PROMOTING SYSTEMS THINKING AND PROBLEM SOLVING SKILLS THROUGH ACTIVE LEARNING

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ABSTRACT

This paper is based on the experience of using contextualised practical activities to promote active learning, systems thinking and problem solving amongst the second year students of the Diploma in Chemical Engineering course at the School of Chemical and Life Sciences in Singapore Polytechnic. It provides a basic framework of systems thinking as a discipline, and some tools used in systems thinking training. It also discusses why students, not trained in systems thinking, usually cannot see the inter-relationships between constituents within a system. It highlights the use of a contextualised practical that involves the dismantling of an industrial scale centrifugal pump to promote systems thinking. The methods and approaches used in promoting systems thinking and systematic problem solving are outlined. The paper also presents the results of the systems thinking exercise performed by the students, which demonstrated students ability to inter-relate between the various parts of the pump. The results of the application of problem solving techniques on the given case scenario by the students are also shown using the problem solving template provided. The students' experiences of this new learning format was explored through a survey conducted to determine if the students were aware of the skills practised and whether these skills have benefited them in working through the scenario. Students were asked to provide a response to a set of questions using a 5-point Likert Scale and the results of the survey are discussed. In closing, the paper identifies the key challenges faced and the level of staff commitment and administrative supported needed in conducting such training.

Keywords: Systems thinking, problem solving, contextualised, active learning.

INTRODUCTION

Cotton (1991) reported that Presseisen,(1986) asserted that the most basic premise in the thinking skills movement is the notion that students can learn to think better if schools concentrate on teaching them how to do so. One of the challenges in the teaching of chemical engineering is therefore the inculcation of thinking skills that will help students to make inferences and possibly find answers that cannot be found in textbooks, to addressing issues encountered at the work place.

Traditionally, the thinking skills were implicit analytical skills derived via the solving of complex equations that describe a system or process. Invariably, there was a lack of focus and emphasis on promoting thinking skills and systematic problem solving required in the real world. Practical sessions were conducted only to verify the theories and concepts taught in class. When it comes to problem solving, it was usually limited to technical troubleshooting of a problem specific to a process or solving a set of complex equations that describe a system. There is also a tendency to restrict the investigation of the causes of a problem to the process from which the problem was discovered. In the real world, the cause of a problem that surfaces in one process may actually stem from another process prior to it or from an external source. To illustrate this, an example is briefly provided under the section on “Approach Used In Systematic Problem Solving Training”.

Engineers need to understand that problem solving is not necessarily limited to process troubleshooting, which relies only on process knowledge and experience. There is also a need for engineers to understand that complex problems are usually systemic and chronic in nature and may require a logical organised and systematic approach to their solution..

Felder, et al (2000) and Rugarcia ,et al. (2000) noted that it is becoming apparent that there is an increasing need to improve the quality and focus of engineering education. Apart from acquiring technical content knowledge and skills, students require competence in the applications of engineering design and operations and vital skills such as systems thinking and problem solving. Cotton (1991) reported that thinking skills research has shown that these skills are teachable and learnable.

Brent & Felder (2003) noted that the only way a skill is developed is practice.Why don’t we help students develop some skills by giving them some practice? Essentially, why don’t we use active learning?

SYSTEMS THINKING IN OUR CONTEXT

Aronson (1996) noted that systems thinking focuses on how the things being studied interact with other constituents of the system. It is a process of going beyond events, to look for patterns of behaviour and to seek underlying systemic interrelationships which are responsible for the patterns of behaviour and the events. Systems thinking is seen as a core competence in engineering as it involves the capability of looking beyond the surface of problems and seeingnot only technical connections between different systems, but also social and psychological connections. Hadgraft (2008) highlighted that systems thinking is particularly important in disciplines such as chemical engineering and electrical engineering, where engineers are designing and implementing complex, interconnected systems and artifacts.

A basic set of tools in systems thinking involves the 4W1H: What, When, Why, Where and How. Very often, students cannot see the relationship between the constituents within a system simply because they have preconceived notions about the system and its constituents. Usually these pre-conceived notions do not have any scientific basis and are derived from their own experiences, thus giving rise to possible wrong understandings and inferences. Also, many students often jump to conclusions without realising that they have by-passed a very important process of thinking. Such behaviours often lead to the wrong analysis of the system. For example, if you asked students what actions they would take if they heard an abnormal noise coming from a process, it would not be surprising to note that the action taken by many of them would be to shut down the process plant without actually finding out where the noise actually originates from. If the same question was posed but set in a different context, for example, in the bedroom while resting, many would be able to provide the right answer. Why is this so? Pre-conceived notion are largely to be blame! My experiences with the students today tell me that they want fast and convenient answers without having to think too much. They rely heavily on information from the internet and many will simply copy what they have found on the internet without understanding the content. A lot of them do not realise that they can get the answers they want by using systems thinking. Very often, in the real work place, there is no model answer and one has to draw on systems thinking to analyse a problem, especially when the problem is not just technical but complex in nature. In this paper, the teaching of systems thinking was carried out using contextualised practical activity that involved the studies on the anatomy of an industrial scale centrifugal pump by dismantling and assembling it.

SYSTEMATIC PROBLEM SOLVING IN OUR CONTEXT

Systematic problem solving is the organised approach and framework of deductive reasoning and questioning to isolate root causes and recommend corrective actions. It is not limited to the technical troubleshooting of a process. Very often in academic institutions, students would equate problem solving to the technical troubleshooting of a process. This led them to look into the technical aspects of the processes to find the solutions to the problems. Even in the process industries, experienced process personnel would invariably draw upon their experiences to troubleshoot a process problem in an unorganised and unsystematic trial-and-error manner. If they were lucky and the problem was purely process specific in nature, they might be able to solve it based on their experiences. On the other hand, they could be blinded by their own experiences if the problem encountered is not process specific but complex in nature, whereby the causes of the problem could arise from another process or an external source.

So how do we know if we have a problem at hand? How do we define a problem? These are initial crucial questions that need to be raised when it comes to systematic problem solving. In systematic problem solving, the ability to identify a problem is important. If you are unable to identify a problem, you will not even know that you have a problem. For example, your normal body temperature is $37^{o}C$. If it goes up to $37.3^{o}C$ and you are still feeling comfortable, you might not even be aware that your body temperature has risen to above the norm. In such a case, no problem is identified because you don’t even realise it has occurred. You simply accept it as it is. On the other hand, if you felt uncomfortable with a body temperature above the norm, you have a problem to solve. Take another instance for example. You have a process that produces an inherent reject rate of 1% over the year. One day you discover that the process produces a reject rate of 10%. If you accept it as it is, then you won’t have a problem to solve as far as the process is concerned. However, if you cannot accept the deviation of the reject rate from the norm value (1%), you have a problem with that process. Hence, the first step in problem solving is to be able to identify the problem. This fundamentally relates to understanding the importance and application of baseline behaviours of a process or system. In this paper, the teaching of systematic problem solving was carried out via a given case scenario provided in the contextualised practical.

METHOD AND APPROACH USED IN PROMOTING SYSTEMS THINKING AND PROBLEM SOLVING.

Use of Contextualised Scenario-based Practical Activity

In contextualising the practical, a case scenario was given for the practical activity and students were asked to imagine that they were working for the company as described in the scenario. The practical activity consists of the following assessment components: pre-practical assessment (Group and Individual), in-practical assessment (Group and Individual) and post-practical assessment (Group and Individual). The skills to be trained are mostly incorporated in the pre-practical and in-practical assessments. The contextualised scenario is as shown in Table 1.

Table 1
Contextualised Scenario-based Practical Activity
For 2nd Year Students of the Singapore Polytechnic Diploma in Chemical Engineering Course

You are a process supervisor in the Utilities Department (Dept) of **SJI Petrochemical Pte Ltd.** Your main responsibility is to ensure the smooth operations of Industrial Water Plant, Seawater Plant, Cooling Water Plant, Pure Water Plant, Nitrogen Plant and Air Compressor System so that the supplies of these utilities are smooth and met the requirements of the processes. You have a group of technicians reporting to you. A part of the routine tasks for the technicians involves patrolling of the plants and recording all the necessary process parameters every 2 hours. Everything was working fine in terms of operations behaviours and performances and the data collected have not shown any deviation from the norm before the plant shutdown. However, 3 weeks into the operations after a plant shutdown, your technicians reported hearing abnormal noise from the cooling water plant. They also reported an increase in the pump motor current. You know that there was this potential danger of getting the motor overheated if the problem is left unattended and that would be most costly. You did some checks and confirmed that the noise came from the cooling water supply centrifugal pump. You contacted the Maintenance Department. The maintenance people came and repaired the pump (You had to put the standby pump into operation). They reported that the pump's bearings had given way and they have replaced them. The noise disappeared when the pump was put into operation after the repair. You thought that the problem had been solved. However, 4 weeks later, the same noise came back. Once again, you request for the pump to be repaired by the Maintenance Department which found the same problem with the pump bearings. You noticed that before the plant shutdown, these bearings could last for 1 year.

Your Boss, Mr, Ben Tan, thought that this was more like a chronic problem and the maintenance people were just solving the symptoms and not the causes. The problem had since led to losses of equipment time and increased overhead costs for your Department as the replacement of the pump bearings were charged to your Department each time. The economy was not good at the point in time and every dept had been asked to think of cost saving measures to cut down overhead cost. The General Manager issued an order asking the following departments to think of ways to cut down the overhead cost by 10 %: Maintenance Dept, Utilities Dept, Purchasing Dept and Production (Process) Department.

For your department, the immediate task was to solve the cooling water pump problem. Mr. Ben Tan, asked you to form a task force comprising representatives from the Production, Maintenance, Utilities and Purchasing departments to investigate into the root cause of the problem. The Maintenance Department had not been able to identify the root cause of the problem. This was not a typical process problem as you had seen before.

In order to investigate the root cause, you thought that it would be helpful if you have a better understanding of the centrifugal pump and the functions of its components. Hence, you and your technicians decided to dismantle a centrifugal pump that was used for training in the Maintenance Department to gain a better better visualisation of the pump's internal components.
The procedures for dismantling and assembling the centrifugal pump are given in Appendices 1 and 2 of your practical manual.

You had also decided to apply the Systematic Problem Solving technique which you have learnt recently to help you define the problem and identify the possible root causes. The concept behind this technique is shown in appendices 3 and 4 of your practical manual.

Providing the rationales and clear learning outcomes of the contextualised practical

As mentioned above, the traditional way of teaching practical involved a set of experimental objectives and a set of procedures to be followed. The purpose of conducting a particular experiment is usually not spelt out explicitly. The learning outcomes at the end of the practical are also not mentioned. Likewise, the relevance of the experiment to applications in the work place is usually not highlighted to the students. As a result, students find it difficult to associate what they have learnt with what they see at their work place. In some cases, they cannot even see the rationale of performing the practical and most of them simply go through the motion, taking it as part of the many requirements needed for them to graduate from the course. In a matter of weeks, they will have no impression of the practical sessions. Brent & Felder (1992) noted that a necessary condition for most students to adopt a deep approach to learning is the understanding of the relevance of the subject to their lives. Hence, at the contextualised practical briefing, the following rationales and expected learning outcomes were explained to the students:

Rationales of the practical

1. Practise systems thinking using the Job Safety Analysis to identify Job hazards and precautions involved in the dismantling and assembling of a 12-inch (Impeller diameter) gland-packing centrifugal pump.
2. Practise process problem solving through a case study which involves the use of problem descriptions to identify problem, to write problem statement and to identify a list of potential causes.

Intended learning outcomes of the contextualised practical.

At the end of this practical you are expected to have

1. Enhanced abilities to make relevant and appropriate observations.
2. Enhanced abilities to apply the knowledge and theories learnt to explain the observations made during the practical.
3. Enhanced abilities to use systems thinking to analyse processes and make inferences.
4. Enhanced abilities to identify, define and solve problems in a systematic way.

Approach Used In Systems Thinking Training.

The systems thinking training adopted here is that of hands-on approach. Students were asked to dismantle an industrial-scale centrifugal pump to investigate the functions of different parts of the pump. A summary of systems thinking assessment used during the practical is shown in Table 2.

Table 2
Summary of Systems Thinking Assessment
For 2nd Year Students of the Singapore Polytechnic Diploma in Chemical Engineering Course

Pre-practical assessment 1. Identify the major parts of the pump with reference to figure given. (6 major parts, namely, impeller, motor, coupling, casing cover, bearing housing and bearing cover). Students will be picked at random to identify the parts. Requirements: You are required to refer to the module website to view "Parts of the centrifugal pump" in interactive PowerPoint format as well as the "Pictorial Guides to help you visualise the Centrifugal Pump Dismantling Procedures". 2. Identify the sequence of removal of these major parts (mentioned above). Requirements: You are required to refer to the video on dismantling and assembling of centrifugal pump in the module website Practical Folder to help you to visualise the sequence of removal of major parts. 3. Identify the potential job hazards and the prevention methods for the major parts to be removed during the dismantling process. The following questions help you identify the job hazard systematically: (i) **What** is to be removed or to be done? (ii) **How** do you remove it ? (iii) If you remove it in such a manner, **what** could be the potential hazard that you may face? (iv) **How** do you prevent such a potential hazard identified in (iii)?
In-class assessment 1. Examine and study the various parts of the pump and answer the following questions: a) What is the system that is being studied? b) Identify the various elements (parts) that can affect the behaviour of the system being studied. c) Describe how each of these elements or factors influence the behaviour of the system. d) Describe how these elements affect one another. 2. Applying systems thinking, explain what will happen to the pump motor if suction valve to the pump casing is shut off for a long time during operation? (Use basic concepts learnt in the Applied Electricity and Electronics to explain).

Figure 1 shows the activities during the training of systems thinking and problem solving skills

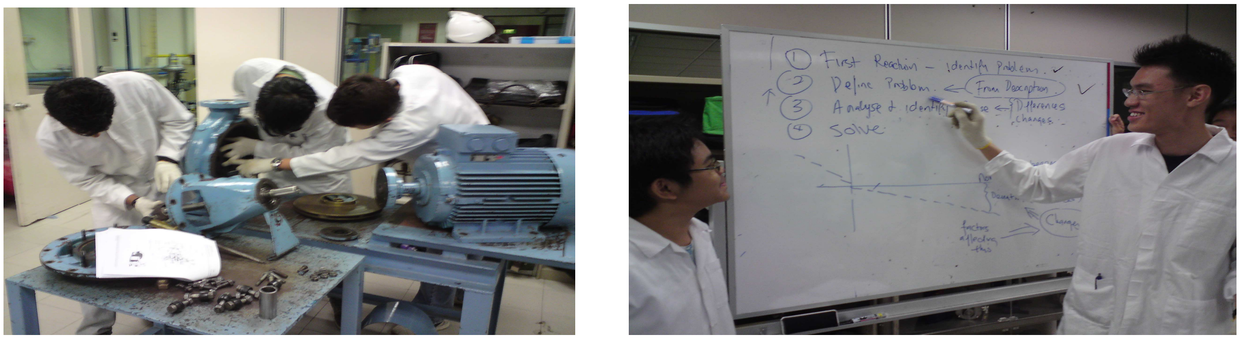

Figure 1. Practical activity for systems thinking and problem solving

The systems thinking exercise provided in the practical enable students to learn how different parts of the pump can affect one another. This is depicted in Figure 2 shown below. The arrow shown in the figures showed that it affect the part it pointed. For example, the arrow from the pump's gland was pointed to the pump packing, which means that the gland can affect the performance of the pump packing. Similarly coupling is arrowed to the motor, which means that the coupling can affect the motor of the pump.

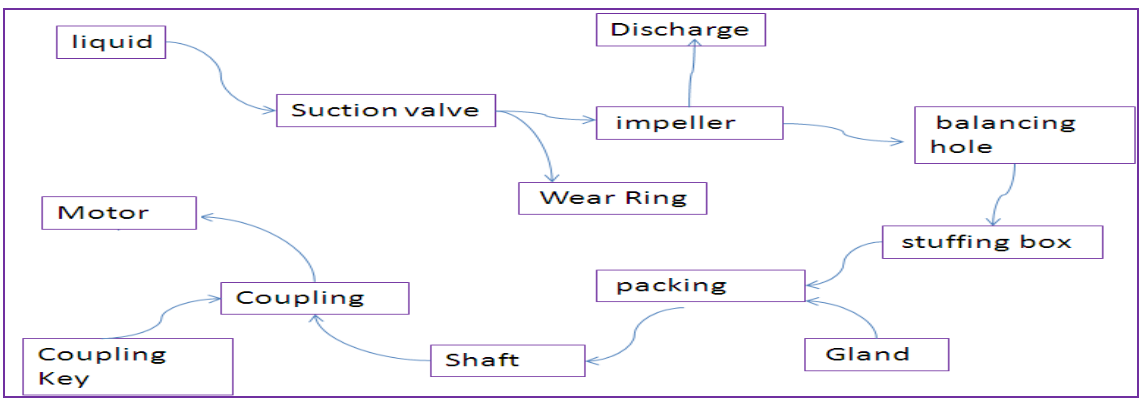

Figure 2. Inter-relationship between the different parts of a centrifugal pump

Approach Used In Systematic Problem Solving Training

There are many approaches to problem solving, depending on the nature of the problem and the people involved in the problem. Marquis (2006) described the systematic problem solving approach used which is based on Kepner Tregoe Analysis. The principle behind this problem solving technique is depicted in Figure 3 shown below. A set of simulated data was provided to the students as shown in Figure 4.

Personally, I had used Kepner Tregoe Analysis successfully to solve a couple of problems in the industry that I had worked, whereby the causes of the problems originated from external sources outside the process. For example, I had to bear with the large amount of rework on the products (Printed Circuit Board) produced from the electroplating process that I was looking after. The symptoms of the problem largely manifested in the electroplating process. This had incurred a lot of overtime and high rework cost for the department. The monthly reject rate from the process increased dramatically from 0.5% to 16%. The problem was chronic in nature as it lasted for almost 12 months. Although my initial feeling was that the problem was not created at the electroplating process, I was never able to prove it until I adopted the systematic problem solving approach. With this approach, the root cause of the problem was traced to stemming from the CNC (Computer Numerical Controlled) drilling process. This was the process before the electroplating process. One of the drilling parameters was lowered by the process owner.. To verify the suspected root cause, the drilling parameter concerned was adjusted back to the original value and the reject rate fell back to 0.5% which was the acceptable rate. The 12-month old problem was solved!

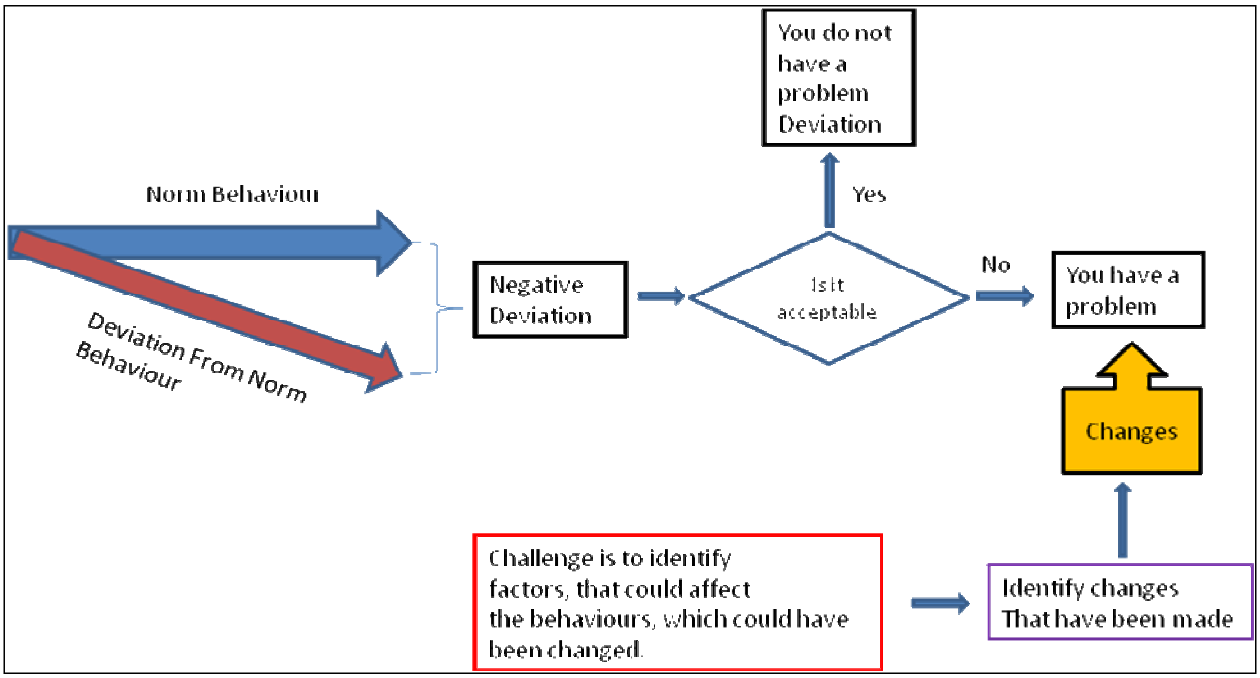

Figure 3. Principle of the problem solving technique

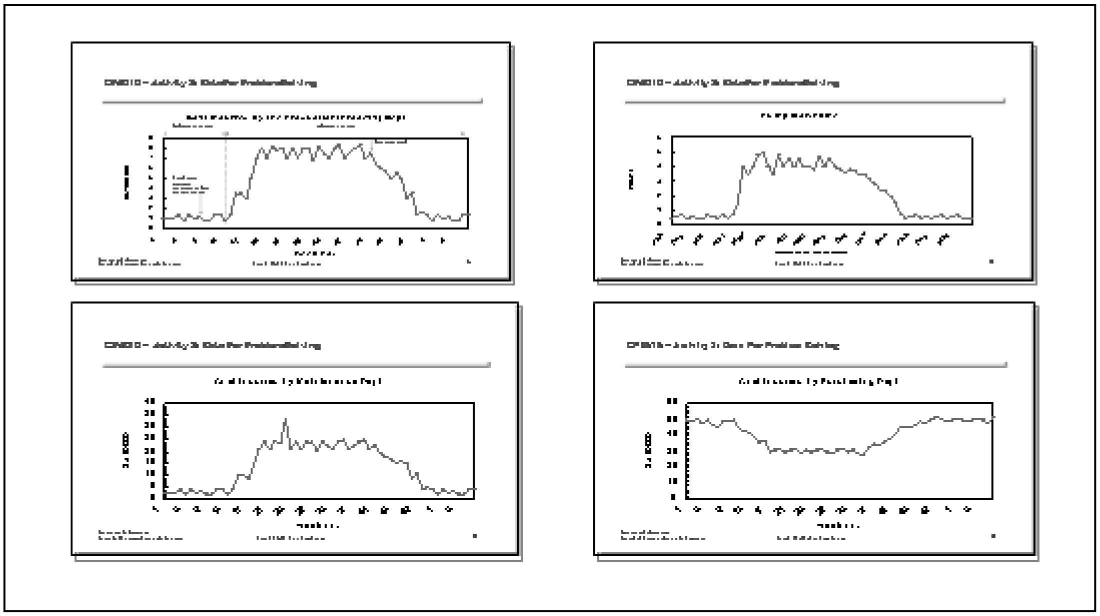

Figure 4. Simulated data for problem solving

The students were introduced to the seven steps involving problem solving namely:

a. Identifying the problem
b. Defining the problem
c. Describing the problem using template provided
d. Analysing and identifying potential causes
e. Verifying potential causes
f. Taking appropriate actions
g. Monitoring results

These steps were also described in the guidelines provided to them at the practical briefing. With reference to the contextualised case scenario (Table 1) and the systems thinking exercise done at the earlier part of the practical activities, the students proceeded to identify, define and describe the problem and identify the potential causes. The hands-on practice stops at step (d) as this is a simulated case. The results of the problem solving analysis were translated onto the problem solving template provided for them as shown in Table 3.

Table 3
Template of the Results of the Problem Solving Analysis.
2nd Year of the Singapore Polytechnic Diploma in Chemical Engineering Course

Norm _Bearing life lasted 1 yr Deviation: Bearing life lasted 4 weeks					
Problem Statement: Shortening of pump bearing life from 1 year to 4 weeks					
Dimensions	**Is**	**Is Not**	**Differences**	**Changes**	**Possible causes**
What: Problem Unit. **What: Defective unit**	Cooling water pumps Pump bearing	Compressor, blower, exchanger Bearing cover loose. Gland Loose	Different unit operation Different parts of the pump	Maintenance works carried out. Parts are replaced during the shutdown maintenance	NA NA
Where:	Pump bearing housing	Gland Motor Pump casing Coupling Packings	Different parts of the pump	Maintenance works were done and pump bearings were changed.	NA
When:	After the maintenance	Before maintenance	Maintenance works carried out.	• Type of Bearing • Lubrication oil • Lubrication oil level • Bearing Materials • Supplier of bearing • Suppliers of lub oil • Speed of turning	• Wrong type of bearing used. • Wrong lub oil • Wrong oil level • Wrong material • Wrong supplier • Wrong speed
How much/ How often	every 3-4 weeks	1 year	More often replacement of bearing	• Type of bearing • Bearing material • Supplier of bearing • Material of bearing	• Wrong type of bearing used. • Wrong material • Wrong supplier

EVALUATION

A survey was conducted to determine if the students were aware of the skills practised and whether these skills have benefited them in one way or another. The survey consists of the following questions:

1. I am aware that the systems thinking and problem solving skills are being practised in my practical.
2. I understand the usefulness of systems thinking and systematic problem solving skills in my learning and development as a technologist.
3. I am now better equipped to analyse a process or a system dynamics using basic and logical questioning and therefore able to infer factors that could influence the behaviours of the process or system.
4. I am now better able to see the inter-relationships within a system. (For example how one part of the pump affects other parts of the pump.)
5. I am now better able to use a set of descriptions (What, where, when, how often) to identify a problem and define the problem using a problem statement.
6. I am now better able to identify the possible changes made and list down a set of possible causes to a systemic problem.

Students were asked to provide a response to each question using a 5-point scale from 1(Strongly disagree) to 5 (strongly agree).

RESULTS

From the survey results, 54 students out of a total of 60 students responded to this survey. This gave a 90% response rate.

Figure 5 shows the response to question 1 - 81% and 78% of the students respectively agree and/or strongly agree that they were aware that systems thinking and problem solving skills, are being practised in the practical.

Figure 6 shows the response to question 2 - 80% and 76% of the students respectively agree and/or strongly agree that through this practical they were aware of the usefulness of systems thinking and problem solving skills in their learning and development as technologist.

Figure 7 shows the response to question 3 - 74% of the students agree and/or strongly agree that through this practical, they are better equipped to analyse a process or a system dynamics using basic and logical questioning. They were able to better infer factors that could influence the behaviours of the process or system.

Figure 8 shows the response to question 4 - 78% of the students agree and/or strongly agree that through this practical they were able to see the inter-relationships within a system better.

Figures 9 shows that 70% of the students agree and/or strongly agree that they were better able to use a set of descriptions (What, where, when, how often) to identify a problem and define the problem using a problem statement.

Lastly, Figure 10 shows that 66% of the students agree and/or strongly agree that they were now better able to identify the possible changes made and list down a set of possible causes to a systemic problem.

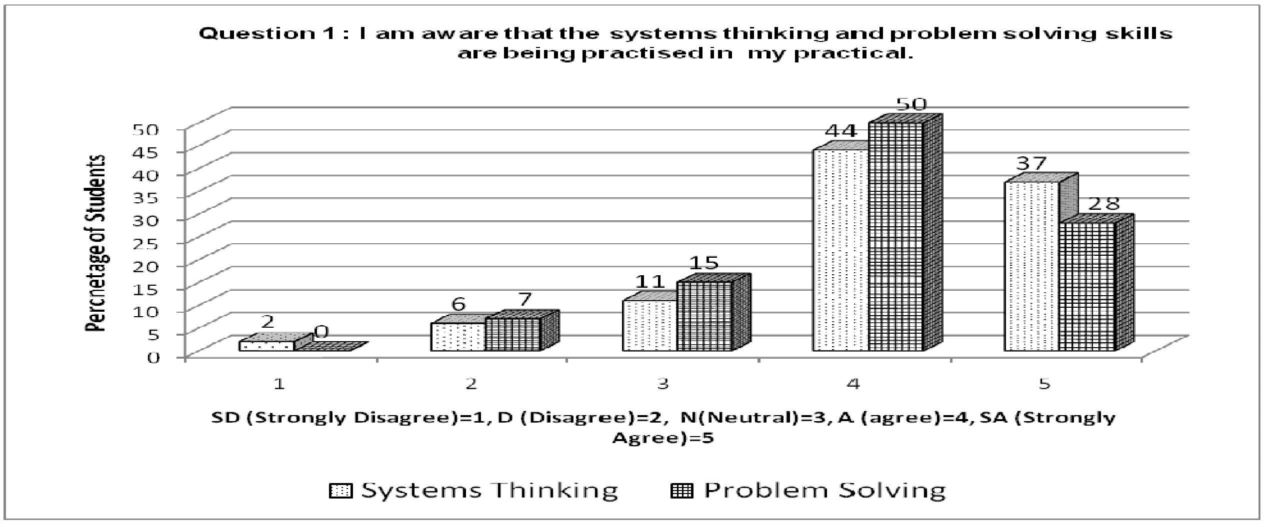

Figure 5. Response to survey question 1

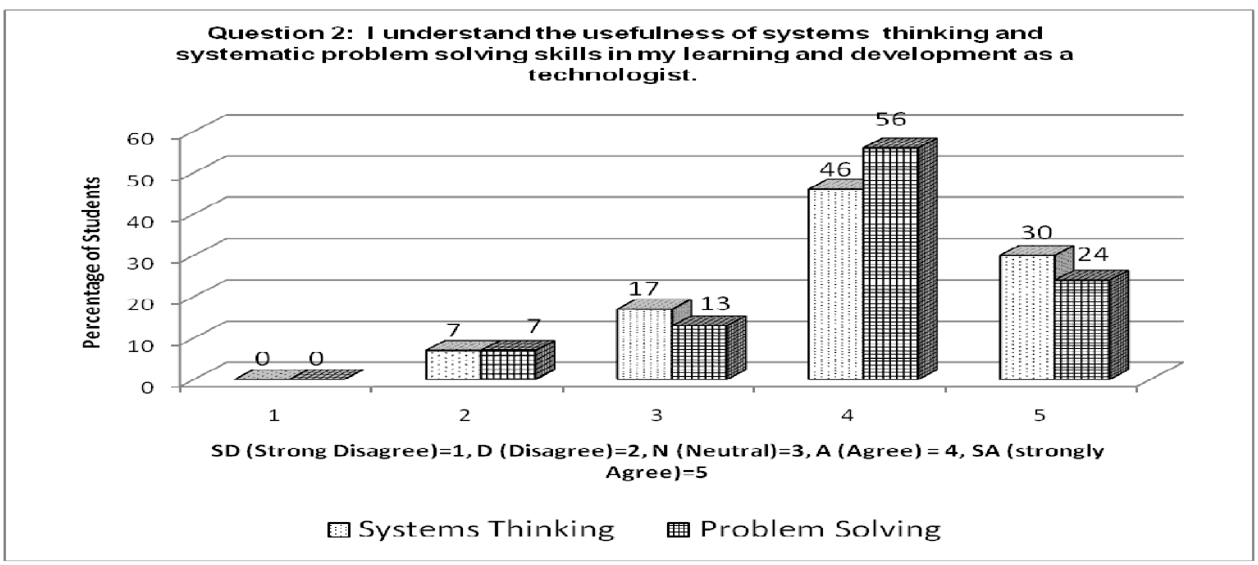

Figure 6. Response to survey question 2

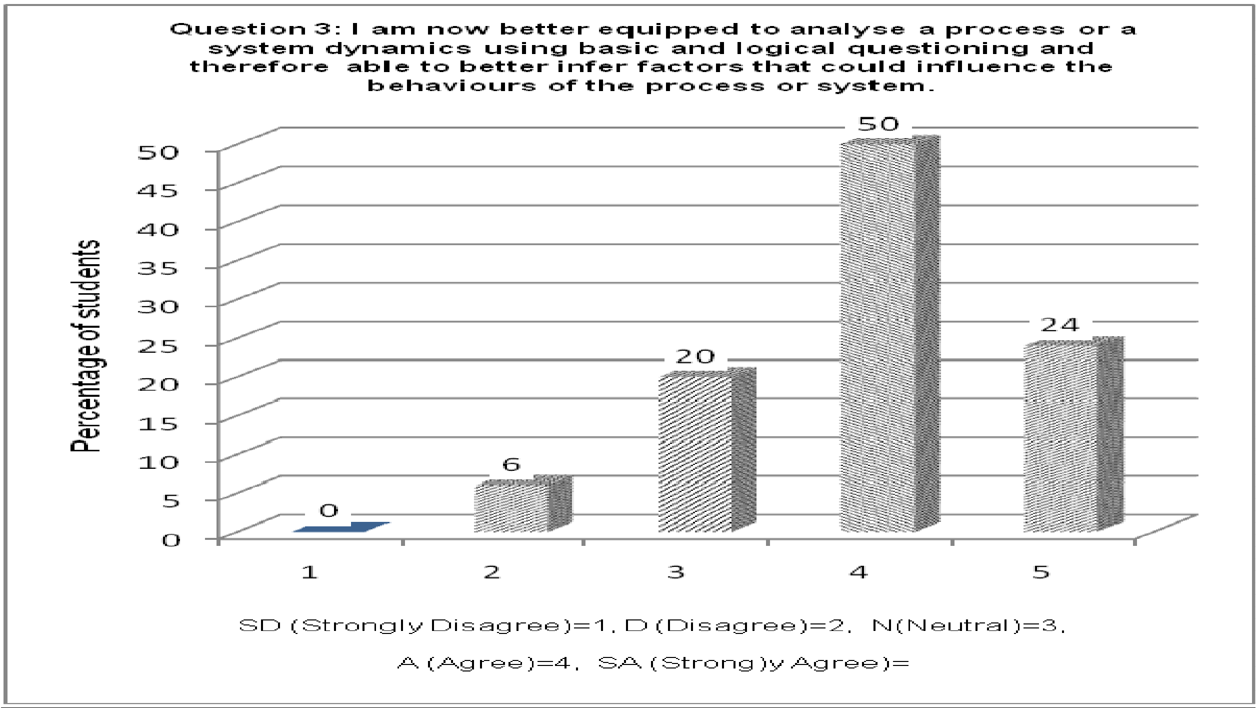

Figure 7. Response to survey question 3

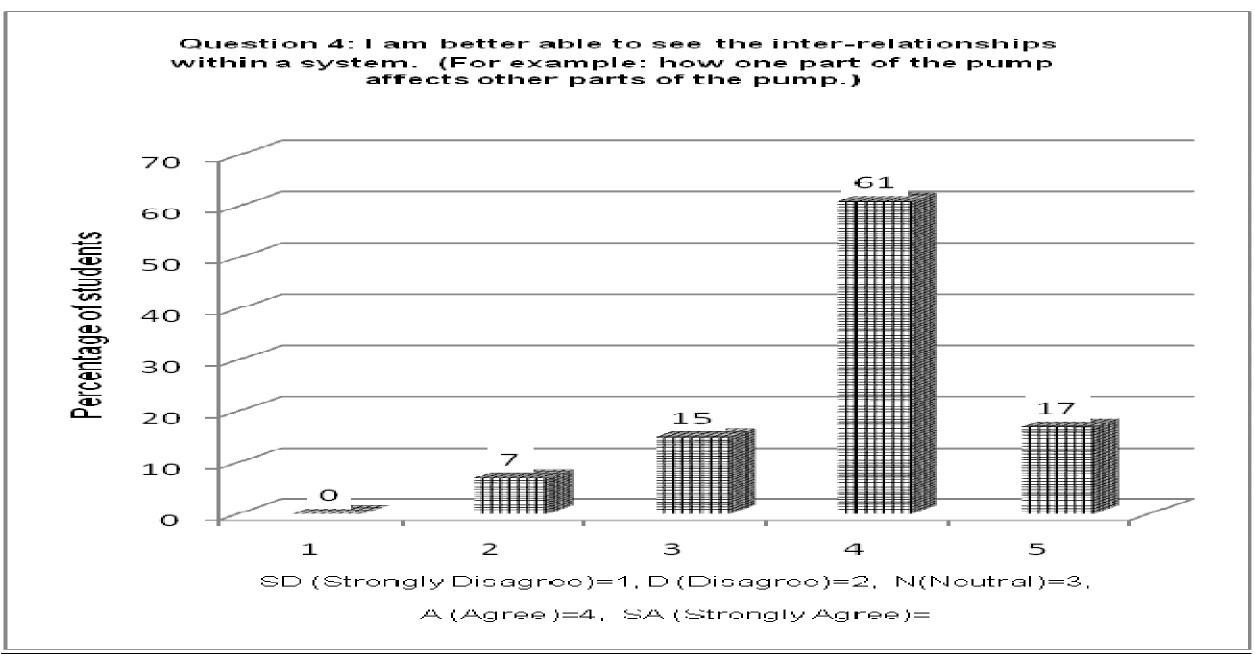

Figure 8. Response to survey question 4

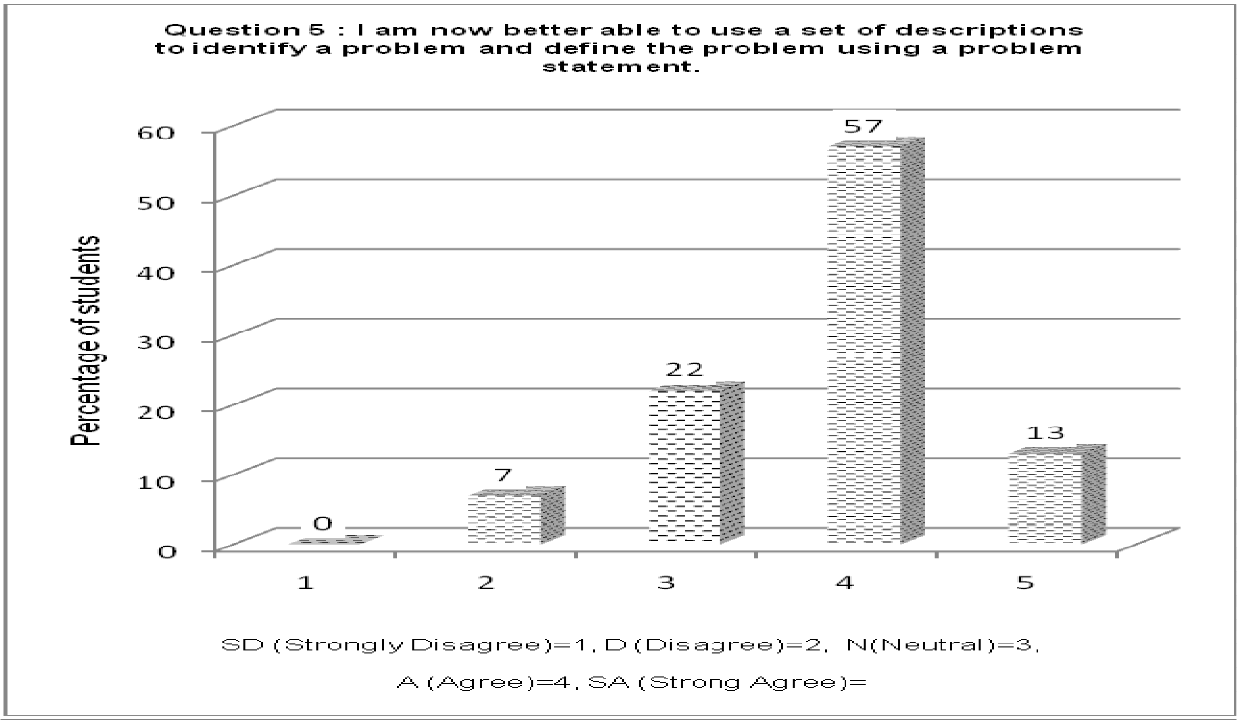

Figure 9 Response to survey question 5

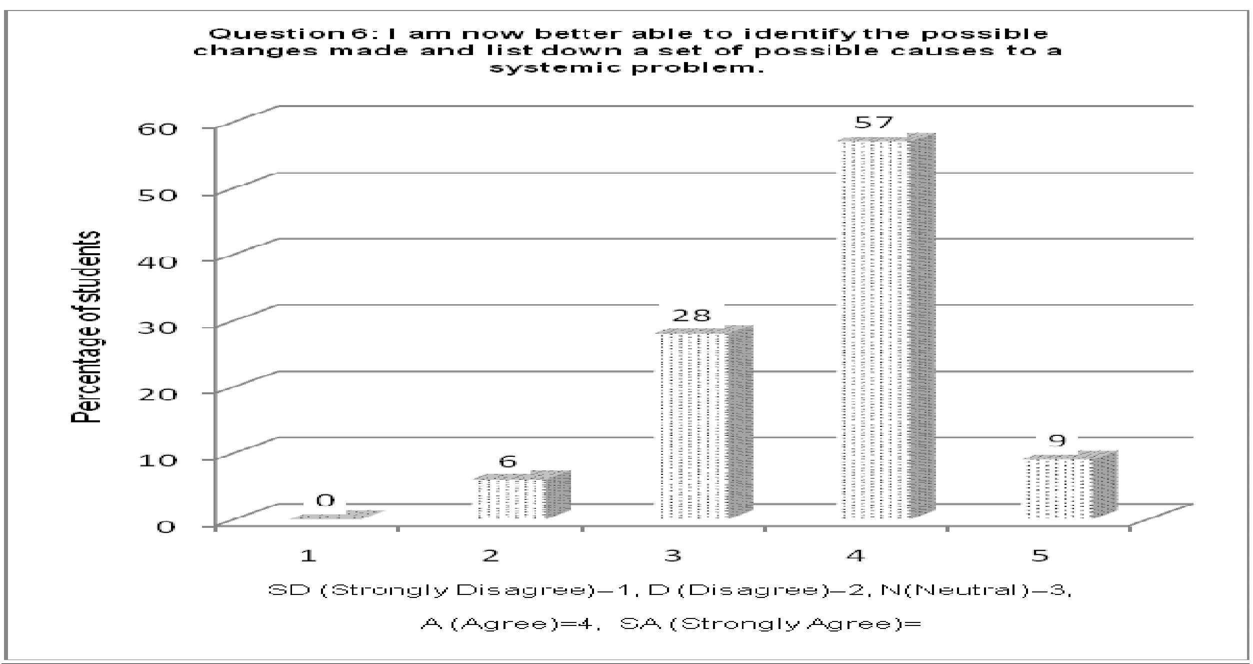

Figure 10. Response to survey question 6

DISCUSSION

The survey's response rate of 90% is encouraging as it indicated the students' willingness to be involved in such skill training during the practical. The survey results indicated that students enjoyed the skill training and new way of assessments during practical. They were not only enthusiastic but also highly receptive to the new learning approach, even though it was more rigorous and time consuming to them compared to the traditional way.

In my opinion, the structured activities carried out in such a manner had made students more mindful of the skills being practised and the importance as well as the usefulness of such skills to the real world context. The relatively higher scores in the responses to questions 1, 2 3 and 4 could be due to the following being carried out before and during the practical.

Before the practical

- Explaining the rationale of using scenario-based practical activity.
- Explaining the learning outcomes of each practical activity.
- Showing the skills Map for the practical.

During the practical

- Providing equal opportunities for all students to practise the skills.
- Asking of prompted questions to guide students' thinking.
- Demonstration of poor thinking process.
- Students' experiences in making inferences without referring to any textbook or references.
- Sharing of real working experiences with students.
- No undermining of students' capabilities
- Exhibiting passion and commitment in conducting such practical training
- Acknowledging every response or answer provided by students

As Cotton (1991) noted, "Research shows that positive classroom climates characterised by high expectations, teacher warmth and encouragement, pleasant physical surroundings and so on, enhance all kinds of learning"

From the survey results, the responses to questions 5 (I am now better able to use a set of descriptions (What, where, when, how often) to identify a problem and define the problem using a problem statement), and question 6 (I am now better able to identify the possible changes made and list down a set of possible causes to a systemic problem), received the lowest score compared to the other 4 questions. Why is that so? The studies by Brent & Felder (2003) implied that skills training take time to master, just like the skills involved in cycling and swimming. Cotton (1991) highlighted in her report that Pogrow (1987) noted, "It takes an extensive amount of time to produce results: at least 35 minutes a day, four days a week, for several months, for true thinking skills development to occur".

What is said by Pogrow in Cotton's report and what is implied by Brent and Felder could be part of the reasons for the relatively lower score in the response to question 5.

Other reasons for the relatively lower score in the response to question 6 could be the possibility that students do not like to think and are constantly asking the lecturers for advice and answers. Many students basically just want to know what they need to know for examinations or tests.

As an educator, I often find myself wondering about such a phenomenon. Most students are dumbfounded when presented with a new problem or scenario they have not encountered before, not knowing what to do or even how to begin tackling the problem. More often than not, they throw in the towel after staring at the problem for a few seconds. The more persistent ones would probably turn to the lecturers for guidance on how to break down the problem. Invariably, when questioned about why they were unable to handle the problem, the unanimous response was "My lecturer hasn't taught me this yet, that's why I can't do it." This then points to the fact that these students are unable to think independently.

Are they too lazy to think? Maybe they do not have the courage to attempt a new problem without 'proper' step-by-step guidance from the lecturers? Or perhaps they have not been trained to think independently since answers and correct methods are often spoon-fed to them? These are a few questions one can ponder about. In today's fast-paced society where every individual is embroiled in a rat race to maintain a competitive edge over another, convenient and quick answers are everything. Seeking solutions in the fastest possible way seems to have eroded the importance of deriving them on one's own. After all, it is the results that matter, not the process. Unfortunately, such a mindset appears to be deeply entrenched in the mainstream, and is perhaps especially reinforced by an education system that places a premium on academic excellence and leaves failures languishing in the dust.

Sometimes, I cannot help but think that the education system in the last few decades may be partly responsible for the lack of thinking skills in our students. From primary one, students begin their mad rush to attain top scores in primary level national examinations, the highest number of distinctions in the secondary level national examinations and the prestigious scholarships that are awarded to mostly academically outstanding students after the 'A' Level (post-secondary level) national examinations. There is no time to think, much less experiment and fail. Students accept whatever they are taught blindly without bothering to question. They stick rigidly to the correct methods of solving problems or the correct procedures of doing experiments, request for immediate answers when facing novel problems and proceed to do tons of past-year papers to gain confidence before sitting for examinations. It is a learning cycle that has been unknowingly inculcated in them from a tender age of seven and remains deep-rooted even when they encounter new challenges in work life that require different approaches. In such situations, students are at a loss simply because they have not been trained to process the problem by themselves, identify the causes and deduce strategies to eradicate the root cause. And regrettably, the negative consequences of such a lack of training only manifests later in life when complex problem solving skills are required. In this information age, I think it's time to shove academic grades aside and focus instead, on the vital thinking skills that will mould an individual's mind and sharpen his thinking process. It is important for students and educators alike to realize the importance of systems thinking, a crucial skill that will empower a student to solve any type of problem in his or her life.

Cotton (1991) at the beginning of her report quoted Deborah Gough's words as:

“Perhaps most importantly in today's information age, thinking skills are viewed as crucial for educated persons to cope with a rapidly changing world. Many educators believe that specific knowledge will not be as important to tomorrow's workers and citizens as the ability to learn and make sense of new information”. (D. Gough, 1991)

CHALLENGES FACED IN CONDUCTING SUCH TRAINING

One of the challenges faced is deciding that amount of time to be devoted to such training in order for the students to internalise the skills. The time allocated for the practical activities may not be sufficient enough for students to emerge with a firm grasp of the skills. However, as Cotton (1991) noted, the time requirements will differ for different students, and experience shows that some students become adept thinkers without any explicit instruction. Nevertheless, the contextualised practical mentioned in this paper aims to provide fundamental exposure to these soft skills which can be further polished and sharpened if students make conscious efforts to practise and apply them in different situations. They will gradually become unconsciously competent in doing so.

Given the kind of time demand for the inculcation of such skills,, conducting meaningful thinking skills activities clearly requires a high level of staff commitment and administrative support. The task of providing more real world contextualized learning experiences is not easy as it requires more time and effort from the academic staff. More time is needed to prepare and conduct test runs on the practical activities before introducing them to the students. Assessments have to be redesigned to assess the thinking skills instead of just knowledge. The style of teaching the practical also has to be modified. A staff who is less experienced might face difficulties in developing real world contextualised practical activities. Similarly, the students might find it difficult to imagine themselves working in the company as they do not have the actual working experience. A lot of guidance has to be given to the students when it comes to the systematic problem solving.

Another significant challenge faced is changing the mindset of staff. Staff has to believe that such skills can be taught in school before a thinking culture can be created. It is quite common to hear a staff lamenting that it is difficult to teach such skills as students are already used to the traditional approaches of teaching before coming to the polytechnic. However, it is important for staff to understand that they need to persevere as it takes time for the students to master the skills well.

CONCLUSION

The typical way of teaching problem solving in chemical engineering education placed emphasis on the technical troubleshooting of process plant problem. There was little or no emphasis on the problem solving approach that takes into consideration contributing factors from external sources. Hence, it is my belief that students should be exposed to systematic problem solving besides technical troubleshooting in order to develop a more holistic outlook at potential problems faced in the real world.

To accomplish that, it is important that students and staff understand the increasing need to improve chemical engineering education so that it encompasses not just the transfer of knowledge but also inculcating students' mastery of skills that are necessary to solve challenging multidisciplinary problems in the real working world. The continual inculcation of such skills in students, in my opinion, would help them jump start their careers when they work in the industries.

ACKNOWLEDGEMENT

I would like to express my gratitude to Dr. Lee Kim Lian for her helpful review of a draft of this paper.

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