oven gets worse, at points a, b, c, d, warpage making a lot
	Problem handling	Besides whether the process causes component defects. Similarly, the SMT process is problematic or not. For example, solder printing is impractical. The PCB surface will crack when the PCB is pressed while testing is running and assembled with the cabinet, thus making the component crack
	Communicating mathematically	Well, once I get an email from QC, I will pick the exact problem with the different problem syntax used,
		The purpose is to find the correct issue information and the rights situation, in which case we will also discuss some issues on the issue, such as how much Quantity? How often

Development of meaning units

The next step is meaning Units or Themes, as every significant statement is initially treated as possessing equal value, as in Table 5. This next step deletes those statements irrelevant to the topic and, for this study, what is always mathematical competency frequently used. The remaining statements are the horizons or textural meanings. The researcher carefully examines the identified significant statements and clusters them into themes or meaning units (Moustakas, 1994). But this paper will show only for step *Plan* to show how to analyze at this step. Constructing themes will be performed based on deductive methods. Deductive ways are the knowledge, theory, or framework that has since become a code/theme (Boyatzis, 1998).

Textual Description and Structural Description Formation

In textural descript, the researcher then describes "what" was experienced in the textural description from the thematic analysis. Next, textural descriptions are considered, and additional meanings are sought from different perspectives, roles, and functions (Moustakas, 1994), and the *structural stage*; the researcher then describes "How" was experienced in textural descriptions.

In the following section, examples of respondent textural and structural descriptions are presented. Samples from this individual were selected to illustrate common horizons that emerged among the participants' interviews regarding their experience during task or workplace work. The analysis of individual textural and structural descriptions precedes the final step of the phenomenological analysis, textural–structural synthesis. The experiences of E1 below reveal both similarities and differences in their experience conducting tasks or working at the workplace. The respondents' analyses were intentionally selected to highlight the structures that were part of the absolute essence of their experience conducting tasks or working at the workplace. The search for similarities and reliance in E1 description, experience during conduct task or work at the workplace. In line with the phenomenological approach's goal, the final results that follow the textural and structural descriptions refer to the essence of the shared experience while conducting tasks or working at the workplace. The similarities in their experiences are elaborated upon in this Results section, in which we describe the structures that underlie the essence of the phenomenon under study.

In E1 individual textural description, he describes thinking mathematically about how to understand when he received the problem or task during work.

"Well, by the time I get the email from QC, I will take the problem with the problem of the relevant problem symptom, that are if there is information such as quantity of reject, percentage of reject, scene of occurrence of push. Received a PCB quality issue out of spec above 2.6mm, where a ten pcs sample found 4 pcs reject from 10PCs over 1.56, meaning 40% reject—after the oven getting worse, at point a, b, c, d, warpage making a lot. So we have to check the size of all 10 points in the original state and after the oven process, besides whether the process causes component defects. Similarly, the SMT process is problematic or not. For example, solder printing is impractical. The PCB surface will crack when the PCB is pressed while testing's running and assemble with the cabinet, thus making component crack."

The researcher can express the E1 individual structural description as follows:

"He received information on the quality problem regarding the PCB via email. He tries to understand and think about the problem by taking the information in the email, such as quantity of rejects, percentage of rejects, percentage of rejects, where it happened, and so upon, knowing the information involved. He thinks whether the information or data received is enough to help continue the calculation and solve the problem. Therefore, he need to think of initial expectations that need to be taken, such as taking the example of PCB and checking to carry additional data to strengthen all the problems involved. Meanwhile, it is also trying to determine the probable cause of this problem. For example, he stated the possible SMT process might be problematic. He also thinks about what issues will occur in other processes due to these problems, such as cracked components."

Results

The last step is the essence and finding and result. The concept of "saturation" was used to determine the number of samples involved in this phenomenology study. Typically, a qualitative researcher will collect data until they reach data saturation (Simon, 2011; Fusch and Ness, 2015; Nascimento et al., 2018). *The last step is the essence of engineer mathematical competency used for each PDCA process while working in the workplace*. After that, all finding and transcribe will ask a respondent to see and verify and validate them.

Mathematical competencies in PDCA Step.

To extract the essence of engineer mathematical competency in how to perform or solve the problem or task during work, the composite textural and structural descriptions developed for each engineer were integrated and synthesized. The essence underlying the experiences of engineer mathematical competency in performing or solving the problem or task during work is that the engineer describes mathematical Competency used for each PDCA process while working in the workplace.

Three composite structural descriptions of the experiences of engineer mathematical competency in how to perform or solve the problem or task during work by following PDCA,

(1) Thinking Mathematically

(2) Problem handling

(3) Communication mathematically

Plan step:

Engineers use mathematical competency to solve or do work tasks during the performance or solving the problem or task during work.

Thinking Mathematically

In this step, the engineer uses mathematical thinking by extracting and understanding the raw data or raw information received. Besides, with the help of engineers posing questions characteristic of mathematics to understand the problem they received, for example, "how many presents rejects? How often does it happen?

> *"I get an email from QC.; I will understand the real problem by understanding the symptoms of the reported problem if there is information such as quantity reject, percentage reject, and scene of reject. That information, t will help me understand more and be able to make initial guesses and hypotheses of what the problem is and why. it also helps me to explain to others about the problem." (E2)*

Problem handling

Also, engineers use problem handling during this stage; engineers try to understand the problem and what is related to the main problem. Then, in an implicit sense, the engineer tries to plan how to conduct an investigation and find additional information.

> *"Besides whether the process causes component defects. Similarly, the SMT process is problematic or not. For example, solder printing is impractical. The PCB surface will crack when the PCB is pressed while testing is running and assembled with the cabinet, thus making the component crack …. it started with a data collection that would send out an email to call the meeting several departments as Q.C., Production, warehouse, and Engineering. "(E3*)

Communication mathematically.

Engineers use mathematical communication at the planning stage. Engineer understands other mathematical texts when received information problem. Also, engineers communicate to explain the real situation regarding data and information obtained from other parties.

> *"Well, once I get an email from Quality Control, I will pick the exact problem with the different problem syntax used. The purpose is to find the correct issue information and the right situation, in which case we will also discuss some issues on the issue, such as how much quantity? How often. "(E2)*

Do step:

Thinking Mathematically

In this step, the engineer uses mathematical thinking by understanding and handling a given concept's scope and limitations.

> *"After that, would measure the curvature using flat mirrors and micrometer gauges, and t proved problematic because the dimensions made were 1.70mm, and the 190mm good section size was 0.2and 0.3mm." (E1)*

Problem handling,

In this step, the engineer uses mathematical thinking by problem handling. Besides, engineers use problem handling during this stage; engineers try to solve various problems related to the main problem. Then, in an implicit sense, the engineer tries to plan how to use the remaining or new data to calculate and get the solution.

> *"The data will be used during analysis and analysis decisions. After taking a sample/sample of the problematic part of 10pcs, and ten pcs…I will record it in one table to facilitate curved or warpage areas. "(E2)*

Communication mathematically.

Besides, engineers use communication mathematically at the do level. For example, engineers communicated to obtain additional data and information during meetings with other parties and tried to give their views to understand the problems.

> *"For the QC Department, at the beginning of the meeting, I will open the meeting by explaining the issues you want to discuss. During the discussion, I will ask the relevant department, for example, the QC department. They will answer the same data (above). that data is meant and intended. Total reject 50pcs means knowing how many parts are at risk, which means different types of problems and sizes we can analyze. A lot of different data can help you find the right root cause. So does the reject ratio. This data is very important to know the real situation in production. Whether production can work or not." (E3)*

Check step:

Thinking Mathematically

At this stage, engineers use mathematical thinking by finding continuous quality improvement by asking questions or anticipating what will happen.

"Discussions with all departments regarding the action we take during the analysis study and how we implement it. What data are you using? action enhancement." (E3)

Problem handling,

In this step, the engineer uses mathematical Competency with Problem Handling. The engineer tries to prepare any possibility when the solution's result is a mistake by asking for feedback from the other party. If there is an error or needs improvement, the engineer plans what data is needed again.

"Then, preparing the report and meeting with the relevant department will receive feedback from the meeting. According to the meeting analysis report, there is no question arising from the study analysis in this case. All can understand and agree. We will only wait for feedback from the supplier." (E1)

Communication mathematically.

Besides, engineers use communication mathematically at the check level. Engineers communicate to obtain additional data and information during meetings with other parties and try to give their views on improvement

"Discussions with all departments regarding the action we take during the analysis study and how we implement it. What data are you using? Action enhancement." (E2)

Action step:

Thinking Mathematically

In this step, the engineer uses mathematical thinking by understanding and handling the scope and limitations of a given concept; for example, the engineer will monitor the data or part after the improvement action if all data is inside the specification. The part considers good.

"Let us see, based on that decision. Based on that data. All the parts are in the specifications we know. mean, this part is OK." (E3)

Problem handling

In this step, the engineer uses mathematical competency with problem handling; engineers try to plan to monitor the part after the action is taken. For example, engineers take measurements or data for some sample parts that are in the production line. Based on that data, the engineer will make the next decision.

"In this case, we will observe the part that has been upgraded. Or the newly arrived part. We will do the same measurements as before. Is the same problem still happening? Or repaired." (E2)

Communication mathematically.

Besides, engineers use communication mathematically at the check level. Engineers communicate to obtain additional data and information during meetings with other parties and try to give their views for improvement

"The discussion is about analysis for continuous improvement. And solve the problems." (E1)

Discussion

Phenomenological Approach

Phenomenology is a fundamental field of research in engineering whose central aim is to describe people's experiences (Norlyk et al., 2010 and Streubert et al., 2011). As a research method, phenomenology is primarily concerned with elucidating the first-person experience of phenomena (Wertz et al., 2011) by verbalizing particular experiences. In choosing this method, prospective researchers are expected to understand its basic assumptions and tenets as a philosophy and method of inquiry. The two questions of 'what' and 'how' is experienced provide a concrete framework for asking questions and recording responses, enabling them to make important decisions such as whether to focus research on 'individual' or 'general' aspects of an experience. This deeper understanding of phenomenological philosophy and method encourages engineering researchers to articulate the study design, including the rationale for their choice and preferred data collection methods and analysis. It also enables researchers to present their findings narratively, using language infused with 'facts' and 'emotions' to lead to a deeper understanding of the phenomena under study. In summary, the fact that this approach relies on participants' experiences means that the stories being told are told from the participants' voices rather than those of the researcher or individuals reporting on studies on the literature, which is consistent with human science research. Previous studies evidence this, and Phenomenology is a great and helpful research strategy that is well suited to explore challenging problems (Neubauer et al., 2019; Picton et al., 2017; Stolz, 2020; Khan, 2014).

Thinking mathematically

Engineers view an issue and a task as more than the ability to perform simple arithmetic or solve an algebra problem. It's a way of looking at things, reducing them to their essential components, whether numerical, structural, or logical, and then evaluating the fundamental patterns. Mathematically, they emphasize how to manage to solve problems by adding data or the size of a problem to each item involved. Based on most of the previous research, thinking mathematically will ease problem-solving (Henderson et al., 2002; Mason, Burton & Stacey, 2010; Blitzer, 2003). The addition of information or published data can help engineers to provide several ways of mathematical solutions.

Problem Handling

Problem handling is involved in most engineering task, and engineers must examine actual problem to get a clear perspective. They need to ensure and modify the mathematical content of the data if necessary. They emphasize how to design to solve the problem by adding data or problem size to each item involved (Grootenboer & Jorgensen, 2009). Ensuring the actual state of the published information or data can help engineers provide mathematical solutions.

Communication mathematically

"Communication is an essential part of mathematics and mathematics education "(National Council of Teachers of Mathematics [NCTM], 2000, p. 60). Writing and discussion are integral to communication, promoting a deeper understanding of concepts (Cramer & Karnowski, 1995; NCTM, 2000). The ability of engineers to organize and connect their mathematical thinking through communication and convey their logical and clear mathematical thinking to their colleagues, superior, and others; engineer also analyzes and evaluates the mathematical thoughts and strategies used by others; and use mathematical language to express mathematical ideas correctly

Conclusion

The results show that MC is suitable for applying problem-solving in the workplace. Therefore, it is suggested that the focus of mathematics teaching for prospective engineers should consider mathematical competencies, and these competencies should be included as important learning outcomes. In view of that, the National Academy of Engineers ;(2005) states that the future engineering curriculum should be built around developing skills such as analytical and problem-solving skills rather than teaching content knowledge. Furthermore, emphasis should be laid on teaching students about methods to derive solutions rather than giving the solutions (the National Academy of Engineers, 2005).

References

Accreditation Council, Board of Engineering Malaysia.

ASCE (2008) Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future, (2008 Second Edi. Reston, Virginia: American Society of Civil Engineers, 2008.

Blitzer, R. (2003). *Thinking mathematically.* New Jersey: Prentice Hall.

Cramer, K., & Karnowski, L. (1995). The importance of informal language in representing mathematical ideas. *Teaching Children Mathematics, 1*(6), 332-6.

Creswell, J. W. (2013). Qualitative inquiry & research design: Choosing among five approaches (3rd ed.). Thousand Oaks, CA: Sage Publications, Inc.

Dukes, S. (1984). Phenomenological methodology in the human sciences. *Journal of religion and health*, *23*(3), 197-203.

EAC-BEM. Engineering Program Accreditation Manual 2012 (2012). Engineering.

Grootenboer, P. & Jorgensen, R. (2009) Towards a theory of identity and agency in coming to learn mathematics. *Eurasia Journal of Mathematics, Science & Technology Education.* 5(3) 255-266.

Henderson, P. B., Hichtner, L., Fritz, S. J., Marion, B., Scharff, C., Hamer, J., & Riedesel, C. (2002). Materials development in support of mathematical thinking. *ACM SIGCSE Bulletin*, *35*(2), 185‑190. Doi: 10.1145/782941.783001

Herro, D., Quigley, C., Andrews, J., & Delacruz, G. (2017). Co-Measure: developing an assessment for student collaboration in STEAM activities. *international Journal of STEM Education*. https://doi.org/10.1186/s40594-017-0094-z

Irish Academy of Engineering. (2004). The Role of Mathematics in Engineering Education. Irish Academy of Engineering, Dublin.

K. J. Devlin, (2002). "The Math Gene: How Mathematical Thinking Are Like Gossip Where Mathematics Comes from: How The Embodied Mind Brings Mathematics into Beino," pp. 74–78, 2002.

K. Stacey, "What is Mathematical Thinking and why is it important? Progress report of the APEC- project Collaborative Studies on innovations for Teaching and Learning Mathematics in Different Cultures (II) Lesson Study focused on Mathematical Thinking.," 2007.

Khan, S. N. (2014). Qualitative research method – Phenomenology. *Asian Social Science*, *10*(21), 298–310. https://doi.org/10.5539/ass.v10n21p298

Kim, S.-W., & Lee, Y. (2016). The Analysis on Research Trends in Programming based STEAM Education in Korea. *Indian Journal of Science and Technology*. https://doi.org/10.17485/ijst/2016/v9i24/96102

Linde, C. (2001). Narrative and social tacit knowledge. Journal of Knowledge Management, 5(2), 160-170

Mason, J., Burton, L., & Stacey, K. (2010). *Thinking mathematically* (Second edition). Harlow England: Pearson Education Limited.

Mediterranean Conference on Mathematical Education City: Athens, The Netherlands.

Moustakas, C. (1994). Phenomenological research methods. Thousand Oaks, CA: SAGE Publication.

National Council of Teachers of Mathematics. (2002). *Principles and standards for school mathematics.* Reston, VA: Author.

Neubauer, B. E., Witkop, C. T., & Varpio, L.(2019). How phenomenology can help us learn from the experiences of others. *Perspectives on Medical Education*. https://doi.org/10.1007/s40037-019-0509-2

Niss, M. A. (2003). "Mathematical Competency and the Learning of Mathematics: The Danish KOM Project," In A. Gagatsis and S. Papastav2012ridis, (eds.), 3rd 472

Niss, M., & Højgaard, T. (Eds.). (2011). Competencies and mathematical learning. Ideas and inspiration for the development of mathematics teaching and learning in Denmark (Tekster fra IMFUFA, no 485). Roskilde: Roskilde University, IMFUFA.

Niss, M., Emanuelsson, J., & Nystro¨m, P. (2013). Methods for studying mathematics teaching and learning internationally. In M. A. Clements, A. J. Bishop, C. Keitel, J. Kilpatrick, & F. K. S. Leung (Eds.), Third international handbook of mathematics education (pp. 975–1008). New York:

Nor N. A. K. M., Ismail, Z., & Yusof, Y. M. (2016). The relationship between emotional intelligence and mathematical Competency among secondary school students. *Journal on Mathematics Education*, 7(2), 91–100. https://doi.org/10.22342/jme.7.2.3534.91-100

Perignat, E., & Katz-Buonincontro, J. (2019). STEAM in practice and research: An integrative literature review. *Thinking Skills and Creativity*, *31*, 31–43. https://doi.org/10.1016/j.tsc.2018.10.002

Picton, C. J., Moxham, L., & Patterson, C. (2017). The use of phenomenology in mental health nursing research. in *Nurse Researcher*. https://doi.org/10.7748/nr.2017.e1513

Polkinghorne, D. E. (1989). Phenomenological research methods. In *Existential-phenomenological perspectives in psychology* (pp. 41-60). Springer US.

Rahman, R. A., Yusof, Y. M., Kashefi, H., & Baharun, S. (2012). Developing Mathematical Communication Skills of Engineering Students. Procedia - Social and Behavioral Sciences, 46, 5541–5547. https://doi.org/10.1016/j.sbspro.2012.06.472

Smith J. A., Flowers P., Larkin M. (2009). *Interpretative Phenomenological Analysis: Theory, Method, and Research.* Sage Publications, London.

Sohaila Firouzian, S., Ismail, Z., Rahman, R. A., Yusof, Y. M., Kashefi, H., & Firouzian, F. (2014). Mathematical Competency of engineers and engineering students. Proceedings - 2014 international Conference on Teaching and Learning in Computing and Engineering, LATICE 2014. https://doi.org/10.1109/LaTiCE.2014.49

Springer.Oxford English Dictionary. (2019). "Oxford Dictionary "Oxford English Dictionary. City: Oxford: Oxford University Press.

Stolz, S. A. (2020). Phenomenology and phenomenography in educational research: A critique. *Educational Philosophy and Theory*, *52*(10), 1077–1096. https://doi.org/10.1080/00131857.2020.1724088

Strotmann, C.; Göbel, C.; Friedrich, S.; Kreyenschmidt, J.; Ritter, G.; Teitscheid, P. A Participatory (2017). Approach to Minimizing Food Waste in the Food industry—A Manual for Managers. Sustainability 2017, 9, 66.

U.S. Department of Labor website. (2011). "Occupational Outlook Handbook." City: Washington, DC.

W. A., and Fisher, G. M. C. (2002). "A Makeover for Engineering Education" issues in Science and Technology, 18(3), 35-39.

Wessner, C. W. (2013). Best practice in state and regional innovation.

Wulf, W. A., and Fisher, G. M. C. (2002). "A Makeover for Engineering Education" Issues in Science and Technology, 18(3), 35-39.

Zeynivandnezhad, F., Ismail, Z., & Yusof, Y. M. (2016). Teaching mathematical structures in differential equations using a computer algebra system to engineering students. 2015 EEE 7th international Conference on Engineering Education, CEED 2015, 10–15. https://doi.org/10.1109/ICEED.2015.7451483.