The Impact of Problem-based Learning on Students' Competencies in Technical Vocational Education and Training

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THE IMPACT OF PROBLEM-BASED LEARNING ON STUDENTS' COMPETENCIES IN TECHNICAL VOCATIONAL EDUCATION AND TRAINING

BY
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AALBORG UNIVERSITY
DENMARK

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TITLE

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Dissertation submitted

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CV

I am Hashim bin Mohamad. I have followed the PhD study programme at Aalborg University, Denmark in January 2013 and finished in December 2016. I am a Principal Technical Training Officer at the German-Malaysian Institute, Kajang Selangor, Malaysia. I have my Industry Meister Metal Diploma (1992) from Industrie- und Handelskammer, Nurnberg, Germany, Degree in Bachelor of Mechanical Engineering (2003), Universiti Teknologi Malaysia, Kuala Lumpur and Master of Science in Engineering Business Management (2009), University of Warwick, U. K. I have five years of experience in the manufacturing industry as mould & die designer before with the German-Malaysian Institute as a lecturer. My research interests are in problem-based learning (PBL), project-based learning etc., Technical Vocational Education and Training (TVET) and engineering education.

ENGLISH SUMMARY

The German-Malaysian Institute (GMI) located at Kajang Selangor, Malaysia is one of the Technical Vocational Education and Training (TVET) providers that have played a significant role in producing highly skilled graduates to serve the needs of industry in Malaysia. In the era of globalization, generic knowledge is essential in order for the individual to stay competitive and tuned into the rapid changes of technology (Cheng Hwa et al., 2009; NCVER, 2003). Studies show most employers in the industry prefer employees or workers who possess not only technical skills but also generic skills relevant to the profession.

Traditional education is not up to the challenge of developing a competent workforce (Cheng Hwa et al., 2009). Knowledge of innovative technologies demands a change in the learning approach that can enhance student's generic skills. Studies show that Problem-based Learning (PBL) is highly successful in educating students "learning how to learn" and in developing a positive attitude towards learning. PBL is an innovative learning method that is well-known in medicine, health sciences, and engineering. PBL is gaining prominence not only in higher engineering education but also in TVET, like GMI. PBL has added a new dimension to the TEVT approach, emphasizing more on hands-on training. It is important to assess and understand the students' perceptions, motivations, and awareness as well as the challenges of PBL approach in the TVET.

This study fills a research gap by investigating the impact of a PBL approach to students' learning, technical and social competencies in TVET. The study focuses on the PBL that is newly implemented in the Computer Numerical Control (CNC) programming courses at the GMI. The subjects for this study comprised of 132 Diploma students of semester three and four from the GMI who had attended the 75 hours of Computer Numerical Control (CNC) Programming course.

The study uses an experimental research set-up employing a mixed methods with concurrent triangulation strategy comprising quantitative and qualitative approaches. The quantitative section entails a quasi-experimental design with five instruments: a questionnaire, pre-test, post-test, programming test one and programming test two. The qualitative section follows the example of the ethnographic approach with three methods of data collection namely group interview, researcher's/participants' observations and content analysis. The analysis of qualitative data was done using open coding, axial coding, and selective coding. "Teamwork" was identified as the central theme in the enhancement of students' learning, skills, and knowledge in PBL's learning environment.

The findings of this study show that the PBL approach has been successfully implemented at GMI. The "Teamwork" is chosen as the central theme of importance in promoting the PBL approach among students in the CNC programming courses. The choice was based on the triangulation of qualitative as well as the quantitative data analysis and on the fact that in PBL students were always observed working and studying in groups.

Triangulation of data showed that the students were pretty much aware of PBL and its benefits towards learning. They were highly motivated and had a positive perception about PBL although there were some negative perceptions by small among of students and some weaknesses in some aspects during the PBL implementation. Findings from this study suggest that the level of students' awareness and motivation in PBL were not influenced by the level of students in the semester. The majority of students stated that "time constraint" was the obstacle when learning with PBL approach.

Analysis of paired sample t-tests revealed that students of both semesters three and four had significantly higher scores on their post-test than the pre-test (p = .000). The outcomes of the independent samples t-test revealed that the group of students in both semesters three and four with high Cumulative Grade Point Average (CGPA) scored higher than the low CGPA in both the pre-test and post-test as well as in the programming test one and two. This research finding also revealed that the PBL approach was well accepted by students having a high score in CGPA and students who really participate in learning and worked to solve the problem. This situation indicated that the students' CGPA scores seem to have some relationship with the performance of students learning in the PBL approach. The simulator has benefited the students in assisting them to solve the programming test two and increased the students' centeredness in PBL.

Overall, the findings of this study suggest that PBL has a positive impact on students' learning, technical and social competencies in the TVET. However, more studies to further confirm these findings are highly recommended.

DANSK RESUME

Det tysk-malaysiske Institut (GMI) i Kajang Selangor, Malaysia, er en af de teknisk erhvervsuddannelser (TVET), der har spillet en væsentlig rolle i at producere højt kvalificerede kandidater til at opfylde behovene hos industrien i Malaysia. I en tid med globalisering, er generisk viden afgørende for at den enkelte kan forblive konkurrencedygtig og parat til de hurtige ændringer i teknologien (Cheng Hwa et al., 2009, NCVER, 2003). Undersøgelser viser, at de fleste arbejdsgivere i branchen foretrækker medarbejdere, der ikke blot besidder tekniske færdigheder, men også generelle færdigheder for professionen. Traditionel undervisning er ikke i stand til at takle udfordringen med at udvikle en kompetent arbejdsstyrke (Cheng Hwa et al., 2009). Kendskab til innovative teknologier kræver en ændret læringstilgang, hvormed man kan forbedre de studerendes generelle færdigheder. Undersøgelser viser, at problembaseret læring (PBL) udvikler de studerende så disse er i stand til at "lære at lære", og samtidig udvikle en positiv holdning til læring. PBL er en innovativ læringsmetode, der er kendt inden for medicin, sundhedsvidenskab og teknik. PBL får stadig større anerkendelse, ikke kun i højere ingeniøruddannelse, men også på TVET, lige som GMI. PBL har tilføjet en ny dimension til undervisningen på TEVT, herunder mere hands-on træning. Det er vigtigt at vurdere og forstå de studerendes opfattelser, motivation og viden samt de udfordringer, en PBL-tilgang på TVET giver.

Denne undersøgelse udfylder derfor et forskningshul, da den undersøger virkningen af en PBL-tilgang på de studerendes læring samt tekniske og sociale kompetencer på TVET. Undersøgelsen fokuserer på PBL, der for nyligt blev implementeret i Computer Numerical Control (CNC) programmeringskurser på GMI. Undersøgelsen består af 132 Diplomstuderende på semestret tre og fire fra GMI, der havde deltaget i et 75-timers Computer Numerical Control (CNC) programmeringskursus.

Undersøgelsen blev designet som eksperimentel forskning og benytter sig af en blandet metode omfattende både kvantitative og kvalitative metoder samt triangulering. Den kvantitative del er et kvasi-eksperimentelt design med fem instrumenter: spørgeskema, pre-test, post-test, programmeringstest et og programmering test to. Den kvalitative del anvendte en etnografiske tilgang med tre dataindsamlingsmetoder: gruppeinterview, forskers / deltagernes observationer og indholdsanalyse. Analysen af de kvalitative data blev udført ved hjælp af åben kodning, aksial kodning, og selektiv kodning. "Teamwork" blev identificeret som en central tema til forbedring af de studerendes læring, færdigheder og viden i PBLlæringsmiljøet.

Resultatet viste at PBL var blevet implementeret med succes på GMI. ”Teamwork” blev valgt som det centrale tema til at fremme PBL blandt studerende i CNC

programmeringskurset. Valget var baseret på trianguleringen af kvalitative og kvantitative data analyse samt det faktum at PBL studerende altid blev observeret mens de arbejdede og studerede i grupper.

Triangulering af data viste, at de studerende var temmelig opmærksomme på PBL og dets fordele for læring. De var meget motiverede og havde en positiv opfattelse af PBL selv om der også var nogle negative opfattelser blandt ene mindre andel af studerende og svagheder i nogle aspekter under gennemførelsen af PBL. Resultaterne fra undersøgelsen tyder på, at niveauet for de studerendes viden og motivation i PBL ikke var påvirket af de studerendes niveau gennem semesteret. De fleste af de studerende, mente at "tidspres" var den primære forhindring i PBL.

En t-test analyse viste, at de studerende på både semester tre og fire havde signifikant højere score på deres post-test end den præ-test (p = ,000). Resultaterne af den uafhængige stikprøve t-test viste, at gruppen af studerende på både semestre tre og fire med høj CGPA (Cumulative Grade Point Average) scorede højere end den lave CGPA i både præ-test og post-test samt i programmeringen test et og to. Undersøgelsen viste også, at de studerendes CGPA påvirkede de studerendes læring i PBL og som også anført, er PBL mere succesfuld for studerende med gode akademiske resultater og studerende, der virkelig deltager i læringen og arbejdet med at løse problemet. Samlet set tyder resultaterne af denne undersøgelse på, at PBL har en positiv indvirkning på de studerendes læring af tekniske og sociale kompetencer på TVET. Simulatoren har hjulpet de studerende til at løse programmering test to og den har øget de studerendes fokus i PBL.

Generelt viser studiet at PBL hare n positive effekt for de studerendes læring samt tekniske og sociale kompetencer i TVET. Men flere undersøgelser er nødvendige for at bekræfte disse resultater.

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CHAPTER 1. INTRODUCTION

1.1. BACKGROUND OF STUDY

Most industries worldwide and in particular in Malaysia have a great need for a highly skilled workforce graduates from higher education institutions as well as Technical Vocational Education and Training (TVET). New and emerging technologies will continue to have an impact on Malaysia's industrial and economic development according to MITI, (2006). In the era of globalization, the need for knowledge manpower with generic attributes is essential in order for the individual to stay competitive and relevant with the rapid changes of technology (Cheng Hwa et al., 2009; National Centre for Vocational Education Research (NCVER), 2003).

There have been many discussions locally and internationally about graduates lacking in attributes of generic skills as required by the job market resulting in a low rate of employability. Many studies for instance Jones (1997), Kanapathy (2001), Lee et al. (2001), Pumphrey & Slater (2002), Curry et al. (2003), Borthwick & Wissler (2003), Crebert et al. (2004), Khir (2006), Noordin et al. (2009), Jones (2009), Li (2011), Singh et al. (2013) and Winterbotham et al. (2014) have discovered that employers are not satisfied with the generic skills possessed by graduates. A study entitled "Future of Engineering Education in Malaysia" was conducted in 2006 under the auspices of the Ministry of Higher Education, on 422 employers in Malaysia, regarding their expectations and satisfaction levels of the graduates that they have employed (Hassan et al., 2007). The study indicated that employers were very much concerned with improving the competencies of engineering graduates such as, the ability to undertake problem identification, formulation and solution, the ability to communicate effectively, teamwork, ability to utilise a systems approach to design and evaluate operational performance.

In November 2011, a survey was conducted on 571 human resource managers by JobStreet.com, a Malaysian employment agency. The study revealed that employers were unable to employ graduates due to their poor communication skills and lack of command in using English (Izwan & Zurairi, 2012). The Director of the Division Development and Student Affairs of the Ministry of Higher Education, Prof. Dr Mohd Fauzi Ramlan stated that issues causing difficulties in the employment of graduates were weakness in solving problems, job-switching and a lack of self-confidence (Bernama, 2012).

Research conducted by Ramlee (1999), found that, although Malaysian's graduates had equipped themselves with technical skills yet; they were unable to convince the employers of their suitability for the job because they lacked generic skills such as communication, entrepreneurship, motivational, social interaction, critical thinking, and problem-solving skills. This scenario happens due to the existing system in higher education as well as TVET that puts less emphasis on the mastery of generic skills among students (Quek, 2000; Lee, 2000; Asma & Lim, 2000).

The elements of generic skills especially the communication, problem-solving and teamwork which are the top three requirements by the industries in Malaysia are essential to ensure the TVET providers stay relevant in the training of the workforce with competencies as required by specific industries. Teamwork skills, decision-making, initiative, problem-solving and communication skills are essential components for graduates to possess that are relevant to an industry which enables them to be more competitive and increase the chance of employability (Clarke, 1997). According to Hassan (2002), the lacking of generic skills is among the factors that contributed to the unemployed graduates of higher education institutions because they do not have the ability to convince the employer with their personality, confidence, communication, decision-making and team working. This situation demonstrates that generic skills are essentially necessary for the graduates besides having the technical skills for them to succeed (Clagett, 1997; Goldberg, 1996; NSPE, 1992) and according to Adnan (2004) to have competent workforce as needed by the employers in the industries; Graduates of higher institutions, as well as TVET, need to equip themselves with generic skills in order to fulfil the demand of employers and to stay relevant to the specific industry's need. TVET educational system has gradually experienced changes in most of the developing countries particularly in Malaysia where generic skills have gained serious attention (Shakir, 2009) for it to be applied in the learning and training syllabus (Ministry of Higher Education, 2006; Ministry of Higher Education, 2007). This situation is based on the feedback from many surveys done among employers which showed that a majority of the graduates lacked in mastering the generic skills that make them difficult to be employed (Quek, 2000; Baharuddin, 2003).

The government of Malaysia has taken firm action to overcome this issue by introducing generic skills also known as soft skills into the curriculum of all higher educational institutions in Malaysia (Ministry of Higher Education, 2006; Ministry of Higher Education, 2007). Educators in the higher education institutions as well as in TVET continue to strive to identify instructional approaches that can effectively promote and stimulate generic skills. Many educational institutions in Malaysia especially in the field of engineering as well as in technical vocational learning have used instructional strategies such as problem-based, project-based and production-based learning (PBL) to achieve the desired generic skills (Adnan et al., 2009; Cheng Hwa et al., 2009). Many studies have shown that PBL is very successful in educating students to "learn how to learn" and develop a positive attitude towards learning. A study by Othman et al. (2010) proposes that changes in the learning approach utilising problem-based learning (PBL) can increase the employability of graduates. According to the published work by Albanese and Mitchell (1993); Ryan (1993); Ostwald & Kingsland (1994) and Little et al. (1995), that although PBL has proved to be an effective learning strategy such as in medicine and health sciences, it was also found to be effective by professional studies such as engineering, law, psychology, education, economics and architecture.

There is a need for further investigation in order establish that PBL could also effectively be implemented in TVET, since:

- There is no known research carried out in Malaysia so far; specifically on the implementation of PBL on students in TVET that involves theoretical and practical works.
- TVET is different from other fields of studies because it emphasizes more on hands-on skills which mostly involve in mastering and handling sophisticated machine tools. For PBL to be successfully implemented in TVET, many factors need consideration especially in the design of PBL's framework in order to achieve the desired learning objectives and outcomes.

This issue is not a matter of how effective PBL is, but rather how PBL can be used effectively under the specific conditions of TVET in Malaysia. The PBL approach is a student-centered approach, the learning capabilities or learning pace among students varies, hence, "sufficient time" for them to work out on problems is very time consuming and which the normal TVET approaches are unable to provide. It is a common practice in the TVET approach where 60% to 70% from the total learning hour is allocated for practical work or hands-on training and only 30% to 40% for the theoretical which involve lectures. At the German Malaysian Institute (GMI), the PBL approach is embedded together with the current traditional teaching approach and shared the allocated learning time for the course without any additional time given.

In the context of TVET providers particularly at GMI, the question also arises whether the PBL approach applies to students of any level of academic performance abilities and how it affects the learning, technical and social competencies of students in the TVET at the GMI. One of the hypotheses of this study is that the students with good prior academic performance are more motivated toward learning. The hypothesis is based on the researcher's teaching experience at the GMI when conducting traditional lecture-based classes with a various level of students' prior academic performance. Therefore it would be expected that there are differences regarding learning competency which influence the learning outcome. The entry qualification to study at the GMI's Diploma level programme is five credits and above for students with Malaysian Certificate of Education (MCE) holders (O level equivalence) and three credits (MCE) or lower for Technical certificates holders from technical institutions in Malaysia. For the German A-Level Preparatory Program (GAPP), the entry qualification is with straight "A" in MCE. GAPP is a programme recognized by the University of Applied Sciences (UAS) or

Fachhochschule in Germany to prepare students with technical and practical practices as a requirement to enrol for degree programmes in these learning institutions. Qualified students will later be given the opportunity to enrol in the degree programmes at the University of Applied Sciences (UAS) or at a Fachhochschule in Germany.

Therefore, it is essential for GMI to comprehend the students' learning ability and apply the right learning approach to achieving the utmost of desired learning outcomes efficiently and effectively. However, without a proper "method of instruction" or learning approach that can stimulate generic skills effectively among students, such intended and desired attributes will be difficult to achieve. The learning approach that attracted GMI's attention for its students was the problem-based learning (PBL) approach because that is known to have good results with training for professional practise.

1.2. GERMAN-MALAYSIAN INSTITUTE

The German-Malaysian Institute (GMI) was established in 1991 and it operates as a technical and vocational training institute. The Institute is a joint venture project between the Governments of Malaysia and Germany, which was established to train students in technical and vocational education. The institute is governed by a ten-member Board of Directors comprising representatives of the governments, public and industrial bodies, GMI is set up as a Company Limited by Guarantee whereby the founders are Majlis Amanah Rakyat (MARA) and the Malaysian-German Chamber of Commerce and Industry (MGCC), and its implementing agencies are MARA and German Technical Corporation (GTZ – Deutsche Gesellschaft für Technische Zusammenarbeit). Besides GMI, MARA which is a government agency has also set up a University of Kuala Lumpur (UniKL), seven colleges; Kolej Kemahiran Tinggi MARA (KKTM), twelve institutes; Institut Kemahiran MARA and 209 GiatMARA learning centres. Learning institutions such as KKTM offers TVET programmes at Diploma level while IKM and GiatMARA offer TVET courses at certificate level and has its skill standards supervised and controlled by the National Occupancy Skill Standards (NOSS). Whereas UniKL offers engineering technology programmes at Diploma, Degree, Master and PhD levels.

GMI offers diverse TVET programmes at Diploma level in line with the need of work force in the manufacturing industry in Malaysia. The Institute aims to support the Malaysian industries by training students to become highly skilled and competent technicians/technologist who can operate modern technologies efficiently. Present, a total number of twelve Diploma programmes are offered by GMI through the Department of Industrial Electronics and the Department of Production Technology (see Table 1-1). The Department of Industrial Electronics offers Diploma programmes such as Mechatronics, Electronics and Information Technology, Network Security, Sustainable Energy and Power Distribution System and Industrial Plant Maintenance, whereas in the Department of Production Technology programmes include Tool and Die Technology, Mould Technology, Product Design and Manufacturing, CNC Precision Technology, Manufacturing System and Sheet Metal Fabrication and Development.

Short and customized courses are also offered by GMI to cater for people from industries and other technical training institutions who want to enhance their technical knowledge as well as training for advanced technology. Another programme offered by GMI is the German A-Level Preparatory Programme (GAPP). GAPP is a 20-month preparatory programme that prepares students for technical and practical or hands-on experiences that enable them to enrol in the universities in Germany such as University of Applied Sciences (UAS) or Fachhochschule. UAS is a higher learning institution offering Degree programmes which are more application-based and with greater practical-oriented courses to ensure that the students with an academic background are practically better qualified to fit within the work force. UAS professors and lecturers have practical experience besides their academic qualifications that sustain the quality of education and training.

Table 1-1: Diploma Programmes offered at GMI

Department	Courses offered
Industrial Electronics	1. Diploma in Industrial Electronics (Mechatronics) 2. Diploma in Industrial Electronics (Process Instrumentation & Control) 3. Diploma in Industrial Electronics (Electronics and Information Technology) 4. Diploma in Network Security 5. Diploma in Engineering Technology (Sustainable Energy and Power Distribution System) 6. Diploma in Engineering Technology (Industrial Plant Maintenance)
Production Technology	1. Diploma in Industrial Production Technology (Tool and Die Technology 2. Diploma in Industrial Production Technology (Mould Technology) 3. Diploma in Product Design and Manufacturing 4. Diploma in CNC Precision Technology 5. Diploma in Engineering Technology (Manufacturing System) 6. Diploma in Engineering Technology (Sheet Metal Fabrication and Development)

GMI also has collaborated with the Universiti Malaysia Pahang (UMP) to offer bachelor programmes in Manufacturing Engineering Technology and Electrical Engineering Technology. UMP is one of the public higher learning institutions within the Malaysian Technical University Network that emphasis on hands-on education in engineering and technology which integrates theory and practice. Priority of enrollment in these bachelor programmes is given to the graduates of GMI as an opportunity and path for them to further their study at a higher level.

Other than GMI, there are about 194 TVET providers in Malaysia with the total enrollment of 100,000 students, and the government is planning to increase this number in the next five years. These TVET encompasses post-secondary education provided by Polytechnics, Community Colleges and Skill Training Institutes which are under the supervision of Ministry of Higher Education (MoHE) Malaysia. According to the Ministry of International Trade and Industry, (MITI, 2006), in the Third Industrial Master Plan (IMP3), the global economy is being transformed into a knowledge-based economy, where technology assumes an important role and furthermore, new emerging technologies will continue to have an impact on the industrial and economic development in most countries. Through the Ministry of International Trade and Industry (MITI) the government has set nine strategic thrusts for human resource management, planning and development (MITI, 2008). One of the thrusts includes;

- Enhancing the institutional capacity for human resource management, planning and development;
- Increasing the supply of technically-skilled, knowledgeable and ICT-trained workforce;
- Providing greater focus on creativity, innovation and other enabling skills in the educational, and technical and vocational training systems.

The Ministry's strategies aimed to increase the supply of a technically-skilled work force; these included reviewing and enhancing the capacity of vocational schools and community colleges, upgrading skills training to school leavers in vocational schools and community schools and increasing the supply of highly skilled workers in the 17 to 23 age group, from the present 30 percent to 40 percent by 2010 (MITI, 2008). The growth of the Malaysian manufacturing industries over the last ten years had pushed GMI to increase its student intake capacity and to enhance the training approach in order to fulfil the demand for technically-skilled and knowledge workers. This was in line with the government's IMP3, which emphasized the improvement of the number and quality of skilled workers who could respond to the changing environment and enhance competitiveness, arise from progressive trade liberalisation. Presently, the development of human capital with multiple competencies is in great demand (National Centre for Vocational Education Research (NCVER), 2003) and personnel with only one technical competency; is no longer competitive and will not survive (Cheng Hwa, 2010). According to Cheng Hwa et al. (2009), utilizing traditional education is no longer adequate and appropriate to develop knowledge manpower and therefore, concerted efforts will have to be made to increase the supply of highly skilled and knowledge manpower through the expansion of education and training emphasizing on student-centered learning (SCL) approach.

Considering the above-mentioned factors and the requirement for students to be equipped with generic skills in order to stay competitive, employable and to face the challenges of the rapid changes in technology, the German-Malaysian Institute (GMI) identified PBL as the most appropriate instructional approach for the purpose. Therefore, GMI had changed the training approach for some courses from a teacher-centred to a student-centred approach to implementing PBL. Typically, technical and vocational subjects are delivered using the traditional four-step method training approach: describe, demonstrate, try-out by the trainee and evaluate with feedback. In technical and vocational training, students need to acquire technical skills through hands-on work that enables them to solve authentic problems encountered in industry. However, most students trained in the traditional approach lack some generic skill attributes such as problem-solving, critical thinking, communication, teamwork and leadership.

1.3. PURPOSE OF THE STUDY

The purpose of this study is to examine the impact of PBL on students' learning, technical and social competencies in Technical Vocational Education and Training (TVET) specifically in CNC programming courses. PBL has been newly implemented in the TVET specifically at the German-Malaysian Institute. The PBL is an educational approach to foster the student-centered and active learning. Through PBL approach, students experience learning by working in teams to solve problems and determine their own learning objectives. During these activities, they develop skills such as in teamwork, communication, critical thinking, seeking and gather relevant information to the problems, analyse, synthesizing resources and finally defend their findings in a group presentation. In this approach, the lecturer facilitates the learning process by closely supervising the progress of the students and probing questions to ensure students are on the right path in solving the problem. Hence, it is important to study how PBL affect the students' competencies in TVET setting.

This research study has several specific objectives in order to address the purpose of this study such as:

1. To identify the students' perception, motivations, awareness and challenges/obstacles on PBL in a CNC programming course.
2. To examine the relationship between the students' prior academic performance and their learning performance in the PBL approach.
3. To examine the benefits of CNC simulator during PBL sessions in two CNC programming courses namely CNC Milling & programming and CNC Lathe & programming.
4. To examine the aspects of student learning processes and how PBL affect the students' competencies (learning, technical & social).

1.4. RESEARCH QUESTIONS AND HYPOTHESES

This study aims to answer the main research question:

In what ways does PBL affect the students' competencies (learning, technical & social)?

The following sub research questions are focused in order to answer the main research question:

SRQ-1. What is the level of awareness and motivation of students at different semesters; about Problem-Based Learning?

SRQ-2. What are the students' perceptions on the Problem-Based Learning implementation?

SRQ-3. How do the students perceive challenges/obstacles on the Problem-Based Learning implementation?

SRQ-4. What is the relationship between students' prior academic performance and their learning performance in the PBL approach?

H1: Students of semester three and four with above average CGPA scores should have higher scores in both the pre-test and the post-test; than those with below average CGPA scores.

H2: Students of semester four should have higher scores in the pre-test than students of semester three.

H3: There is no difference in post-test scores between students of semester three who attending the CNC programming milling and students of semester four who attending the CNC programming lathe.

SRQ-5. To what extent does the CNC simulator benefit students in the PBL approach?

H4: Students of semester three and four with above average CGPA scores should have higher scores in both the programming test one and the programming test two than those with below-average CGPA scores.

H5: Students of semester three and four should have higher scores in the programming test two than programming test one.

H6: There will be a relation between the scores of programming test one and programming test two; for students in both semesters three and four.

1.5. CONCEPTUAL FRAMEWORK AND OVERVIEW OF RESEARCH VARIABLES

The conceptual framework of this study was developed in line with the research questions (Section 1.4) that aim to examine the impact of PBL on students' competencies in Technical Vocational Education and Training (TVET). The conceptual framework and overview of variables of this study are illustrated in Figure 1-1. This study is applied research which aims to improve the implementation of PBL under specific conditions. The researcher will use whatever is available in the research's data both theoretical as well as practical to conduct this study. An independent variable and four main dependent variables, as well as two moderating variables, were identified. The independent variable was identified as: "the PBL approach in CNC programming courses." According to Johnson & Christensen (2008), an independent variable is a variable that is expected to cause a change in another variable (dependent variable). In this study, the CNC (Computer Numerical Control) programming courses employ the PBL approach for the very first time instead of traditional teaching method. The PBL approach that will be described in more detail in Section 2.4 is an approach to learning and teaching in which students are challenged to work on a problem rather than to receive information during a lecture (Rogal & Snider, 2008). CNC simulators (a computer graphic simulation) are used to assist students in the CNC programming courses. So far, there was no research found specifically in the use of CNC programming simulator in the PBL setting. However, as described in section 2.6.2, previous studies have shown that computer graphic simulation has many advantages and has a great potential in the PBL process. Therefore, this study would like to examine "to what extent does the CNC simulator benefit students in the PBL approach?"

As indicated in Section 1.1 students who enrolled for Diploma programmes at GMI come with different school histories, such as students that are fresh from the secondary schools after their Malaysian Certificate of Education (Sijil Pelajaran Malaysia – SPM). Students who have five credits and above in their SPM eligible to enrol for Diploma programmes without any additional certificate needed.

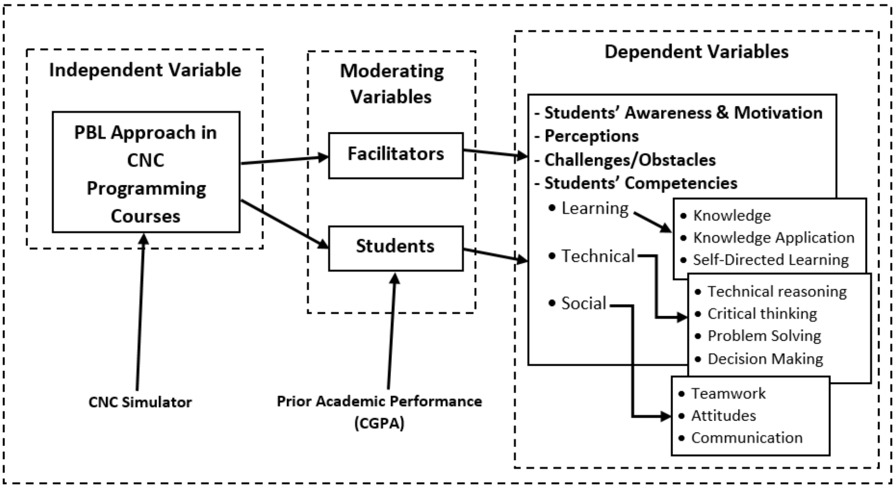


Figure 1-1: Conceptual Framework and Overview of Main Research Variables

Students who have four credits or lower in their SPM need to acquire an additional certificate from technical institutions such as MARA Skills Institute (IKM), GIATMARA, Community College, Skills Training Institute of Youth and Sports (IKBN), Higher Skills Training Institute of Youth and Sports (IKTBN), MARA Higher Skills Institute (KKTM) etc. It means that these students need to spend roughly two years to acquire the certificate from these technical institutions before they can enrol in the Diploma programmes at GMI. Based on the researcher's 24 years of experience in teaching students with a various levels of prior academic performance in TVET, the researcher postulated that students with a good prior academic performance benefit more from the PBL approach. Hence, this study would like to investigate the relationship between the students' prior academic performance and their learning performance with the PBL approach.

In this study, there are four main dependent variables selected, namely the "Students' Awareness and Motivation," "Students' Perceptions," and "Students' Challenges/Obstacles" in the PBL implementation as well as the ultimate one was the "Students' Competencies" because it reflecting the impact of PBL on the CNC programming courses. According to Johnson & Christensen (2008), the dependent variables are the variables that are supposed to be influenced by one or several independent variables. Three aspects of students' competencies were focused upon; consisting of learning, technical and social competencies. These competencies are the job competence that has been the training philosophy of the German-Malaysian Institute's (GMI) since its establishment in 1991.

Table 1-2: Mapping Each Concept, Dependent Variable with Instruments and Research Questions.

Concepts	Main Dependent Variables	Dependent Sub-Variables	Instruments	Research Questions
	Students' Awareness and Motivation		Questionnaire Interview	SRQ1
	Students' Perceptions		Questionnaire Interview	SRQ2
	Students' Challenges/ Obstacles		Questionnaire Interview	SRQ3
Prior Academic Performance			Pre- and Post-tests Academic Records	SRQ4
CNC Simulator			Programming test 1 and 2 Interview Observations Content Analysis	SRQ5
	Students' Learning Competency	Knowledge	Pre- and Post-tests Programming test 1 and 2	Main RQ
		Knowledge application	Programming test 1 and 2 Content Analysis	
		Self-directed learning	Questionnaire Interview Observations	
	Students' Technical Competency	Technical Reasoning	Programming test 1 and 2 Content Analysis Observations	
		Critical Thinking	Programming test 1 and 2 Content Analysis Observations	
		Problem Solving	Programming test 1 and 2 Content Analysis Observations	

		Decision Making	Programming test 1 and 2 Content Analysis Observations	
	Students' Social Competency	Teamwork	Self-assessment Peer-assessment Interview Observations	
		Attitudes	Self-assessment Peer-assessment Observations	
		Communication	Self-assessment Peer-assessment Observations	

The Job Competence of GMI's training philosophy was set up in line with the Malaysian Qualifications Framework (MQF) which take into consideration the cognitive, behaviourist and social values in the framework. According to Mohd Fahmi (2012), MQF stressed on eight domains of generic learning outcome that is important in the Malaysian context for students in higher education institutions as well as in TVET. The MQF is established by the Malaysian Qualifications Agency (MQA) under the Ministry of Higher Education (MoHE). Among the purposes of the MQA are to implement MQF as a reference point for Malaysian qualifications, develop standards and credits and all other relevant instruments as national, quality assure higher education institutions and programmes and accredit courses that fulfil the set criteria and standards.

The learning outcomes of the MQF are based on the following eight learning domains (Vassu, 2012): i) Knowledge of subject area, ii) Practical skills, iii) Social skills and responsibilities, iv) Values, attitudes and professionalism, v) Communication, leadership and teamwork skills, vi) Problem solving and scientific skills, vii) Managerial and entrepreneurial skills and viii) Information management skills. Figure 1-2 illustrates the position of the GMI's training philosophy in this study with the core of this study is to examine the impact of PBL approach on students' competencies through two CNC programming courses.

As shown in the conceptual framework of Figure 1-1, under these three competencies (learning, technical and social), there were sub-dependent variables such as knowledge, knowledge application, self-directed learning, technical reasoning, critical thinking, problem-solving, decision-making, teamwork, attitudes and communication that were given a focus for the purpose of this study. The sub-dependent variables were investigated through various instruments as shown in Table 1-2 that mapping each concept, dependent variable with instruments and research questions. For the mapping of each research question with research methods, sources of data and instruments can be seen in Table 3-1 of Chapter Three.

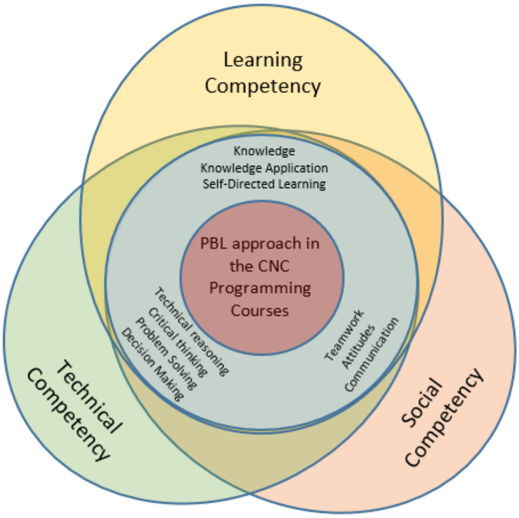


Figure 1-2: The Position of the German-Malaysian Institute's Training Philosophy in the study.

The first three of the main dependent variables (Students' Awareness and Motivation; Students' Perceptions and Students' Challenges/Obstacles) reflect students' opinion, understanding and experience with respect to the PBL implementation in the CNC programming courses. Whereas the main dependent variables of students' competencies (Learning, Technical and Social) intend to measure the results from the PBL courses. The dependent sub-variables of this research are aligned with some aspects of the Malaysian Qualifications Framework (MQF) learning domains such as knowledge of subject area, social skills, attitudes, communication, teamwork skills and problem-solving skills (See Table 1-2). Between the independent variable and the dependent variables, there were two moderating variables identified in this study, specifically the facilitators and students. The Technical Training Officer (TTO) will act as a facilitator aiming to guide the students throughout the learning process to achieve their learning goals in the PBL approach.

The PBL model employed in this study is based on the seven-step approach of Maastricht University in which it could provide a platform for students to practice generic skills. PBL, from a theoretical perspective, has many different psychological theories that contribute to it and the most outstanding is the influence of constructivism. The learning theory behind the PBL approach in this study is constructivism that has its foundation in cognitive learning psychology (Jonassen et al., 1999). Constructivism is a theory which has roots in both philosophy and psychology (Doolittle, 1999). Its roots are based on the theories of Dewey (1896), Piaget (1952), Vygotsky (1978), Papert (1980) and Bruner (1985). Simpson (2002) argues that Constructivism is an epistemology, theory of knowledge or philosophical explanation about the nature of learning. According to Bandura (1997), constructivism shares characteristics with the social cognitive theory that assumes persons, behaviours, and environment interacts in a reciprocal fashion, which is a continuous interaction between behaviours, personal factors including cognitive and the environment. However, he does not suggest that the contribution of the three factors is equal. The influence of persons, behaviour and environment depends on which factor is stronger at any particular moment and the behaviour refers to things like complexity, duration, skill etc. Whereas the environment comprises of the situations, roles, models and relationships and a person's involves mainly cognition but also other factors such as self-efficacy, motivation and personality. Wilson (p.5, 1995), defined a constructivist learning environment as “a place where learners may work together, support each other as they use a variety of tools and information resources in their pursuit of learning goals and problem-solving activities”. This learning approach is regarded as a student-centered instructional model in which students established their own learning goals and needs control their own learning progress and decide how to reach the intended learning outcomes in a collaborative learning environment (Newby et al., 2000; Yildirim, 2005; Savery & Duffy, 1995), describe the instructional principles of PBL in a constructivist framework as the following:

- Learners as constructors that construct their own knowledge: In PBL, students are fostered and expected to think both critically and creatively with multi-directional interactions with the issues, the peers, the resources, and the instructor. Learning is no more a process of transferring information from others to the students themselves, but a process of engaging themselves in a problem situation to actively engage in and monitor their own understanding.
- Problems as stimulus and organizer for learning: In PBL, the learning starts with a problem and arises from discussing the problem in class, making hypotheses, identifying important facts related to the problem, identifying learning issues centred on their study of the problem.
- Knowledge is socially negotiated: In PBL, social negotiation of meaning is an important part of the problem-solving team structure. Students' understanding of the content is continually challenged and tested by others.
- Faculty as mentors and cognitive models to support scaffolding.

The PBL approach is aligned with constructivist, learning theory in which “individuals create their own new understandings on the basis of an interaction between what they already know and believe and ideas and knowledge with which they come in contact” (Richardson, 2003, pp. 1623-1624). Several scientists have backed that students construct their own knowledge (Vygotsky, 1978; Bruner, 1986; Steinberg & Kincheloe, 1998; Smagorinsky, 2001) because students learning in the constructivist form take more responsibility for their own learning and determining their own learning outcomes. They become more active, reflective and critical in learning and learn to construct knowledge on their own. Constructivism drives students to be active learners, think critically, reflectively, responsible for their own learning and construct knowledge on their own besides determining their own learning outcomes (Bruner, 1986; Vygotsky, 1978). In a constructivist learning environment, students are educated to be self-directed and they play an active part in learning activities such as setting learning objectives, progress monitoring and evaluating as well as exploring interest (Bruning et al., 2004). According to Doolittle & Hicks (2003), constructivist emphasis on the active role played by the individual student in the construction of knowledge and the realization that the knowledge attained by the student may differ in its accuracy as a representation of an external reality. Constructivism focuses on the process "how students construct knowledge" that depends on the students' existing knowledge or depends on the kinds of experiences they have had and how they get those experiences organised into knowledge structures (Jonassen, 1995, p. 42). Furthermore, according to Mayer (1998), the constructivist process lead towards determining how the student's structure and process knowledge rather than how much is learned. Therefore, the emphasis is on the learning process rather than on the content, learning 'how to learn' rather than 'how much is learned.' Hence the construction of knowledge by an individual is only true to that person but not sure to someone else since students construct knowledge based on their beliefs and experience in conditions that vary from a person to another (Cobb and Bowers, 1999). According to constructivism, learning is considered as a personal interpretation of the world, as students interpret the world centred on their past experiences and interpretations (Wilson, 1995; Duffy & Cunningham, 1996; Jonassen & Henning, 1999). Students develop critical thinking skills, problem-solving and team skills, experiential learning and interdisciplinary knowledge, with technology being essential to their learning (Cook & Cook, 1998; Oliver, 2000). The educator is no longer perceived as the only authority, but rather as a facilitator of learning, guiding and supporting students in the process of constructing knowledge (Berge, 1999; Nelson, 1999). A facilitator of learning is a teacher who does not operate under the traditional concept of teaching but rather is meant to guide and assist students in learning for themselves. The level of guidance educators provide depends on levels of students' prior knowledge and experiences (Orlich et al., 2004; Vygotsky, 1978). Vygotsky (1978) suggested that social interaction leads to knowledge construction in which communication serves as the main instrument that promotes thinking, develops reasoning and supports activities like reading and writing. According to Schmidt (1993), the activation of prior knowledge through small-group discussion appears to be a well-established phenomenon.

Constructivism can help to engage and motivate students by making them take a more active role in the learning process. The benefit of constructivism is that it provides student-centered activities, which allows students to participate in their own learning process by engaging them in collaborative activities with their team members and to become more self-directed with the lecturer acting as the facilitator assisting the students in learning and thus, encourage the social interactions, communication among students, the collaborative and cooperative learning (Orlich et al., 2004). Collaboration is an essential element of the PBL learning environment because the students can look for more experienced persons for assistance to solve the task and through this process they acquire knowledge and experience that they would not have had if performing individually.

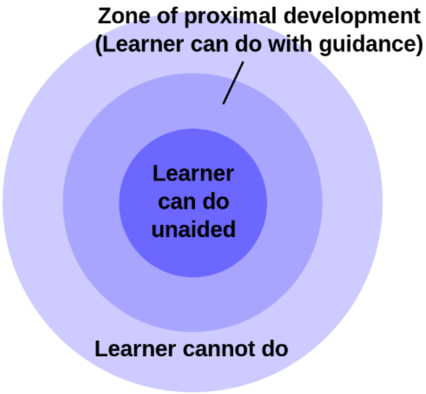


Figure 1-3: The concept of the zone of proximal development by Vygotsky

(Source: By Dcoetzee - Own work, CC0, https://commons.wikimedia.org/w/index.php?curid=20903046)

The characteristics of PBL in this study are student-centered learning, collaborative learning in small groups, the teacher is a facilitator, learning is organised around problems and new knowledge is acquired through self-directed learning. Vygotsky's zone of proximal development (ZPD) was applied as the concept of scaffolding in the PBL approach of this study as shown in Figure 1-3. The above constructivist theory provided a conceptual framework for this study.

1.6. SCOPE OF THE STUDY

This study focuses on the students of engineering technology in TVET who attend the CNC Milling and Lathe programming courses at the German-Malaysian Institute, Malaysia (GMI). GMI was selected as the research field in this study because of its reputation as one of the premier TVET providers that produce good graduates who are recognised by most of the employers in Malaysia. GMI has gradually changed the training approach from teacher-centred to student-centred in order to cultivate generic attributes among students as required by employers in the industry especially in Malaysia. In this study the impact of the PBL approach on students' learning, technical and social specifically on two CNC programming courses will be investigated.

1.7. SIGNIFICANCE OF THE STUDY

This study is important because no study has been carried out so far on the effect of the PBL approach with regards to generic skills implemented in the Malaysian TVET which emphasise more on hands-on skills, especially in CNC programming courses. This study was intended to identify whether PBL approach has contributed to the development of students' generic skills, which is important to ensure the TVET providers stay relevant in producing students' attributes as required by the employers. The findings of this study will contribute to the existing literature on PBL, specifically PBL in TVET setting and potentially impact on the current practice of TVET in Malaysia especially and worldwide generally. The results are also expected to contribute to enhancing the effectiveness of the PBL in the courses at GMI through the design of a PBL framework that suits students in the TVET setting. This framework could be used as a general guideline to help technical and vocational training providers, particularly in Malaysia or countries with similar conditions, to develop and implement PBL at their training institution.

1.8. LIMITATIONS OF THE STUDY

The following limitations have been identified which were expected to affect the findings of this study. These included the followings:

I. The subjects of this study were limited students from the GMI comprising groups of students in two different semesters namely semester 3 & 4. The

CNC Milling programming course was offered to students in semester three and the CNC lathe course was offered in semester four.

II. The study was restricted to the technical and vocational education training which emphasised hands-on skills for students at Diploma level; specifically on two programming courses using CNC simulator.

III. The difference in the level of prior knowledge of the students on the content of the courses in the study.

IV. The level of educational background of each student may be different because they came from various schools, technical schools, technical institution and technical college.

V. The differences of the cultural identity of Malaysian or cultural background among the students.

The main aim of this project was to evaluate the impact of students' learning, technical and social competencies in PBL-TVET specifically in Computerized Numerical Control (CNC) Programming Courses. CNC simulators in these courses are used to teach and help the students to be more self-directed or self-regulated and facilitate them in their learning process as well as to develop their technical competency.

This study also examined the learning performance of two different levels of students' prior academic performance in the PBL approach. This study's primary question was identified as: To what extents, PBL affects the students' competencies in the TVET? To address this question and to guide this study, a series of sub research questions were formulated which will be elaborated upon in the next chapter of this thesis. The primary data collection of this study was obtained from students at Diploma level of Technical Vocational Education and Training (TVET) studying at the German-Malaysian Institute. The study was conducted with groups of the GMI's students for a period of six months and the data collection was concentrated on the students in two disciplines of CNC programming courses namely; CNC Milling and CNC Lathe Programs at the GMI. Two groups of students with different level of academic background were studied to measure their level of achievement in the technical, learning and social competencies. These students comprise trades of Tool and Die Technology, Mould Technology and CNC Precision Technology. The research methodology employed was a mixed methods with a combination of qualitative and quantitative approaches during different phases of the research process, which will be further elaborated in Chapter Three.

This study was expected to identify whether the PBL approach contributed to the development of students' generic skills, which is very important to ensure that the TVET providers stay relevant in producing students' attributes as required by the industrial employers. The findings were also expected to contribute to enhancing the effectiveness of PBL in the specific courses through a better designed of a PBL framework to suit students in a TVET setting. The significance of this study was to provide a framework to the technical and vocational training providers particularly in Malaysia or countries with similar conditions, as a general guidance to help them to develop and implement PBL at their training institution.

In order to establish a solid research design for this study, a comprehensive literature review was carried out and presented in Chapter Two. The chapter reviews a number of issues in the literature concerning the Generic Skills, TVET, PBL Introduction, The McMaster PBL Model, The Maastricht PBL Model, The Aalborg PBL Engineering Model, Rationale of Implementing PBL in the TVET, Computer Numerical Control (CNC), CNC Simulator (Computer Simulation) and presents the implementation of PBL in the CNC programming courses at the German-Malaysian Institute in Kajang, Malaysia.

CHAPTER 2. LITERATURE REVIEW AND BACKGROUND INFORMATION

2.1. INTRODUCTION

Students today have to contend with the challenges of the future including the emergence of new technologies, complex situations and real life problems. The world of education has also changed in parallel with the development of Information and Communication Technologies (ICT). The education approach has also evolved from teacher-centred to student-centered with the purpose of preparing the students with generic skills to cope with the challenges. Knowledge of innovative technologies demands a change in the learning approach that can enhance generic skills of graduates. Innovation in engineering education as well as in TVET needs to ensure that the learning stays attractive and motivating. Whereas, to make use of Information and Communication Technology (ICT) could enhance learning and able to prepare graduates to face the future challenges of engineering work it can also exploit new science and technology innovations.

Technical Vocational Education and Training (TVET) is a part of the education system that plays a significant role in producing students with skills needed by the industrial employers. The rapid advancement of technology has demand not only the engineering education but also the TVET to move in line in producing not only engineers but also the technologist who can cope with the rapid progress of technology in the industry. On top of that, the engineers and technologist need to have the necessary skill attributes that are more relevant to the industries' stakeholders. Studies also show that most employers in the industry prefer employees or workers who possess not only technical skills but also the generic skills for effective operational activities of the employees.

Since knowledge is no longer an end, but a means of creating better problem solvers and encourage lifelong learning, problem-based learning is becoming more and more popular in educational institutions as a tool to address the insufficiencies of traditional teaching (Neo & Neo, 2001). Presently, many educational institutions are moving towards problem-based learning as a solution to produce graduates who can think creatively, critically, and analytically in solving a particular problem (Neo & Neo, 2001).

Several studies indicated that PBL is an innovative learning method that is well-known to have been implemented successfully and proven to be an effective learning strategy in many fields of studies (Biggs, 2003). Many of these studies have also shown that PBL is very successful in educating students to "learning how to learn" and develop a positive attitude towards learning. The European Union defined 'learning to learn' as *"the ability to pursue and persist in learning, to organise one's own learning, including through effective management of time and information, both individually and in groups. This competence includes awareness of one's learning process and needs, identifying available opportunities, and the ability to overcome obstacles in order to learn successfully. This competence means gaining, processing and assimilating new knowledge and skills as well as seeking and making use of guidance. Learning to learn engages learners to build on prior learning and life experiences in order to use and apply knowledge and skills in a variety of contexts: at home, at work, in education and training. Motivation and confidence are crucial to an individual's competence."* (Education Council, 2006 annex, paragraph 5).

Over the past decades many researcher focused their studies on PBL such as: Barrows & Tamblyn (1980), Schmidt (1983), Boud (1987), Boud & Felleti (1997), Woods (2003), Albanese and Mitchell (1993), Kjersdam & Enemark (1994), Graaff & Kolmos (2003), Kolmos et al. (2004), Savin-Baden (2006), Graaff, & Kolmos, (Eds.) (2007c), Hmelo-Silver (2009), Du et al. (2009), any many more. The PBL approach is believed to be presently the most appropriate approach known to develop students' generic skills as required by industrial organisations. Many studies such as Schroder (1989), Lee et al. (2001), Callan (2003), Mitchell (2003), Boud & Middleton (2003), (Gibb, 2004), Khir (2006), Noordin et al. (2009), Jackling & Watty (2010), Ismail et al. (2011), and many more revealed the connection of generic skills with the phenomena of unemployment of graduates; is not only in Malaysia but also worldwide.

Another innovative strategy in education is the integration of computer simulation as a learning tool together with the PBL approach. Computer simulation with a lecture-based approach has been extensively used in education fields such as mechanical, civil, electrical, electronics, chemical, and many more for analysis including modelling, forecasting, dry-run and other practical purposes. The combination of PBL and computer simulation seems to be highly relevant and shall have a great potential to be acceptable and widely used as a learning strategy in engineering education as well as in TVET approach in the future. Computer simulation has a high potential in PBL process as it provides students with the opportunity to see a real world experience and interact with it (Sahin, 2006). Furthermore, computer simulation might contribute to conceptual changes; provide open-end experiences, tools for scientific inquiry and problem-solving experiences that increase the effectiveness of PBL (Araz & Sungur, 2007). This integration could potentially impact the current practice of many fields of education as well as the TVET. However, research on the implementation of PBL in the TVET context is very limited. Therefore, the effectiveness of this approach in the context of Malaysian's education especially in TVET, need a further investigation so that fine-tuning can be made for further improvement.

2.2. GENERIC SKILLS

The studies and discussions concerning generic skills especially in the context of higher education have been reported in the literature for several decades whereby many stakeholders have expressed concerns about graduates who lack many of the generic attributes essential for them entering the work force (Jackling & Watty, 2010). Generic skills are the set of qualities and skills which "also known as employability skills" (Australian Chamber of Commerce and Industry & Business Council of Australian, 2002) and once known by the term 'key competencies' (Mayer, 1992) are those skills essential for employment and for personal development, fulfilment, community life active citizenship" (Gibb, 2004). Internationally, generic skills are known by a number of terms including core skills, key skills, essential skills, basic skills and workplace know-how (Gibb, 2004), which are better known as soft skills in Malaysia (Ministry of Higher Education, 2006). There is no one universal term of generic skills because it changes according to the countries of researchers. However, the basic concept remains alike. For example, the generic skills are typically regarded as necessary skills in the United States, leadership skills in Australia, and key skills in the United Kingdom (University of Western Australia, 1996; Centre for Understanding Research in Vocational Education, 2001).

Pearce (2002) defines generic skills as the capabilities, abilities and knowledge that one needs to function as a sophisticated professional in an information-rich civilisation. Generic skills were also addressed as graduate attributes or applied skills in many previous studies (Harvey, 2000; Pearce, 2002). Pearce and Foster (2007), describe the concept of generic skills to include the abilities to recognise and solving problems, communicating with a variety of audiences, persuading others, managing time well, continuing one's learning and, amongst others, managing financial resources.

In a global and competitive commercial world, most employers are concerned with the levels of generic skills that graduates must possess before they enter the job market. Therefore, graduates will have a better chance to be employed because lacking the generic skills is causing difficulties for them to secure employment upon graduation. Callan (2003), argues that graduates are expected to have well-developed technical skills, as well as generic skills that permit high levels of flexibility and adaptability and an ability to work across a variety of occupations in order to continue to succeed in a global economy. Generic skills are known to be most critical skills in the current global job market especially in the rapid progress era of technology (Ministry of Higher Education, 2006). Although the technical knowledge is important, however, surveys indicated it is secondary, employers preferred graduates with good attributes rather than technical knowledge (Mitchell, 2003). Empirical studies on employment, interestingly found important aspect in hiring and promoting employees to top positions with regards to graduate attributes for instance included; team working (Boud & Middleton, 2003; Quek, 2005), speaking and writing skills (Schroder, 1989; Tong, 2003; Lee et al., 2001), social and leadership skills (Quek, 2005; Lee, 2000). The employers are giving priority to the employees who have variability in skills (Boud & Middleton, 2003; Schroder, 1989; Lee et al., 2001).

At present, the issue of unemployment among the graduates is a global issue not just in Malaysia. The human capital development in Malaysia has been a major boost in the past decades, especially in the Ninth Malaysia Plan for period 2006 until 2010 (Malaysia, 2006). Various initiatives have been executed to increase the employability amongst graduates in which The Ministry of Higher Education aims of at least 75% of the graduates will be employed in relevant fields within six months after graduation (Ismail & Hassan, 2013). However, Malaysia is confronting issues in terms of skilled human resources (Ramlee et al., 2008), and a study conducted by Khir (2006), revealed that presently Malaysian graduates lack generic skills as well as technical knowledge, and this situation is triggering new problems to them, such as employability. The unemployment rate of Malaysian graduates in 2005 was about 3.5% (Malaysia, 2006) and increased to 3.7% in 2009 (Department of Statistics, 2011). According to Ismail et al. (2011), the quality of the Malaysian graduates is one of the factors that contribute to the unemployment problem. The studies by Ahmad (2005) and Institut Penyelidikan Pendidikan Tinggi Negara (2007) indicated that the majority of the unemployed graduates in Malaysia were mainly due to the weakness in generic skills and non-technical abilities. In another study done by Rasul et al., (2009) discovered that the generic skills possessed by the graduates such as communications skills, interpersonal, critical thinking, problem-solving and entrepreneurial skills are still not to the expectation of the employers in Malaysia. A research done by Noordin et al. (2009), demonstrated that most employers in construction industry prefer employees that not only possess technical skills but generic skills as well; in order to enhance their productivity and competitiveness. Although this research has been done within the construction industry in Malaysia, the finding should be looked as an indicator of the same scenario which is happening in other industries like in manufacturing. Table 2-1, illustrates the finding of “generic skills” ranked according to the requirement of industrial employers.

The above findings are presented in Table 2-1, which shows that “Communication skill” is the most important generic skills followed with “Problem-solving skill” and “Teamwork skill” which both are ranked second. The research by Noordin et al. (2009) shows, and the elements of generic skills especially the communication, problem-solving and teamwork (top three industries’ requirement) are important to ensure the learning institutions and TVET providers stay relevant in producing a workforce with competencies as required by industry. This is inline with the research done by Dench et al. (1998) which showed that (British) employers put the highest priority on communication skill compared to other skills. Nevertheless, problem-solving and teamwork are equally important in the portfolio of good students' attribute.

Table 2-1: The ranking of priority of generic skills according to the requirement of industries.

Generic Skills	Ranking
Communication Skill	1
Problem Solving Skill	2
Team working skill	2
Professional Ethics and Morals	3
Life Long Learning	4
Leadership Skill	5
Entrepreneurship Skill	6

According to Hassan (2002), lacking generic skills is among the factors that contributed to the unemployed graduates of higher education institutions because they do not have the ability to convince the employer with their personality, confidence, communication, decision making and team working. The issue of graduate attributes that relate to the employability has become the major concern in Malaysia (Shakir, 2009; Rahman et al., 2011) and in many other countries including Australia (Engineers Australia, 2005); the United Kingdom (Bennett et al., 1999; The Engineering Professors Council, 2000) and the United States of America (Engineering Accreditation Commission, 2003; Baxter & Young, 1982). The teamwork skills, decision-making, initiative, problem-solving and communication skills are essential components for graduates to possess that are important to an industry which enables them to be more competitive and increase the chance of employability (Clarke, 1997). Ranjit (2009) underlined ten main weaknesses of Malaysian graduates that include the management, problem-solving, communication, leadership, creativity, critical thinking, proactive, self-confidence and interaction skills. The Government of Malaysia through its Ministry of Higher Education (MoHE) has underlined seven attributes of generic skills which are better known as soft skills in Malaysia and which are to be applied by all higher education institutions and TVET as well, in order to produce employable graduates that can face the competitive and challenging working environment (Ministry of Higher Education, 2006):

- Communication skills
- Critical thinking and problem-solving skills
- Teamwork

- Lifelong learning and information management
- Entrepreneurial skills
- Professional ethics and morals
- Leadership skills

Therefore, the higher learning institutions and training providers in Malaysia need to play a vital role in producing human capital who can meet the demand of the industry.

2.3. TECHNICAL VOCATIONAL EDUCATION AND TRAINING

Technical Vocational Education and Training (TVET) is one of the branches of learning in the educational system all over the world and is based on field work necessary to meet the manpower needs of the industry. According to (Imran, 2011), "policy makers, administrators and educators in the field of TVET all agree that TVET plays a significant role in the economic and social development of a nation." (p. 119). Eichhorst et al. (2012), argue that Vocational Education and Training provides an opportunity for youths who lack resources, skills or motivation to further their education to a higher level. The terms of "Technical Vocational Education and Training" (TVET) and "Vocational Education and Training" (VET) are used interchangeably in the literature and is an education system that deals with practical hands-on experience, which is always associated with the working environment (Eichhorst et al., 2012). However, there are many definitions given concerning TVET by different organisations. According to the definition by United Nations Educational, Scientific and Cultural Organisation (UNESCO) and the International Labour Organization (ILO), TVET is described as:

> "aspects of educational process involving, in addition to general education, the study of technologies and related sciences, and the acquisition of practical skills, attitudes, understanding and knowledge relating to occupations in various sectors of economic and social life" (UNEVOC, 1989, p. 2).

UNESCO (2005) describes TVET as the educational process concerning "the study of technologies and related sciences, and the acquisition of practical skills, attitudes, understanding and knowledge relating to occupations in various sectors of economic and social life." (p. 7). The TVET is further understood to be: (UNESCO, 2005).

a) an integral part of general education;

b) a means of preparing for work-related fields and for effective participation in the world of work;
c) an aspect of lifelong learning and a preparation for responsible citizenship;
d) an instrument for promoting environmentally sound sustainable development;
e) a method of facilitating poverty alleviation.

Source: UNESCO Revised Recommendation 2001.

(MacKenzie & Polvere, 2009) define TVET as the "post-compulsory education and training, excluding degree and higher level programmes delivered by higher education institutions, which provides people with occupational or work-related knowledge and skills." (p. 73). The TVET can also be referred to as:

- Career and technical education (CTE) in the USA;
- Further education and training (FET) in the UK and South Africa;
- Vocational and technical education and training (VTET) in South-East Asia;
- Vocational education and training (VET) or Vocational and technical education (VTE) in Australia (MacKenzie & Polvere, 2009).

The Malaysia Education Blueprint 2013-2025 Preliminary Report defines TVET as:

> *"Vocational education prepares students for career requiring expertise in a specific set of techniques. These careers range from technical or vocational skills like carpentry to position in engineering and other occupations. In contrast to the technical stream which prepares students for further education, the vocation stream is more career oriented" (Malaysia, 2012).*

Management & Training Corporation (MTC) which is an international corporation recognizes the diversity of TVET system and that it might not work well in every country, and has underlined six fundamental principles of an effective TVET system, (MacDonald et al., 2010) which are:

i. Relevance to the labour market (one that meets employer's needs and expectations);

ii. Access for trainees;
iii. Quality of delivery;
iv. Standardization;
v. Inclusion of soft skills; and
vi. Funding for the system is secure and uninterrupted.

The model of TVET utilised in Malaysia is aligned with the model of technical and vocational education utilised by the UNESCO (Alias & Hassan, 2012). Over time, the TVET system has developed in line with the rapid change and emergence of new technologies and has played a significant role in the development of skills and knowledge to the students all over the world to fulfil the needs of industry. The rapid growth of manufacturing industries particularly in Malaysia, demands that the TVET providers produce highly skilled workforces to cater for the rapid progress of technologies. The rapid technological progress implies the need for workers that not only have specialised knowledge and skills but have developed the generic skills required to adapt fast to new emerging technologies (UNESCO, 2012). The statement from UNESCO clearly shows the need to equip the students with generic skills so that they can adapt with the emerging of new technologies.

In addition, it has been the vision and aspirations of the Malaysian government to enhance an education system that emphasis on skills and attributes that students would need to thrive in tomorrow's economy and the globalised world (Malaysia, 2012). One of the aspirations mentioned in the National Education Philosophy refers to students' "thinking skills"; to master a range of main cognitive skills, including problem-solving, reasoning, creative thinking and innovation. This is an area where the system has historically fallen short, with students being less able than they should be in applying knowledge and thinking critically outside familiar academic contexts (Malaysia, 2012).

Therefore, in order to ensure the training provided by the TVET providers; like the German-Malaysian Institute (GMI) to stay relevant to the need of the industries, the elements such as generic skills should be embedded into the training. Although there are such elements available in the current TVET, however, these elements are not so emphasized and measured to determine the level of achievement. Furthermore, the TVET structure now emphasizes more on technical skills rather than generic skills. The GMI for instance has its training philosophy in three competencies that are; technical, learning and social, however only the technical competence has been truly assessed but not for learning and social, which means there is no proper assessment tool developed for the purpose. GMI realizes the importance of students to possess generic skills; and therefore the author's opinion: that PBL is the right approach to developing students' generic skills in particular in the Malaysian context, and hence this research study.

2.4. PROBLEM-BASED LEARNING

2.4.1. INTRODUCTION

Howard Barrows, a prolific author who contributed much to the disseminating of PBL opens his ground-breaking book on PBL with the following statement:

> *"Learning from problems is a condition of human existence. In our attempts to solve the many problems we face every day, learning occurs." (Barrows and Tamblyn, 1980, p. 1).*

Problem-based Learning (PBL), was an innovative learning method to medical education introduced in 1969 at McMaster University in Canada (Barrows, 1996), and has gained prominence not only in Higher Education but also in Technical Vocational Education and Training (TVET). Moreover, PBL has proven to be a successful educational strategy in many different study domains all over the world (Du et al., 2009). The term problem-based learning is frequently used interchangeably with problem-centred learning or problem-centered instruction to allude to instructional methodologies that use real-world simulated, contextualised problems of practice to motivate, concentration, initiate content learning as well as skill development (Boud & Feletti, 1997). PBL is an educational strategy and a method to organize the learning process in such a manner that the students are actively engaged in finding answers by themselves (Graaff and Kolmos, 2007a). Bridges (1992) underlines four major goals of PBL: (1) acquisition of the knowledge base underlying administrative practice, (2) development of administrative skills, (3) development of problem-solving skills, and (4) development of lifelong learning skills.

The main idea behind PBL is that the starting point of learning should be a problem, a query that the learner wishes to solve (Boud, 1987). Students work on the problem to identify and search for the knowledge that they need to obtain in order to approach the problem (Davis & Harden, 2005). Learners in the PBL environment play an active role in the knowledge acquisition process by trying to solve ill-structured problems through participation in small group discussions and self-study (Albanese, 1993). The learning is triggered by offering ill-structured problems and the problems should be authentic, adapted to the students' level of prior knowledge, engage students in discussion, lead to the identification of appropriate learning issues stimulate SDL, and interesting (Schmidt et al., 2011).

The PBL approach requires the students to be self-directed or self-regulated with respect to their own learning process. Self-Regulated Learning is ubiquitous in research on education today and it is an umbrella term for various processes such as goal setting, metacognition, and self-assessment, all of which influence learning in various ways (e.g., Boekaerts 1999; Paris & Paris, 2001; Zimmerman 1989). It is important to prepare students for self-directed learning and the PBL process by conducting an orientation at the beginning of the course or program (Ong, 2006).

Norman & Schmidt, (1992) and Hmelo-Silver (2004), state that the ultimate aim of PBL is to assist students to be intrinsically motivated, and that can be attained when students work on a task motivated by their own interests, challenges, or sense of satisfaction. Gackowski (2003), states that the realism of problem-based learning inspires greater motivation that brings into the practice elements of excitement, active participation, and involvement. Such components of the learning environment; not only challenges students' cognitive abilities but also enhance students' affective, attitudinal, ethical and behavioural dimensions of learning (Gackowski, 2003). According to a study by Bridges (1992), the PBL approach triggers the students' learning, and they become highly motivated, they enjoy the activities they do, appreciate the value of what they learn, consider how they will use their newly acquired knowledge and skills in the real situation in future and experience sense of achievement upon the completion of a project.

Many studies have shown that PBL is very successful in educating students to "learn how to learn" and develop a positive attitude. The motivating effect of PBL approach is essential to promote a positive attitude among students towards learning. According to Thomas, (2000), a report of a study showed that students' attendance was found to be higher in schools with PBL approach (Thomas 2000). A case study conducted by Harun et al. (2012), revealed that through systematic motivation given by the facilitator, the level of students' motivation can be enhanced to encourage them to reach deep learning. Hmelo-Silver (2004) claims that "enhancing student motivation is purported to be a major advantage of PBL. Because learning issues arise from the problem (in response to students' need to know), intrinsic motivation should be enhanced." (p. 259). However, Hmelo-Silver (2004) notes that there are only a few studies that bear directly on the issue concerning students' motivation since most of the research focused on student satisfaction or confidence instead. PBL promotes intrinsic motivation to students who often reach higher and attempt to read more challenging material to gather the information they seek, hence, improve their reading abilities as they strive to understand and learn (Bell, 2010). Students' motivation is essential in learning, and it is one of a key success factor in PBL implementation or it will infuse negative mind-sets towards PBL among students who are not familiar with inductive learning methods (Harun et al., 2012). In the PBL context, students' motivations towards learning can be achieved in many different ways. According to Pintrich (Cited in Gentry et al. (2001)), in the education literature, the students' motivation could be affected by the three factors of:

- Students' beliefs about the importance and value of the task;
- Students' beliefs about the ability to perform the task;
- Students' feelings about themselves or their emotional reactions to the task.

It is usual that students who are highly motivated showed a high commitment towards their individual learning as well as their learning in teams. However, the nature of students' motivation in PBL can be influenced by their academic or professional discipline of study (Dahlgren & Dahlgren, 2002).

The criteria for effective teaching and learning are all fostered in small group interactions, especially in PBL. Small group teaching depends more on the characteristics displayed by that group rather than the numbers in it. Therefore, the aim of a small group session should be to encourage students to adopt deep approach towards learning and to be a self-directed, active learner (Walton, 1999). PBL is an approach to learning and instruction in which students tackle problems in a small group under the supervision of a tutor (Schmidt, 1983). To assist students to be effective in their learning, teachers should help students become aware of alternative ways of approaching learning situation (McKeachie, 1988), but Weinstein & Mayer (1986) suggest that learning strategies appropriate for one type of learning situation may not be appropriate for another. According to Yeo (2005a), "PBL is a different concept that not many people have heard of, and therefore it is important for the school to communicate the purpose to all staff and students; otherwise, both teachers and students will be left in the dark, only to group for the rationale."

Literature shows that PBL has been defined and described in many different ways. Li et al. (2009), argue that a distinct definition of PBL with one general term is quite difficult to reach due to the complexity of its meanings; however, the majority tries to define and understand PBL mainly deal with four forms of relationships, which are stated as:

- Subject versus problem;
- Teacher versus student;
- Individual versus social;
- Single discipline versus inter-discipline.

The four correspondent principles of PBL are generalized as problem-centered, student-directed learning, social approach, and interdisciplinary learning (Li et al., 2009). Graaff & Kolmos (2003) differentiate the variation of PBL definitions in three levels:

- Theory - central theoretical learning principles;
- Models - specific educational models based on PBL principles; and
- Practices - different practices within the guidelines of traditional educational models.

Even though there is no common consent on PBL practices with specific educational contexts but the learning principles are more or less the same. Thus Boud & Feletti (1997), featured the following characteristic of PBL as an approach to education:

- Utilizing stimulant material that can help students to discuss a key problem, question or issue;
- giving a problem that is simulating the 'real life' situation or professional practice;
- appropriately directing students' critical thinking and providing limited resources to make them learn from defining and make an effort to resolve the given problem;
- having students to work in group cooperatively, seeking appropriate resources in and out of class, with access to a tutor (not necessarily a subject specialist) who knows the problem well and can facilitate the group's learning process;
- getting students to determine their own learning objectives and appropriate use of available resources;
- reapplying this new knowledge to the original problem and evaluating their learning processes.

Weizman et al., (2008) underlines several components in order to be successful in applying the PBL approach. The components include:

- Strong conceptual understanding of subject matter.

- The ability to apply knowledge in new or unanticipated contexts for problem-solving.
- The ability to reason with incomplete information and make decisions that will be the best for the class as well as for individual students.
- The motivation for self-directed learning to stay apprised of current thinking within their subject matter.

Historically, the students' rebellion in the Northern part of Europe around the 1960s had changed the university culture that lead to the development of new educational models, for instance, the project- and problem-based learning (PBL) models that were realized at Bremen University in Germany, Maastricht University in the Netherlands, Linköping University in Sweden, and Roskilde and Aalborg University in Denmark (Kolmos, 2008).

The PBL approaches which originated from two different backgrounds and primary sources namely; McMaster and Roskilde have been widely spread all over the world (Figure 2-1). PBL has evolved and adapted to suit the learning disciplines, learning objectives as well as the local learning culture and environment. Presently, there are thousands of learning institutions all over the world practising PBL which have been inspired in one way or another by a combination of these two original approaches. Kolmos (2009) identified two well-known PBL models namely the problem-based model that practised at McMaster and Maastricht University (mainly in Medicine and Health Sciences) and the problem- and project-based model practised at Roskilde and Aalborg University in the fields of Engineering, Science, Mathematics, Social Science, and the Humanities.

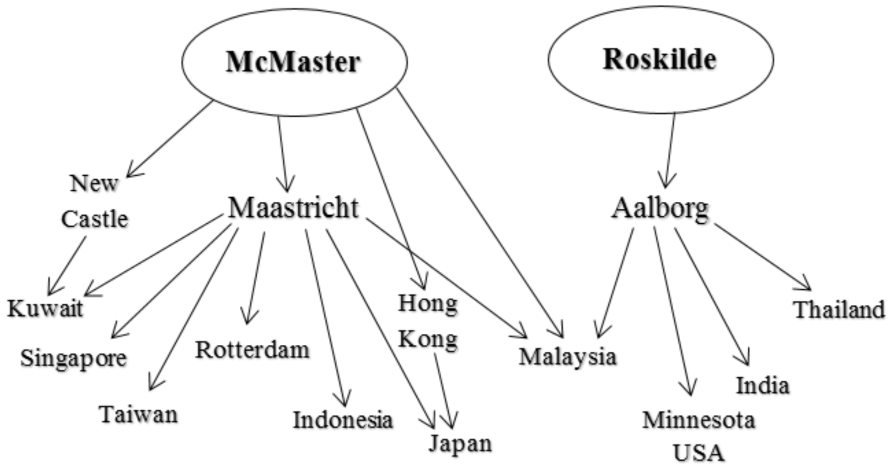


Figure 2-1: Dissemination of PBL according geographical areas

The problem-based model that practiced at McMaster and Maastricht University primarily in Medicine and Health Sciences has inspired many medical education institutions in the countries like Australia, New Castle University (Bokey et al., 2014; Dolmans et al., 2002); Holland, Erasmus University College (Kolmos, 2008; Lee & Kwan, 1997); Kuwait, Kuwait University (Al-Abdulrazzaq et al., 2014); Singapore, Republic Polytechnic (Servant, 2012a); Hong Kong, University of Hong Kong (Servant, 2013a); Indonesia, Gadjah Mada University (Servant, 2012b); Taiwan, Fu Jen Catholic University (Servant, 2013a); Japan, Showa University (Servant, 2012c); and Malaysia, Malaysian Sciences University (Servant & Dewar, 2013; Servant, 2013b; Servant, 2013c; Lee & Kwan, 1997). While the project- and problem-based learning (PBL) models that were practiced at Roskilde and Aalborg University in Denmark have inspired learning institutions in the field of Engineering and Social Sciences such as in Malaysia, Universiti Teknologi Malaysia and Universiti Tun Hussein Onn Malaysia, (Servant & Dewar, 2015); Thailand, Mae Fah Luang University (Coffin, 2014); India, Sinhgad Institute of Technology, Lonavala (Shinde & Inamdar, 2013); and USA, Minnesota's Community Colleges (Ulseth & Johnson, 2015).

The German-Malaysian Institute (GMI) has embraced combination models of Maastricht (seven-step approach) and Aalborg as they are more appropriate to the TVET field that emphasis on the project especially during the final year of study. The Maastricht seven-step approach has inspired the GMI as it has a structured problem-solving process that GMI used as a guide in the PBL sessions and to solve problems which are encountered within the project. The implementation of the PBL approach at the GMI in particular in the CNC Milling and Lathe programming courses is further described in Section 2.7 of this chapter.

2.4.2. THE MCMASTER MODEL OF PROBLEM-BASED LEARNING

The implementation of PBL at McMaster University was driven by the desire to improve the poor clinical performances of students in traditional medical education that emphasis on memorization of disintegrated medical knowledge (Barrows and Tamblyn, 1980). According to Boud & Feletti (1997), in "medical education, with its intensive pattern of basic science lectures followed by an equally exhaustive clinical teaching programme, was rapidly becoming an ineffective and inhumane way to prepare students, given the explosion in medical information and new technology and the rapidly changing demands of future practice" (p. 2).

According to Barrows and Tamblyn (1980), PBL is defined as "the learning that results from the process of working toward the understanding or resolution of a problem. The problem is encountered first in the learning process and serves as a focus or stimulus for the application of problem-solving or reasoning skills, as well as for the search for or study of information or knowledge needed to understand the mechanisms responsible for the problem and how it might be resolved." (p. 18). Barrows underlined four keys of PBL approach:

a) Ill-structured problems: the problems presented to the students as unresolved ill-structured problems that would inspire the generation of multiple assumptions about the reason. The problem models allow free inquiry by the students to gather more information in their effort to achieve understanding and resolution while practising and completing problem-solving skills.

b) A student-centred learning approach: the students have to undertake responsibility for their own learning, determine what they need to learn and seek the appropriate resources for the information (new information is acquired through self-directed learning) to the problems, and responsibility to monitor and assess their own performance and that of their peers.

c) Teachers the facilitators or tutors: the teachers are to facilitate the students in the learning process instead of lecturing and create a close and an adult–adult relationship with students.

d) Authentic problems: the appropriate real-life problems that could challenge the students and make PBL an authentic learning experience.

Source: Adapted from Barrows (1996; 2002).

In complementing the underlined four keys of PBL approach above, Barrows (2002) suggested that the learning should be in small groups, face to face, in the form of knowledge and experience sharing, with active discussion among the students. According to Barrows (2002), in the beginning, the facilitators should guide the students over meta cognitive questioning to stimulate their problem-solving skills, determine the learning objectives and resources, the blend of new knowledge to their problem, summarization of learning issues and their self and peer assessment. The facilitators should withdraw as the students achieve comfort and experience with the approach (Barrows, 2002). Barrows (1986) underlines the learning objectives achievable with PBL with regards to medical education:

- Structuring of knowledge for use in clinical contexts
- The developing of an effective clinical reasoning process.
- The development of effective self-directed learning skills.
- Increased motivation for learning

According to Barrows (1988, 1996), PBL emphasizes on the ability of students to master the learning and develop lifelong students who can think critically, integrate knowledge, self-directed, reflective and able to work collaboratively with others as a team. As an example, Barrows and Tamblyn (1980) summarized the PBL process that practised in the health professional education at McMaster University as follows:

I. The problem is encountered first in the learning sequence before any preparation or study has occurred.

II. The problem situation is presented to the student in the same way it would present in reality.

III. The student works with the problem in a manner that permits his ability to reason and apply knowledge to be challenged and evaluated, appropriate to his level of learning.

IV. Needed areas of learning are identified in the process of work with the problem and used as a guide to individualized study.

V. The skills and knowledge acquired by this study are applied back to the problem, to evaluate the effectiveness and to reinforce learning.

VI. The learning that has occurred in work with the problem and an individualized study is summarized and integrated into the student's existing knowledge and skills (p. 191–192).

A problem is not just a case that is relevant for applying prior learned content knowledge but more to an unresolved issue that needs to be resolved (Barrows and Tamblyn, 1980). Boud (1987) regards a problem as a point of departure and a query that the students need to resolve. Albanese and Mitchell (1993, p. 53) quote that "Problem-based learning at its most fundamental level, is an instructional method characterized by the use of "real-world" problems as a context for students to learn critical thinking and problem-solving skills, and acquire knowledge of the essential concepts of the course." Problem-based learning is a method for organising educational modules challenging students with problems from practice that provide motivation for learning (Boud & Feletti, 1997). The quality of a problem can also influence the students' motivation towards learning (Noordzij & Te Lindert, 2010). Jonassen (1991) claims that "the most effective learning contexts are those which are a problem or case-based and activity oriented, that immerse the learner in the situation requiring him or her to acquire skills or knowledge in order to solve the problem or manipulate the solution." (p. 36).

2.4.3. THE MAASTRICHT PBL MODEL

The University of Maastricht introduced the 'Seven Step' approach model (Bouhuijs & Gijselaer, 1987) also known as the Seven Jump Step approach (Table 2-2) for scaffolding PBL in which students work together in groups of 5 to 12 members, one member chosen as a Chair and another as a Minutes Secretary (Hoidn and Kärkkäinen, 2014). The Seven Jump Step is an approach that students utilise to explain main mechanisms, processes or principles of phenomena described in a problem (Moust et al., 2005). According to Maurer & Neuhold (2014), the 'Seven

Jump Step' (see Table 2-2), also named 'seven-step approach', was developed at Maastricht University to facilitate and structure the students' learning processes within a PBL framework. Table 2-2 shows the Maastricht University 'Seven Jump Step' approach to PBL.

Table 2-2: Maastricht University 'Seven Jump Step' approach to PBL

Step 1:	Classify and clarify unclear terms and concepts in the problem statement.
Step 2:	Define and list the issues in the problem through discussion in a group.
Step 3:	Analyse the issues in the problem through group brainstorming to generate as many as possible reasonable explanations to the phenomenon.
Step 4:	Review steps 2 and 3 and arranges explanations into tentative solutions; scribe organises the explanations and restructures if required.
Step 5:	Formulate learning objectives; group reaches consensus on the learning objectives; tutor ensures learning objectives are focused, achievable, comprehensive, and appropriate.
Step 6:	Self-study; Students seek information related to each learning objective individually.
Step 7:	Students share and discuss findings of self-study with the group and the facilitator checks and assess the learning by probing questions related to the issues.

Source: Adapted from Schmidt (1983), Bouhuijs & Gijselaer (1987) and Woods (2003).

When applying the Seven Jump Step approach the instructor facilitates the learning process by assisting the Chair to sustain group dynamics so as to move the group through the tasks with suitable learning objectives corresponding to the curriculum (Hoidn and Kärkkäinen, 2014). Graaff and Bouhuijs (1993) pointed out that the problem-based learning as applied to the Medical Faculty of the Limburg State (Maastricht) University had the following characteristics:

- Integration of disciplines and skills;
- Curriculum structure with thematic blocks;
- Learning-oriented work in small groups; and
- Self-directed learning.

2.4.4. PBL IN ENGINEERING, THE AALBORG MODEL

In Denmark, a tradition of project pedagogy in engineering education surfaced parallel to the development of PBL (Graaff, & Kolmos, 2007b). Consequently, Aalborg University was established in 1974 as a PBL University and introduced the Aalborg PBL model based on the problem and project-based learning (Graaff, & Kolmos, 2007a; Kolmos, 2009). According to Kolmos (2009), the establishment of Aalborg University as a PBL University was affected by the students' movement as well as being the result of lobbying by the industry. Over time, together with a broad utilization of PBL, thus the PBL concept evolved and practised in a variety of ways to suit the field of studies in the institution. Graaff and Kolmos (2003, 2007a), argued that "there will always be variations in the models used; especially when utilising PBL in various educational systems that represent a wide range of cultures, the very concrete models will and must be different." According to Mohd-Yusof et al. (2012), the diversity of PBL models exists "due to differing needs and cultures, constraints, supporting structures and desired learning outcomes." Furthermore, the PBL model can be practised in many different forms according to the nature of the domain and the specific objectives of the programmes in the educational institutions (Barrows, 1986; Boud, 1987).

The nature of learning in medical education emphasizing patient cases or complaints made their PBL model the suitable approach and was successfully implemented at McMaster as well as Maastricht University and Newcastle University. In medical education, the students examine patients' complaints by making diagnoses and hypotheses. Through these activities; learning by the student occurs while dealing with the cases and developing their understanding of the problems and enhance their knowledge on the subject matter. However, according to Kolmos (1996), "in scientific and technical education it may be very difficult to practise a problem orientation of that kind."

Kolmos (2009) stated that "PBL as a teaching and learning model also has a lot in common with other educational approaches such as active learning, inquiry-based learning, experiential learning, cooperative learning, and case-based learning." Kolmos et al. (2004) argue that, although there are differences in how problem-based models are practiced at the learning institutions worldwide, they are established on the similar theoretical basis and thus the same learning principles introduced by Piaget (1974), Dewey (1933), Lewin (1948) and Vygotsky (1978).

The Aalborg University introduced the Danish problem-based and project organized model (The Aalborg PBL Model) based on the ideas of Illeris who formulated principles as problem-orientation, project work, interdisciplinary, participant directed learning, and the exemplary principle and teamwork (as cited in Kolmos et al., 2004). The concept of problem orientation of the Danish PBL approach was comparatively equal to the definition of problem-based learning introduced at McMaster University (Kolmos et al., 2004). However, according to Kolmos et al. (2004), in Aalborg when applying the PBL model the students analyse and also define problems (see Figure 2-2) within a defined subject structure, work together in teams on their project and produce a common project report. Figure 2-2 shows the key principles of the Aalborg PBL model. Aalborg University makes use of the Problem and Project-Based Learning (PBL) as an innovative teaching and learning model that incorporates problem- into project-based learning with a substantial focus on project activities throughout the educational module (Kolmos, 1996).

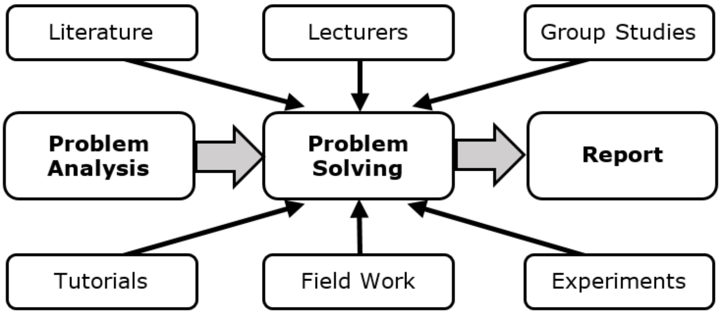


Figure 2-2: Principles of project-organized problem-solving

Source: Adapted from Kjærsdam and Enemark (1994).

The practice at Aalborg University demonstrated that the concept of problem-orientation in some ways has been separated from the idea of project work in which the problem orientation is integrated into project work in three ways (Kolmos, 1996):

- In the first year the assignment and the problem project dominate;

- In the second and third years the assignment and the subject project dominate; and
- In the fourth and fifth years, the problem project dominates.

The project work model differentiates the Aalborg PBL model (see Figure 2-3) from other PBL models where it is applied in all study programmes in the faculties such as Faculty of Humanities, the Faculty of Social Science, and the Faculty of Engineering and Science at Aalborg University (Kolmos et al., 2004). According to Kolmos et al. (2004), the project work is made in groups of 6-7 students in the first semester and reduced to a maximum of 2-3 students in the final semester. The selected projects replicate the real-life projects which are based on open or controlled problem formulations that are able to motivate and challenge the students (Kolmos et al., 2004). Hence, the learning takes place once students in the teams worked on the projects and applied their knowledge (know-how and know-why) on the real or simulated problems. Learning takes place through the application of knowledge and skills to the solution of problems that are often in the context of actual practice (Bligh, 1995). Graaff & Kolmos (2003), indicate that "the problem", "the content" and "the teams" are the three dimensions of the central theoretical learning principles for problem-based and project-organised learning. The most important requirement for students about to start working on a project is genuine interest (Olsen & Pedersen, 2008). Blumenfeld et al. (1991), argue that the issues that motivate students to involve themselves in project work are diverse, the authenticity of a problem, the challenge of a problem, the choice about what and/or how the work is done and the chances to work collaboratively with others in a group.

In the Aalborg PBL Model, the learning process takes place in teams in the early semester where students start to work on the project. The students conduct a meeting in groups to determine their learning objectives and formulate their project proposal with a supervisor to approve the proposal (Kolmos et al., 2004).

Doppelt (2003), argues that the students' "motivation to learn, their discipline and their willingness to work on their projects longer hours indicate that they behaved like high achievers" (p. 264). In the organisation of Aalborg PBL model (Figure 2-3), besides the project works, the students are required to enrol for project courses that enable them to apply in their project work. The organisation of the studies can be illustrated as the model in Figure 2-3.

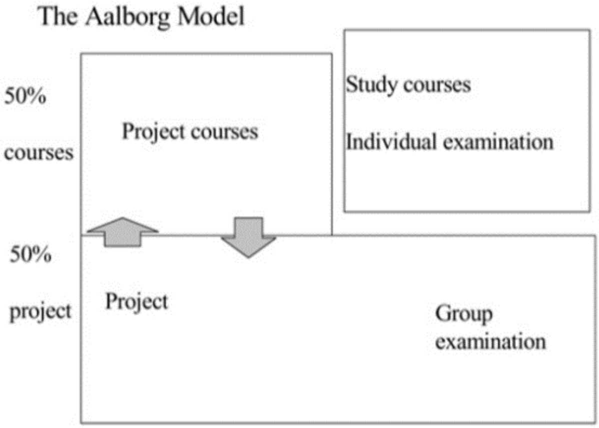


Figure 2-3: The organisation of the traditional Aalborg PBL model.

Source: Adapted from Kolmos et al. (2004).

In terms of assessment, the students are subjected to a joint group examination with individual marks for project work and traditional examination for study courses. Graaff and Kolmos (2007b) and Barge (2010), define the terms used in the Aalborg PBL model as follows:

> **Problem:** The problem is the point of departure driving the students' learning process and positions the learning in a context. A problem can be theoretical, practical, social, technical, symbolic cultural and/or scientific problems.
>
> **Project:** A project is a complex students' group work that involves planning and project management skills to deal with problem analyses. Projects are essentially diverse without a specific standard and according to the scope and specific definition.
>
> **Interdisciplinary:** Interdisciplinary includes the crossing of the professional discipline boundaries in which the problem analysis process and solutions are not restrained to traditional professional limits.
>
> **Participant control:** Participant control refers to the students (themselves) who are responsible in making relevant decisions and control the progress of the process to ensure the learning is experienced and significant.

Exemplarity: Exemplarity is a principle of choosing appropriate specific learning outcomes and content or scientific knowledge that is exemplary to overall learning outcomes. A problem needs to refer to a particular practical, scientific and/or technical domain and should manifest the general learning outcomes related to knowledge and/or modes of inquiry.

Team: A team is a group of students who share and work closely together in the design, decision making, analysis and reflection to complete a project successfully.

Supervisor: A supervisor is a person who regularly held by a faculty member serving as a resource for groups of students involved in project work. A supervisor who is also known as an advisor or facilitator does not have a formal multi-term or multi-year relationship with any student (or group of students).

Project Courses: A project course that is also known as project subject is a part of an education programme that relates directly to the term theme and the students' project work. The selection of a project course by students is based on the course's relevance to their project work.

Study Courses: A study course which is also known as study subject is a part of an education programme that introduces students to fundamental concepts, theories or skills of a particular discipline. The assessment of the courses is done separately from the project courses and project work.

However, the PBL curricula of the Aalborg PBL model in the Faculty of Engineering and Science was redesigned and the new curricula of the PBL model (Figure 2-4) has been implemented in the middle of 2010 (Dahl et al., 2016). The differences between the two models are the assessment and the relationship between the courses dominated by lectures and the students' projects. The original PBL model evaluated some of the courses and projects together, while for the new the Aalborg PBL model the assessment is done separately for each course and project (Dahl et al., 2016). In the original Aalborg model (Figure 2-3), the ‘‘project unit’’ represented 75% of the semester and consisted of a project covering 50% of the semester and project unit courses amounting to 25% of the semester (Kolmos et al., 2004; Dahl et al., 2016). In the new PBL model (Figure 2-4), the project unit courses are no longer used and the theme is now associated with the project and in each semester there are three-course modules of 5 ECTS with their own assessment and a project of 15 ECTS (Dahl et al., 2016).

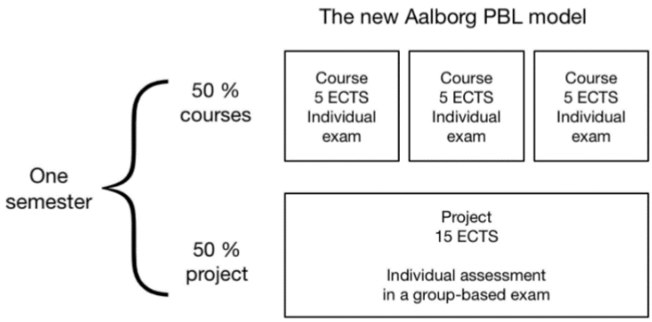


Figure 2-4: The organisation of the new Aalborg PBL model.

Source: Adapted from Dahl et al. (2016).

2.5. RATIONALE OF IMPLEMENTING PBL IN THE TVET

The author suggests that students cannot continuously be spoon-feeding in acquiring knowledge, but they should be exposed to "learning how to learn" to help them cope with demands of a rapidly changing and competitive working environment. Gackowski (2003) argues that "students must not only complete the course requirements, but also must demonstrate, at specified levels of sophistication, the ability for effective communications, analysis, problem-solving, decision-making, social interaction, and regard for aesthetic aspects of their presentations and system documentation." (p. 364). Furthermore, according to Lucas et al. (2012), the effectiveness of all education systems depends vitally on the quality of teaching and learning in the classrooms, workshops, laboratories and other areas in which the education occurs The technical training provider should develop learning and training opportunities that help students develop problem-solving skills and lifelong learning. The employers in the industries required students who could think critically, solve problems and work in teams with other employees.

The rapid advancement of technology has demanded the engineering education as well as Technical Vocational Education and Training (TVET) to move in line in producing not only engineers but also the technologist that can cope with the rapid progress of technology in the industry. On top of that, the engineers and technologist need to have the necessary attributes, which are more relevant to the industry stakeholders. As discussed in Chapter One most surveys showed that graduates including engineering graduates are not reaching the expected levels of competence skills needed by the industry, especially in Malaysia. There is a common perception that engineering graduates in Malaysia and other countries as well, are not competent enough in terms of their generic skills such as teamwork, communication, lifelong learning, and entrepreneurial skills. The study regarding "Future of Engineering Education in Malaysia" in 2006, as discussed in Chapter One, revealed that employers are concerned with enhancing the competencies of graduates. Furthermore, the study recommended that the learning experience in the engineering programmes should be strengthened in all areas with greater emphasis is given on communication skills, teamwork, problem-solving, creativity and innovative thinking (Hassan et al., 2007).

It has been the vision and aspirations of the Malaysian government to enhance the education system so that it is capable of developing skills and attributes needed for the 21st century (Malaysia, 2012). Therefore, being aware of this issue, the government of Malaysia through the Ministry of Higher Education urged the higher education institutions to embed graduate attributes into the curriculum and training system. The former Higher Education Minister, Datuk Mustapa Mohamed, stated that the action of embedding the graduate attributes into the curriculums was based on the feedback from employers that the outputs from local education institutions lacked in graduate attributes that result in the unemployment (Quek, 2000; Baharuddin, 2003).

Therefore, the real challenge lies within the learning institution's educational approach itself to fulfil the Malaysian government's vision and aspirations. Hence the challenge is to educate and equip the engineering and technologist graduates with the necessary attributes in order for them to be well prepared to face future challenges in the practice of technology and engineering in the era of globalisation, rapid technological and ICT advancement as well as ethics and civil obligations. However, without a right and proper approach to promoting such important skills and attributes, the Malaysian government's objective will not be successful and effectively achieved.

The literature on PBL presented in Section 2.4 highlighted some of the available information as well as research studies related to the PBL characteristics and models which championed the many advantages of students' learning. However in a medical environment, according to Vries et al. (1989), the students in the PBL curriculum developed stronger clinical competencies than their traditionally trained colleagues, although the differences were small. This particular research has been done in a medical environment in which "clinical competencies" is also sometimes labelled as medical problem-solving ability, which means the ability of a position to recognize symptoms to know what should be done about that. Medical skills are very much practical-oriented and consist of a combination of diagnostic capabilities of relevant knowledge and the ability to make quick decisions. Similarly, just like medical students who need to make an instant decision to solve complex situations, the same mental ability is also necessary for students in the fields of engineering and TVET. The fact that PBL has demonstrated that there is an increase in clinical competencies in medical problem-solving competence; there is a good reason to expect that something similar will result with students in the engineering field as well as in TVET.

The discussion in Section 2.4.1 has shown how and why PBL is a valid education strategy and a method of organising the learning process by the students who willingly and actively engaged in finding answers by themselves, thus leading to a number of characterises values of PBL, such as: Learners in the PBL environment play an active role in the knowledge acquisition process by trying to solve ill-structured problems through participation in small group discussions and self-study. PBL inspires greater motivation, which brings into the practice elements of excitement, active participation, and involvement. PBL approach triggers the students' learning, and they become highly motivated, they enjoy the activities they do, appreciate the value of what they learn, consider how they will use their newly acquired knowledge and skills in the real situation in future and experience sense of achievement upon completion of a project. PBL promotes intrinsic motivation to students who often reach higher and attempt to read the more challenging material to gather the information they seek, hence, improve their reading abilities as they strive to understand and learn. PBL provides a more realistic approach to learning and creating an educational method that emphasizes real-world challenges, higher order thinking skills, multi-disciplinary learning, independent learning, and teamwork and communication skills.

The values and characteristics of PBL, as described above, have inspired the GMI, which is a premier TVET provider in Malaysia to embed PBL in its courses and be a part of the learning approach. Adapting PBL as a teaching approach will assist students to improve the ability to reach informed judgements by effectually defining problems, gathering and assessing information linked to those problems, and developing solutions (Savery, 2009). The students will demonstrate the capacity to function in a global community; adaptability; the ease with diversity; motivation; creativity; technical competence; and finally, the ability to work with others, particularly in team settings (Savery, 2009).

In addition, the literature study done by Sada et al. (2015) conclude that PBL is an essential tool for educating students in technical and vocational fields. They concluded that making use of the PBL approach in TVET will enhance the students' skills in communication and information retrieval which will enable individuals to gain and apply new knowledge and expertise as required. The students will demonstrate the ability to organise all of the previous skills to address particular problems in complex, real-world settings, where the development of realistic solutions is essential (Sada et al., 2015).

Judging by these facts, the GMI was convinced and identified PBL as a learning approach because it has the qualities to train TVET students effectively in line with the aspiration of the Malaysian Ministry of Education, in order to equip the students with generic skills such as communication, teamwork and problem-solving. The implementation of the PBL in TVET could fulfil the aim of the GMI to produce graduates who are competitive, employable and who can face the challenges of the rapid changes in technology. This aim is also consistent with the aspiration of the Malaysian Ministry of Education. The PBL activities in the CNC programming courses can be seen in Appendix I-1.

2.6. COMPUTER NUMERICAL CONTROL

The requirement of mass production and the need to automate machinery in the manufacturing sector developed a demand for greater precision and indicated greater competition in the marketplace; these needs have pushed researchers to search for ways in which production depends more on machines than on human capabilities (Pollack et al., 1990). The production requirements during the World War II in the 1940s became more stringent due to demands of the United States Air Force for military weapons, missiles and aircraft components that were more complicated and sophisticated; exceeded industry's capability to produce with high precision (Pollack et al., 1990).

The introduction of Computer Numerical Control (CNC) machines and other new technologies has enhanced the production and precision in the manufacturing industry (Demarco, 2013). The development of CNC machine began back in 1949 when John Parsons and Massachusetts Institute of Technology (MIT) were appointed by the U.S. Air Force to develop a machine where the positioning of the machine axes would be directly controlled by a computer (Pollack et al., 1990). Later, they delivered the first numerically controlled (NC) machine tool with a vertical spindle (NC Milling machine) that could travel in 3 linear axes, getting binary coded data stored using punch paper tape identified as Cincinnati Hydrotel (Kief & Waters, 1992). According to Sinha (2010), the "numerical control is an application of digital technology to control a machine tool by actuating various drive motors, relays, etc. by a series of coded instructions, called part programs. These machines were initially called numerically controlled (NC) machines." (p. 1).

The era of Computer Numerical Control (CNC) began in 1976 with the frequent use of a microcomputer where microprocessors substituted the older generation of diodes computers (Kief & Waters, 1992). The advancement in the CNC technology was followed closely with the rapid progress in the computer field (Seames, 2001). The CNC machine provided with micro-computer would enable the machine to store, read, edit, and process programmed data (Seames, 2001). Moreover, it also provides graphical abilities (graphic simulation), diagnostic procedures, alarm messages, and system troubleshooting. According to Leatham-Jones (1986), Computer Numerical Control (CNC) retained the basic concepts of Numerical

Control (NC) but utilizes a dedicated programme stored in a computer within the machine control unit. Valentino & Goldenberg (2013), describe the Computer Numerical Control (CNC) machine as Numerical Control (NC) machine using the added feature of an on-board computer.

The on-board computer was often referred to as the machine control unit or MCU. Valentino & Goldenberg (2013), further define the Numerical Control (NC) was a method of automatically operating a manufacturing machine built on a code of a letter, numbers, and special characters. Amic (1997), argued that when numerical control was performed under computer supervision, it was called Computer Numerical Control in which the computer is the control unit of a CNC machine which was built-in or linked to the machines using communications channels.

At present, the CNC technology is used in a variety of manufacturing equipment such as lathes and milling for metal machining, water jet cutting, wood cutting routes, laser cutting, flame cutting, grinders, welding, and testing and inspection equipment (Amic, 1997) and many more. After World War II, product demand was shifted to consumer goods such as automobiles, appliances, radios, and televisions.

The main difference and the principal advantage of CNC equipment were the enhanced repeatability of the cutting tool and control (Kuric et al., 2012). CNC machine allows for the manufacturing of components which would otherwise be hard or impossible to manufacture with conventional machines and techniques. CNC has demonstrated to be an economical and efficient way of controlling and operating machine tools. According to Valentino & Goldenberg (2013), the Numerical control NC system offers some of the following advantages over conventional methods of production:

- Better control of tool movements under optimum cutting conditions;
- Improved part quality and repeatability;
- Reduced tooling costs, tool wear, and job setup time;
- Reduced time to manufacture parts;
- Reduced scrap;
- Better production planning and placement of machining processes in the hands of engineering.

Leatham-Jones (1986), underlines the several applications in which CNC may be applied for cost-effectiveness:

- Where reliable and high-quality components were concerned;
- Where operations or set-ups were numerous or costly;
- When machine run-time was disproportionately low, compared with set-up time;
- Where the part was so complex that quantity production involves the possibility of human error;
- Where design changes, or individual variations, were required for a family of parts;
- When tooling costs were significantly high, or where tool storage was a problem.

2.6.1. THE CNC MILLING AND LATHE MACHINES

Milling and Lathe machines which are known as machining centres are the machine tools used to shape metal and other solid materials using milling cutters (for CNC milling) and single-point cutter (for CNC lathe). The main difference between CNC milling and turning (lathe) machines is the application of tools in which the tools of milling operation are of the rotary type while standard lathe, tools are stationary or fixed (Smid, 2010).

In milling operation (see Figure 2-5), the cutting tool (end-mill) rotates about the spindle axis and move with the certain cutting feed into the material (work-piece) which is affixed to a clamping device (Kalpakjian et al., 2014). The CNC milling operation involves the movement of the rotating cutter (End-mill) sideways as well as 'in and out' following a pre-programmed path or contour (see Figure 2-9).

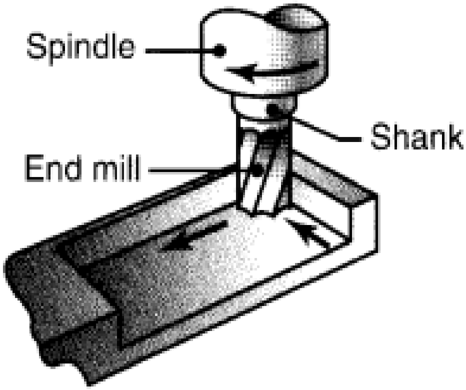


Figure 2-5: Milling Operation

Source: (Kalpakjian et al., 2014).

The cutter and work piece travel relative to each other, generating a tool path along which material is removed. Often the movement is accomplished by moving the table while the cutter revolves in one place, but regardless of how the components of the machine slide; the result that matters is the relative motion between the cutter and the work piece.

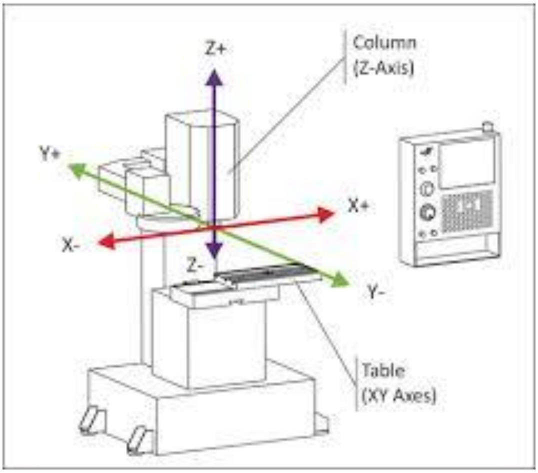


Figure 2-6: The axes of a CNC milling machine.

Figure 2-7: Typical of CNC milling machine provided with graphic simulation at the controller.

Generally, the CNC milling operates along the three linear axes as shown in Figure 2-6, these axes known as X for longitudinal, Y for the cross, and Z for the vertical of machine coordinate system (IFAO, 1985). The CNC Milling machines may be operated either manually or an in automatic mode. Figure 2-7 shows a modern three linear axes of X, Y, and Z CNC milling machine fitted with graphic simulation at the controller and typical machining operation (see Figure 2-8) which can be performed at the CNC milling machine.

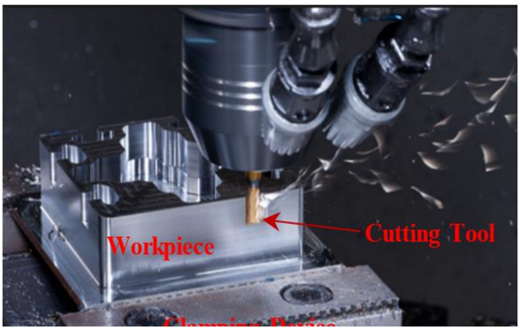


Figure 2-8: Typical machining operation performed by a CNC Milling machine.

```
%LINEAR G71 *
N10 G30 G17 X+0 Y+0 Z-20 *
N20 G31 G90 X+100 Y+100 Z+0 *
N30 G99 T1 L+0 R+10 *
N40 T1 G17 S4000 *
N50 G00 G40 G90 Z+250 *
N60 X-10 Y-10 *
N70 G01 Z-5 F1000 M3 *
N80 G01 G41 X+5 Y+5 F300 *
N90 G26 R5 F150 *
N100 Y+95 *
N110 X+95 *
N120 G24 R10 *
N130 Y+5 *
N140 G24 R20 *
N150 X+5 *
N160 G27 R5 F500 *
N170 G40 X-20 Y-20 F1000 *
N180 G00 Z+250 M2 *
N999999 %LINEAR G71 *
```

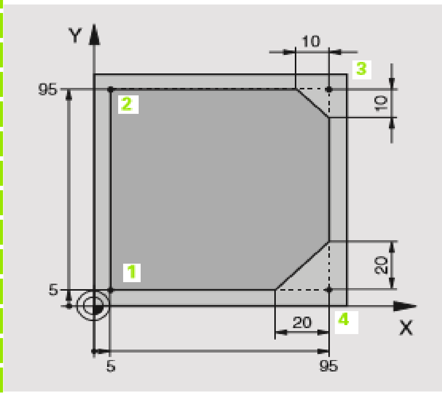


Figure 2-9: Example of a CNC Milling programme.

Source: Heidenhain (2004).

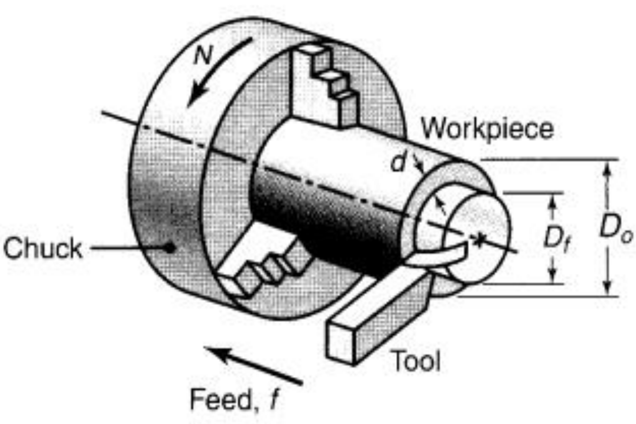


Figure 2-10: Lathe Operation.

Source: (Kalpakjian et al., 2014).

In lathe operation (see Figure 2.10), the cylinder-shaped work piece clamped to the chuck is rotated on its axis while it is being machined with a fixed single-point cutting tool and move with certain cutting feed (Kalpakjian et al., 2014). The CNC lathe operation involves the movement of the cutting tool fixed at the turret towards the rotating work piece according to the pre-programmed path or contour (see Figure 2-14). The typical CNC lathe working with two axes as shown in Figure 2-11, these axes are known as X for the cross, and Z for longitudinal of machine coordinate system (IFAO, 1985). Similar to the CNC milling machine, the CNC lathe machine can also be operated either manually or in an automatic mode.

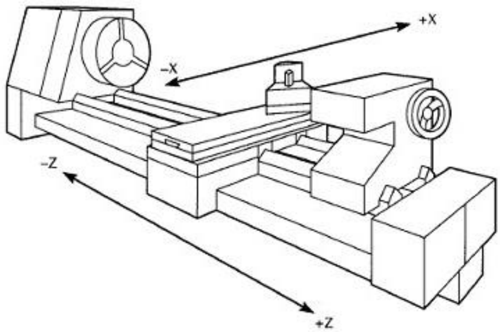


Figure 2-11: The Axes of a CNC Lathe machine

Figure 2-12: Typical of CNC lathe machine provided with graphic simulation at the controller.

Source: Goodway Machine Corp.

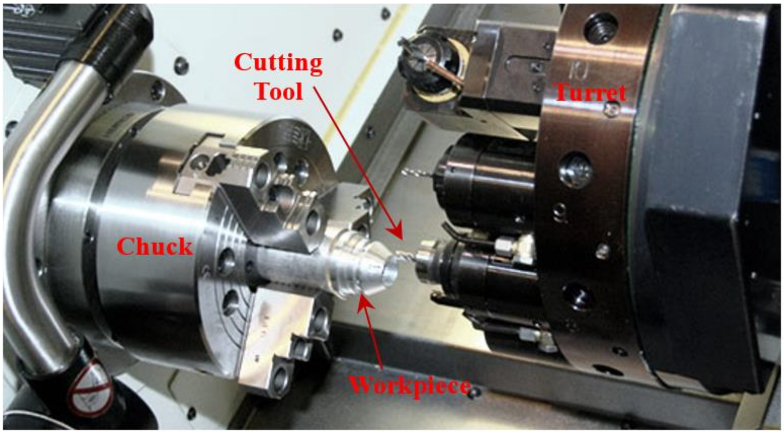


Figure 2-13: Typical machining operation performed by a CNC Lathe machine.

Typically, according to Chapman (2004), a machining centre such as CNC milling or lathe are numerically controlled machines with multipurpose capabilities such as milling, drilling, boring, tapping and reaming. Figure 2-12 shows a modern CNC lathe machine provided with graphic simulation at the controller and Figure 2-13 shows a typical machining operation that can be performed at the CNC lathe machine.

```
. . .
N1 T3 G95 F0.25 G96 S200 M3
N2 G0 X120 Z2
N3 G83 X80 Z0 I4 K0.3
N4 G0 X80 Z0
N5 G1 Z-15 B-1
N6 G1 X102 B2
N7 G1 Z-22
N8 G1 X90 Zi-12 B1
N9 G1 Zi-6
N10 G1 X100 A80 B-1
N11 G1 Z-47
N12 G1 X110
N13 G0 Z2
N14 G80
```

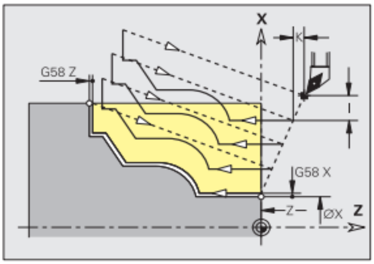


Figure 2-14: Example of a CNC Lathe programme.

Source: Heidenhain (2010).

2.6.2. THE CNC MACHINE SIMULATOR

Computer simulations are currently used extensively in many fields of education such as science, technology, medical, aviation, architecture, engineering (Fang, 2012; Guoqiang, 2010), TVET and also in the manufacturing industries, and according to Smith & Pollard (1986), the computer simulation can also be utilized in teaching the techniques of engineering design and manufacture and the underlying principles which determine the behaviour of engineering systems. Furthermore, computer simulation has been used in engineering fields such as mechanical, civil, electrical, electronics and chemical and many other engineering fields for analysis, modelling, forecasting, dry-run and practical purposes (Fang, 2012).

The computer simulation represents the actual situation and condition that allow students to experience the learning intensively without the worry of injuries, danger to the environment and/or material (Jong, 1991) or damage to the system or machine when a mistake has been done. Within the context of education Alessi and Trollip, (1991), recognized four distinct types of simulation:

- Physical simulations: Students learn and acquire skills from a simulation of physical objects;
- Procedural simulations: Students learn and acquire skills through operating systems;
- Process simulations: Students learn and acquire skills through observation of the development of the simulation state over time;
- Situational simulations: Students learn and acquire skills through playing certain roles.

Computer simulations are very safe, cost effective and within acceptable time frames when compared to real-life situations, without sacrificing data analysis, access to large amounts of information, critical thinking, strategic reasoning and problem-solving skills (Faryniarz and Lockwood, 1992).

Currently the Computer Numerical Control (CNC) machines' tools are equipped with a simulator at the machine controller as shown in Figure 2-15 which is capable of simulating the machining processes and final geometry of a component before the actual machining take place. Furthermore offline CNC programming simulators are also available for training purposes as shown in Figure 2-16.

The simulator comes very usefully to avoid damage if students are trained with real and very expensive, delicate and highly sophisticated equipment and machines.

Students can utilize the danger free environment to more easily transfer knowledge to real-world situations (Barrows and Tamblyn, 1980).

Heidenhain (2010) underlines the purposes of the simulation as follows:

- Contour simulation: Simulation of programmed contours;
- Machining simulation: Checking the machining process;
- Motion Simulation: Simulation of real-time machining with continuous contour regeneration;
- 3-D view: 3-D depiction of machined contours;
- Time calculation: Display of the machining times and idle times for each tool used;
- Synchronous point analysis: Depiction of work-piece machining with multiple slides. The display shows both the time sequence and the dependencies of the slides among each other;
- Debug functions: Display and simulation of variables and events.

Figure 2-15: The CNC controller with 3-D graphic simulation capabilities.

Source: DMG MORI

According to Shivasheshadri et al. (2012), simulation has many advantages, for instance:

- interrupting the real system, to avoid inventing the high cost of implementing a system;
- to enable training and to make learning possible;
- to check if the analytic solutions offered by the analysis of mathematical models are correct;
- to answer questions about how or why the phenomena occur;
- or to know how small change in a part of the system affects whole manufacturing system.

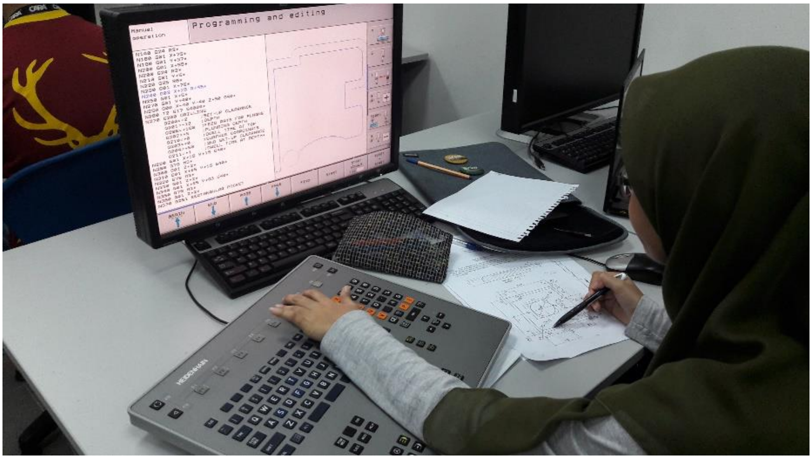


Figure 2-16: The offline CNC programming simulator used by students for training purpose.

Another advantage of computer simulation is that it can model the designed product or the machining strategy before the actual one is performed and optimization can be made to reduce the production time and cost.

As with PBL, computer simulation has a great potential in the PBL process because it provides students with the chance to observe a real world experience and interact with it (Sahin, 2006). Furthermore, computer simulation might contribute to conceptual changes; provide open-end experiences, tools for scientific inquiry and problem-solving experiences that increase the effectiveness of PBL (Araz & Sungur, 2007).

2.7. THE IMPLEMENTATION OF PBL AT THE GERMAN-MALAYSIAN INSTITUTE

As described in Section 2.5, the PBL implementation at GMI is driven by the vision and aspirations of the Malaysian government to enhance the education system and aiming to develop the skills and attributes needed for the 21st century. Prior to the implementation of PBL at the GMI in 2010, several study visits were performed in 2008 by a group people from the GMI (Director and Department Heads) as well as the agencies and ministries (Directors and Deputy Chief Executive Officer) of the Malaysian government. The study visits were made to several PBL practitioners in Indonesia, Politeknik Manufaktur Negeri Bandung (Polman, Bandung) & Politeknik ATMI, Solo; Singapore, Institute of Technical Education (ITE) & Republic Polytechnic; Netherlands, Maastricht University; Denmark, Aalborg University; and United Kingdom, University of Manchester & University of Loughborough. The objectives of these study visits were to look more closely at the implementation of the PBL models in various education fields and conduct a comparative study as well as benchmarking of various Student-Centred Learning (SCL) methodologies so that best practices can be identified (Cheng Hwa et al., 2009). As a result of the study visits, a model of learning approach was introduced to suit the learning and training at the GMI namely the Problem-Project-Production-Based Learning (Pro3BL), which is depicted in Figure 2-17. According to Cheng Hwa et al. (2009), Pro3BL is an innovative "instructional approach" in a Student-Centred Learning (SCL) environment that allows for flexible adaptation of guidance through problem-solving, project works and real life production, furthermore with Pro3BL in the SCL environment requires teachers to be facilitators to facilitate the students' learning in a form of group or work project which is generally less structured than traditional, teacher-led classroom activities. The expected educational outcomes of this Pro3BL model are to produce lifelong learners, innovative and employable graduates and with versatile knowledge workers. In this model of Pro3BL, the "instructional approach" has its own definition due to the fact that the institution like GMI comes from a traditional teaching of using an instructional method to an SCL environment. Changing to PBL is not just changing the instructional method but it is actually changing to a different educational philosophy where things have a different meaning at a different place. In fact, PBL is therefore not an instructional method, but much more than that. Therefore, all these models are actually a summing-up of how people have done the PBL in different ways at different places.

Figure 2-18 shows that Pro3BL consists of Problem-, Project- and Production-Based Learning and Figure 2-19 shows show how it is applied at the different level of three-year study of Diploma programme. Thus the Problem- and Project-Based Learning implemented in year one and two while Production-Based Learning is practised in year three of study. The underpinning idea is that the students in the first year are exposed to problems (Problem-BL) within the subject matters so that they are oriented to the new way of learning. This is because the majority or almost all of the students during the first semester at GMI are not familiar with PBL approach. At this stage, the students main focus only on solving the problems in a team working. In the second year of study, the students need to work on a project (Project-Based Learning) where they are exposed to planning, organising a project (i.e. a mould project) and collaborating with other team members besides solving the problems in a team. Throughout the implementation of a project (Project-BL), the students would encounter many technical problems as well as problems in planning, organising as well as collaborate with other team members and here they develop their skills in managing a project. In the final year of study, students are involved with the real industrial activities using multi-disciplinary knowledge and skills to produce the product through the Production-BL approach. The concept of Production-BL approach at GMI is where students will further working with their project. For instance, a mould of a product that they need to do a trial out on the mould that they have made on the plastic injection moulding machine. From the trial out the students would identify the defect on the injected product and try to make remedies by adjusting the setting of machine parameter. The activity of trial out will go on until the students have the product that meets their requirement and specification. Though, this Pro3BL model still needs further fine-tuning especially the Production-BL since not many definitions on the Production-BL and learning institutions that adopting this approach that could be used as a reference. However, Ganefri (2013), defines the Production-based Learning model "as the procedures or steps that need to be performed by the educator to facilitate learners to actively learn, participate and interact, with a competency-orientation to produce a product either goods or services required."

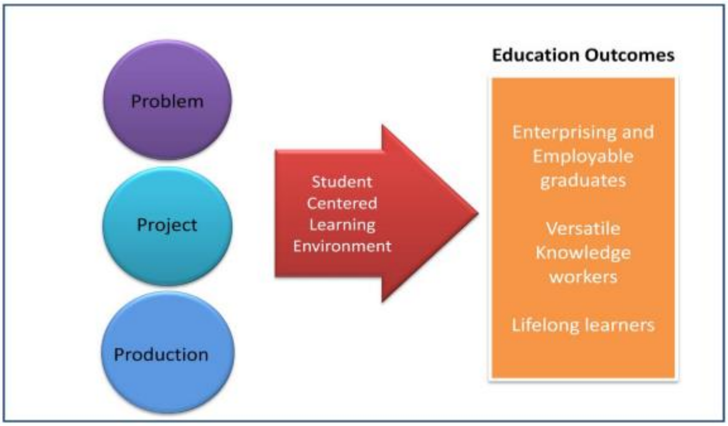


Figure 2-17: Model of Pro3BL with the educational outcomes.

Source: Cheng Hwa et al. (2009).

Taking into account the structure of Pro3BL in Figure 2.18, the deployment can be done in sequence or even as a single approach depending on the needs, the level of study and complexity of the task to be achieved. The process and learning steps of Pro3BL are illustrated in Figure 2.20 in which students will be assigned to a group of four or six. This Pro3BL model is a hybrid model inspired from the seven-step of Maastricht and Aalborg University Problem- and Project-Based Learning. While the Production-Based Learning of Pro3BL is enthused from the Production-Based Education practised by the Politeknik Manufaktur Negeri Bandung (POLMAN Bandung) and the Politeknik ATMI, Solo in Indonesia which integrate education and manufacturing/production concurrently.

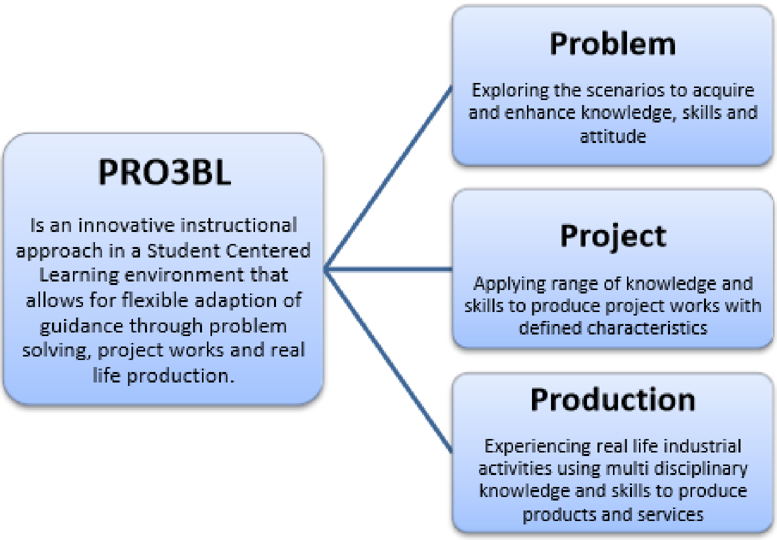


Figure 2-18: Pro3BL Structure.

Source: Cheng Hwa et al. (2009).

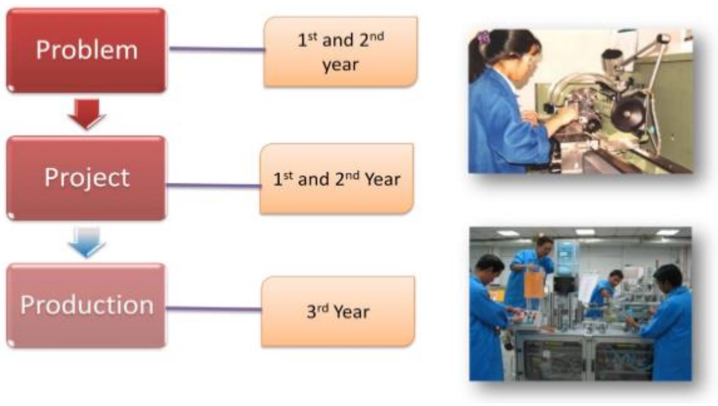


Figure 2-19: The sequence of implementing Pro3BL

Source: Cheng Hwa et al. (2009).

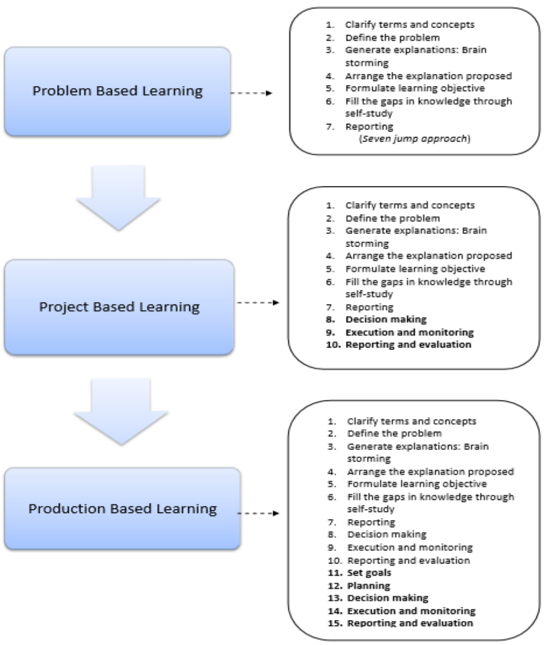


Figure 2-20: The process and learning steps of Pro3BL.

Source: Cheng Hwa et al. (2009).

The literature review indicated that many other “PBL” hybrid models are also applied in other learning institutions including Stanford University in the USA. According to Fruchter (1996), Problem-, Project-, Product-, Process-, People-Based Learning (P5BL) approach has been practised for the past few years in the innovative Architecture/Engineering/Construction course offered at Stanford’s Civil Engineering Department in collaboration with University of California (UC), Berkeley. Furthermore, Fruchter (1998) states that P5BL is about teaching and learning teamwork in the information age; is a methodology of teaching and learning that emphases on problem-based, project- organized activities that produce a product for a client.

In order to implement the Pro3BL within the GMI, it was necessary for the staff to familiarise themselves with the PBL approaches and to be trained accordingly. To this end, a total of 25 participants comprising of GMI’s teaching staffs and officers of various Ministries have participated in a 3-day workshop on PBL at Republic Polytechnic in Singapore. They were given the responsibility to develop Pro3BL at GMI. A total of 16 subjects as depicted in Table 2-3 was selected as a pilot and initiated with Pro3BL in January 2010. The subjects mostly of semester one consisted of the general and technical subjects of three different departments namely Resources Development Centre (RDC), Industrial Electronics (IE) and Production Technology (PT).

Table 2-3: The Subjects of Phase One in implementing Pro3BL.

No.	Subject	Code	Semester
1.	English	ESP 2022	2
2.	English	ESP 2012	1
3.	Physics	MAP 2142	1
4.	German Language	GEL 2312	1
5.	Mathematics	MAP 2113	1
6.	Network Security & Ethics	NTC 1012	1
7.	Digital System	EET 0133	1
8.	Computer & Internet	CIT 0152	1
9.	Electrical Principles	EET 0144	1
10.	Electrical & Electronics	EET 0162	1
11.	Basic Metal Work	MPT 0122	1
12.	Basic Cutting Processes	MPT 0114	1
13.	Engineering Metrology	QAS 0353	1
14.	Material Science	MAS 0412	1
15.	Conventional Turning	GMO 0212	1
16.	Conventional Milling	GMO 0222	1

Source: Cheng Hwa et al. (2009).

Complementary to the above, the important issues pertaining to the Pro3PL implementation at GMI was highlighted by Cheng Hwa et al. (2009) and consisted of the following:

1- Lack of Personnel for Expertise Development

- PBL Curriculum Developer
- Problem Crafters
- Pro3BL Facilitators

Personnel with the above competencies are highly needed to change the learning environment, materials, approach, assessment and also mind-set of students, teachers and administrators.

2- PBL Curriculum

Most of the traditional curricula need to be reviewed and realigned to develop Pro3BL Curriculum that could be theme-oriented, based on learning outcomes or even integrated.

3- Changing Roles

Changing the mind-set will the greatest challenge because most of the teacher and learner have been in the situation of the dominating traditional frontal teaching. Students who have been spoon-fed will now have to be an active and self-reliant learner and on the other hand, a teacher who has been content or knowledge provider will have to be a facilitator in a student-centered learning environment.

The current status of Pro3BL at the GMI since the implementation in 2010 has developed as follows: The number of subjects has increased from 16 to 26 subjects as depicted in Table 2-4. Most of the subjects are the technical subjects of semester two, three and four including; the CNC Milling and Lathe programming subjects. The awareness programmes on Pro3BL are held from time to time so that the teaching staffs and students will further enhance and cultivate a positive mind-set in the implementation of the Pro3BL at GMI. To address the highlighted issues pertaining the Pro3PL implementation at GMI as mentioned above; courses and seminars are provided in-house as well as externally to the teaching staffs, especially in the PBL curriculum development, facilitation, and problem crafter. Several teaching staffs are also sent to further their study at several universities abroad on PBL as part of a long-term strategy. This is a part of GMI's strategic plan to be a future Pro3BL leader in TVET and provide training to other TVET providers (Cheng Hwa et al., 2009).

Table 2-4: The Technical Subjects in Pro3BL.

No.	Subject	Code	Semester
1.	Conventional Turning 2	GMO 0232	2
2.	Conventional Milling 2	GMO 0242	2
3.	Engineering Metrology & CMM	QAS 0353	2
4.	Material Science 2	MAS 0422	2
5.	Engineering Materials	MAS 0432	2
6.	Grinding Technology 1	GMO 0252	2
7.	Engineering Drawing & CAD	TEC 0512	2
8.	Grinding Technology 2	GMO 0262	3
9.	CNC Milling & Programming	CNC 0612	3
10.	CNC Lathe & Programming	CNC 0622	4

2.7.1. THE IMPLEMENTATION OF PBL IN THE CNC PROGRAMMING COURSES

PBL in CNC programming courses of Milling and Lathe were firstly implemented at the GMI during January 2014. The CNC Milling programming course is offered in semester three while CNC Lathe programming course in semester four. The course duration is 75 hours for a CNC programming course. These courses which are practical oriented were presented in a mixed form between PBL approach/traditional lecture (40%) and practical work (60%).

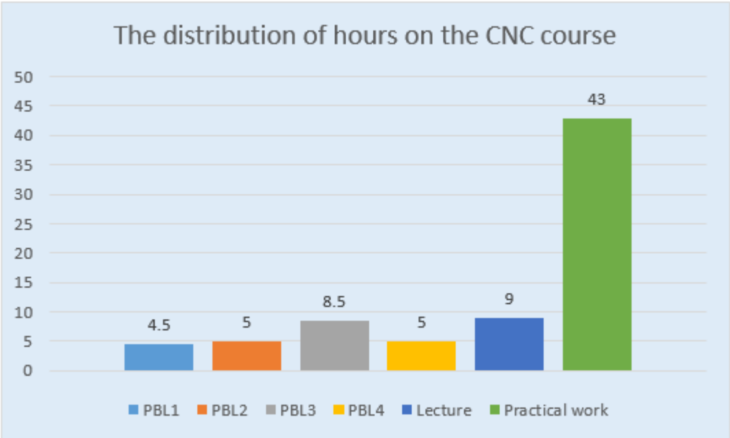


Figure 2-21: The Distribution of hours on the CNC Course

Figure 2.21 shows the distribution of hours of the CNC programming course. The CNC programming course has four PBL sessions with allocated time from four to eight hours. The guidelines were derived from the seven-step of Maastricht University and adapted for each PBL session, including the steps and allocation time which were provided to ease the facilitators; this is demonstrated as an example in Appendices P-2, Q-2, R-3 and S-3.

In the PBL approach when applied in CNC programming course, lecturers or Technical Training Officers (TTO) and students are required to work in different ways. The lecturer will have to act as a facilitator of the learning process rather than as a provider of knowledge. The students will have to engage in an active learning process help them develop flexible knowledge, problem-solving skills, self-directed learning skills, collaboration skills and intrinsic motivation (Hmelo-Silver, 2009). The PBL approach requires the students to be self-directed or self-regulated with respect to their own learning process. The learning content in the traditional teaching method is transformed into a series of problems and students as the problem solvers as demonstrated in Figure 2.22. The students are gathered in a group of four to six to work on the problem which is given by the Facilitator. At first, the students are to discuss in a group the learning objectives, "what they know", "what do they not know" and "what they need to find out". Next, the students are to work individually on "what they need to find out". Then, they are once again to work and discuss in a group on what they have found out with regards to the problem they are working on and come out with the findings of the problem. Finally, the students are to present in groups their solution to the class and followed by questions and answers session. At the end of the PBL session, the students' group together and present their personal reflection on what they have learnt and experienced throughout the PBL process they performed and comments are then followed by the facilitator regarding their presentations.

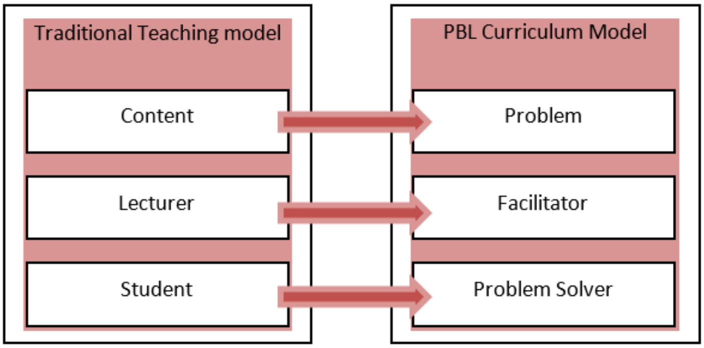


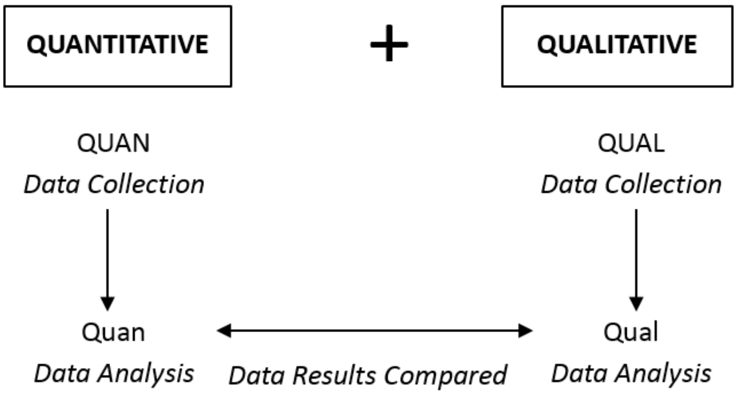
Figure 2-22: Curriculum Transformation Model

Source: Neo & Neo (2005).

CHAPTER 3. METHODOLOGY

3.1. INTRODUCTION

This chapter presents the details of the research design with flowcharts, research subjects, instruments, research strategy, and the process of data collection. The design of this study, which was an experimental research approach, employed a mixed methods design with concurrent triangulation strategy (Figure 3.1) comprising qualitative and quantitative methods approaches. Johnson & Onwuegbuzie (2004) defined mixed methods research as "the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study." (p. 17). "The goal of mixed methods research is not to replace either of these approaches but rather to draw from the strengths and minimize the weaknesses of both in single research studies and across studies" (Johnson & Onwuegbuzie, 2004, p. 14-15).



Source: Creswell, 2003, p. 214

Figure 3-1: Concurrent Triangulation Strategy

Mixed methods approach is employed for the reason that some of these data are qualitative in nature, and they need a qualitative method to analyse them carefully, furthermore, to provide a comprehensive analysis of the research problem (Creswell & Plano Clark, 2011; Creswell, 2013). The data collected from the quantitative approach is broad and not in-depth and it does not explain why things happen. It is not likely to disclose in-depth the views and experiences by utilizing only questionnaire (Clough & Nutbrown, 2002) as well as individuals' values and attitudes (Byrne, 2004).

Concurrent triangulation strategy in the mixed methods which is an approach used by the researcher to collect both quantitative and qualitative data concurrently and then compares the two research results to determine if there is congruence, differences, or some combination (Creswell & Plano Clark, 2011; Creswell, 2013). The combination of qualitative and quantitative data gives a thorough understanding in addressing the research questions, in particular, to provide complementary qualitative data if the quantitative data are insufficient (Creswell & Plano Clark, 2011; Creswell, 2013). Furthermore, mixed methods allow data to be triangulated to give a better picture of the data collected (Lincoln & Guba, 1985) and also according to Greene et al. (1989), employing mixed methods is expected to yield complementary results. Table 3-1 represents a mapping of the research questions with sources of data and instruments used in this study.

Table 3-1: Mapping Each Research Question with Research Methods, Sources of Data and Instruments.

No.	Research Questions	Source of Data	Instruments	Methods
Main	In what ways does PBL affect the students' competencies (learning, technical & social) in the TVET?	Students Participant Observers	• Pre- and Post-tests • Programming test 1 and 2 • Self-assessment • Peer-assessment	Quantitative
			• Observations • Content Analysis	Qualitative
1-	What is the level of awareness and motivations of students at different semester about Problem-Based Learning?	Students	• Questionnaire	Quantitative
			• Interview	Qualitative
2-	What is the students' perception of the Problem-Based Learning implementation?	Students	• Questionnaire	Quantitative
			• Interview	Qualitative

3-	How do the students' perceive challenges/obstacles in the Problem-Based Learning implementation?	Students	• Questionnaire	Quantitative
			• Interview	Qualitative
4-	What is the relationship between students' prior academic performance and their learning performance in the PBL approach?	Students	• Pre-tests and Post-tests • Academic records	Quantitative
5-	To what extent does CNC simulator benefit students in the PBL approach?	Students Participant Observers	• Programming Test 1 • Programming Test 2	Quantitative
			• Observations • Interview • Content Analysis	Qualitative

3.2. RESEARCH METHODOLOGY FLOWCHART

Figure 3-2 illustrated the structure of this research. It comprises of four stages, starting with "preliminary investigation" stage followed by "data collection" in stage two, "analysis & findings" stage three, and "Reporting" in stage four.

Stage 1: Preliminary Investigation

This stage comprises the "preliminary investigation" which was required to research on the current issues concerning the PBL, TVET and generic skills in order to identify issues and the research gaps that can contribute to the novelty of this study. The reasons and requirements for this research have been briefly covered in Chapter One and the "literature review" was carried out to clarify the present body of knowledge to evaluate the areas where the research work could establish a theoretical framework by the researcher.

The researcher started with the literature review; initially with some orientating reading of the key sources by Graaff & Kolmos (2007a), Du et al. (2009), and Savin-Baden (2000), to obtain an overview of the PBL's issues that related to this research topic. The reference lists of the key sources were then examined to expand the search on this issue and the search concerned with some other sources as well. The sources concerned were in particularly on Technical Vocational Education and

Training (TVET) and generic skills. To facilitate the search of key sources, the search engine of "Google Scholar" was used as it showed the "most cited articles" as well as the "related articles". The reference lists of the "most cited articles" and "related articles" were studied, and once again conducted another search of the references that were identified as relevant and important. The online Aalborg University Library (AUB) was also used to give the researcher an extensive search of related books, articles and journals of high class through many databases available in it. Among the databases available at AUB and used by the researcher included Google Scholar, IEEE Xplorer, ProQuest, Emerald, ERIC, and EbscoHost, SAGE knowledge and Taylor & Francis Online. Furthermore, the researcher was also linked to other researchers all over the world through "ResearchGate" and "Academia.edu", and this enables updates over related issues of this research. Besides the manual referencing, the "RefWorks" linked to the "Microsoft Word" was also used to manage all the references which used APA format of this research work.

Among other sources searched concerning PBL was the research publications by Albanese (1993), Barrows (1996), Boud (1987), Bridges & Hallinger (1992), Davis & Harden (2005), (Vries et al, 1989), Hmelo-Silver (2009) and Schmidt (1983). These sources provided a comprehensive understanding of the background, philosophy and the implementation of PBL in various fields, especially in the engineering of higher learning institutions which helped to fill in the research's gaps. Although, there are numerous other sources about PBL available, especially from McMaster and Maastricht universities, however, the implementation of PBL is more towards medical and health sciences approach.

Other published sources such as Neo & Neo (2005), Yeo (2005b), Adnan et al. (2009), and Mahamd Adikan et al. (2004), provided general ideas of the extent of research conducted on PBL in Malaysia and Singapore. The sources by Gibb (2004), Noordin et al. (2009), Adnan (2004), Callan (2003), Forrest & Cramp (2008), Hassan (2002), Kamsah (2004), Ministry of Higher Education (2006), NCVER (2003), Ramlee (1999), Salih (2008) and UNEVOC (1989), UNESCO & ILO (2002), UNESCO (2012), discussed the issues on TVET and generic skills which were relevant to this study. Other sources that gave some background on unemployment graduates and employers' perception were from Dench et al. (1998), Baharuddin (2003), Quek (2000; 2005), and Singh et al. (2013).

A time frame was decided by the researcher consisting of "two months research plan" which was developed to gather the research idea in a systematic manner which enabled other people associated with this study to comprehend the general idea of research especially the project supervisor, and an "eleven months research plan" which was to develop further and detail out the research idea which finally enable it to be implemented.

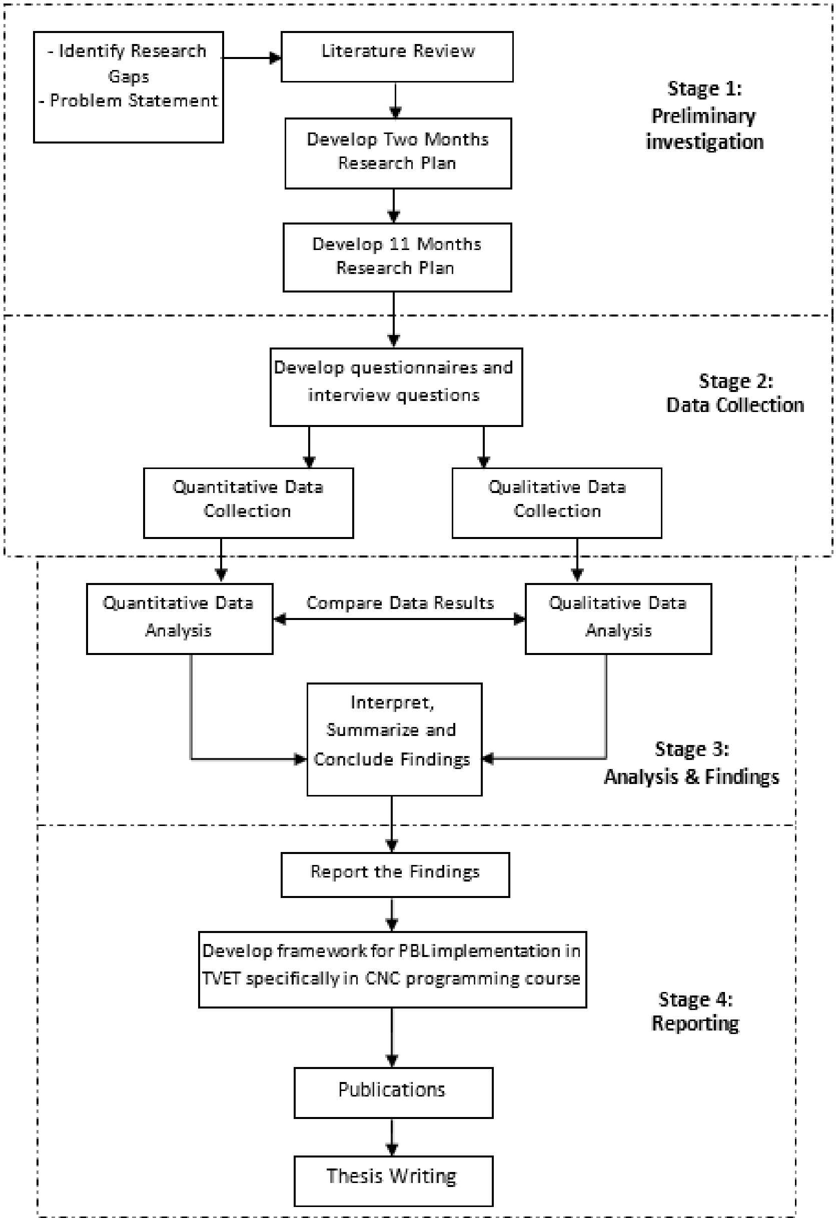


Figure 3-2: Research Methodology Flow Chart

Stage 2: Data Collection

The objective of stage two was the gathering of information on the research's variables through an established scientific manner that enables it to answer the research questions. To meet the research objectives an Appropriate Questionnaire's form and interview questions were developed to facilitate the data collection processes. The questionnaire's form and interview questions have been through several processes of proofreading by people that were considered experts in language as well as the content that researcher aims to address before seeking consent from the PhD's supervisor. These questionnaire's forms and interview questions were meant for both quantitative and qualitative data collection. The instruments and data collection are further described in Section 3.6 (Instruments and Data Collection Methods).

Stage 3: Analysis & Findings

The third stage of this study was the "analysis and findings" stage, which involved numerous quantitative and qualitative data that needed to be analysed. This study, which employed mixed methods approach with concurrent triangulation, was intended to compare both quantitative and qualitative data to establish if there was any correlation as what has been briefly described in 3.1 in this Chapter. The findings were interpreted, summarized and finally concluded according to the research needs, whereas the data analysis process was carried out as described in Section 3.7 (Data Analysis).

Stage 4: Reporting

The last part of this study was the "reporting" of the full research study to meet the University of Alborg criteria leading to the award of Doctor of Philosophy. This required the presentation to the Alborg Doctorate Examination Committee and the Public Defence of the Theses together with other documents describing all the research activities, data collection, findings, conclusions and recommendations and written publications. Therefore the dissemination of information from this study could be used as a guideline for the PBL implementation in TVET; specifically in CNC programming courses and the future learning development using the PBL approach so as to benefit the TVET providers in Malaysia as well as other countries involved in PBL.

3.3. QUANTITATIVE RESEARCH COMPONENTS

The quantitative design of this study used a quasi-experimental approach as described by Cook and Campbell (1979), where subjects cannot be randomly assigned to the experimental and control groups. Subjects in this study were assigned to the experimental group based on their natural setting of the semester and area of specialization. The quasi-experimental design which is also known as 'field-experiment' is a type of experimental design in which the researcher has limited control over the selection of study subjects. In this particular research, the participants comprised students from semester three and four with two different CNC programming courses, namely CNC programming lathe and CNC programming milling course. This research was executed according to the students' timetable for each course issued by the students' administration office. It means that the researcher has no control over where and when the courses should take place.

Both groups were given the pre-test (Appendices A-1 & A-2) at the beginning and according to their CNC programming (lathe or milling) course to assess and compare their prior knowledge and problem-solving skills (learning competency). The pre-test instrument developed by the researcher was equivalent to the standard of a final examination (post-test) which was developed by the lecturers (who is a subject-matter expert) in the research field.

In general, there were two dependent variables in the quantitative design of this study. The first was the students' cognitive skills (learning outcomes and technical competencies) as measured by their responses to the pre-test (Appendices A-1 & A-2) and post-test (Appendices B-1 & B-2) instrument which was actually the final examination and the self-assessment (Appendix J-1) which was developed by the researcher.

The second dependent variable was the students' social competency (teamwork and attitudes) as measured by the peer-assessment (Appendix J-2) which was developed by the researcher.

The third dependent variable was the PBL experience environment as assessed by their feedback in the questionnaire and developed by the researcher (Appendix D-1).

There were two independent variables identified in the quantitative design of this study. The first independent variable was the type of instructional method used in the courses (PBL and lecture) and the second was the students' demographic and academic background.

3.4. QUALITATIVE RESEARCH COMPONENTS

The research's qualitative design was inspired by on the ethnographic approach which enabled the researcher not only making observations on the participants but also experiencing and placing them within a larger context. The qualitative component was included to provide an in-depth study of various events related to the PBL experience that happens in the research field. According to Hammersley & Atkinson (2007), the ethnographic method provides the following features:

a) Study of people's behaviour in natural settings, rather than under experimental conditions (p. 3);
b) Gathering data through various sources, "but main sources are observation and/or relatively informal conversation" (p. 3);
c) Data collection is usually unstructured or semi-structured, "but this does not mean that the research is unsystematic; simply that initially the data collected is in as a narrow form and on as wide a front as feasible" (p. 3);
d) Focus of ethnographic study is usually a "single setting or group, of relatively small-scale" (p. 3);
e) Data analysis "involves interpretations of the meanings and functions of human actions and mainly takes the form of verbal descriptions and explanation, with quantification and statistical playing a subordinate role at most" (p. 3).

Data collection methods for the ethnographic approach employed for this study were:

I. Group interview: The group interview was used to look at students' perceptions and motivations on PBL as well as the benefits of CNC simulator assisting them in programming.
II. The observation approach was used by the researcher in gathering verbal and nonverbal data related to PBL activities in the classroom as well as in the CNC simulator lab.
III. Participant observation: The participant observation was used to assist the researcher in gathering data related to PBL activities in the classroom and in the CNC simulator lab including;

a. Application of knowledge during discussion and presentation,

b. Self-directed learning during the problem-solving process and working with CNC simulator,

c. Critical thinking, technical reasoning & decision-making skills during the problem-solving process and working with CNC simulator,

d. Interactions among students, especially during teamwork's discussion,

e. Communication skills during discussion and presentation.

An "observational tool" (Appendix G-1) was developed partly to assist the participant observers as well as the researcher in the observation process.

IV. Content analysis: The content analysis was used to evaluate the students' programming solutions and rationales of such programming strategy being taken. This evaluation is to look at the students' critical thinking, technical reasoning, problem-solving & decision-making skills in their programming work using CNC simulator.

Therefore, by obtaining data from these three sources, triangulation was achieved which provide validity and reliability to the qualitative data collected in this study (Guba & Lincoln, 1989; Lecompte & Goetz, 1982; Golafshani, 2003). The qualitative data collection instruments and analysis were explained in Sections 3.6.2 and 3.7.

3.5. RESEARCH SUBJECTS

The subjects for this study consisted of 132 Diploma students from the German-Malaysian Institute who attended the 75 hours of PBL-CNC Programming course which is one of the subjects in their syllabus. The students were from two CNC programming courses, namely CNC Milling and CNC Lathe which are offered in semester three and four respectively. These two courses which are practical oriented were presented in a mix between lecture/PBL approach (40%) and hands-on training format (60%). Table 3-2 shows the class schedule for both courses which commenced from January to June 2014.

Table 3-2: Class Scheduled for CNC Programming.

CNC Milling & Programming
Class Schedule

	Calendar Week	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
	Training Week	1	2	3	HL	4	5	6	7	8	9	10	EX	11	12	13	14	15	16	17	18	19	RE	RE	EX
SEMESTER 3 GROUP																									
18	CPT	10	10	10		10	10	10	10	5															
16	TDT			10			10		10		10			10		10		10		5					
13	MOT		10			10		10		10		10			10		10				5				
Total 47																									

Hours per Week

CNC Lathe & Programming
Class Schedule

	Calendar Week	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
	Training Week	1	2	3	HL	4	5	6	7	8	9	10	EX	11	12	13	14	15	16	17	18	19	RE	RE	EX
SEMESTER 4 GROUP																									
15	CPT1	5	10	5		10	10	10	10	10	5														
12	CPT2													10	10	10	5	10	10	10	10	5			
17	CPT3													10	10	10	10	10		10	10	5			
10	TDT1													10	10	10	5	10	10	10	10	5			
7	TDT2		10	10		10	10	10	10	10	5														
8	TDT3		10	10		10	10	10	10	10	5														
16	MOT	10	10	10		10	10	10	10	5															
Total 85																									

Hours per Week

CPT	CNC Precision Technology
TDT	Tool & Die Technology
MOT	Mould Technology
HL	Holiday
EX	Examination
RE	Revision

The 132 students who participated in this study were from various trades and area of specialization, namely CNC Precision Technology (CPT), Tool & Die Technology (TDT) and Mould Technology (MOT). There were three groups with a total of 47 students in semester three who attended the CNC Milling & Programming as follows: CPT, 18 students; TDT, 16 students; and MOT, 13 students. While in semester four, there were seven groups with a total of 85 students attended the CNC Lathe & Programming as follows: CPT1, 15 students; CPT2, 12 students; CPT3, 17 students; TDT1, ten students; TDT2, 17 students; TDT3, eight students; and MOT, 16 students. The subjects in these two courses were selected for this research because PBL approach is newly implemented in this semester (January 2014). Permission was sought and approval gained from the Department of Production Technology to conduct this study for all students in both CNC programming courses. However, for Research's ethical consideration purpose, all of the students involved were given a letter of consent (Appendix F-1) that outlined the purpose of the study, nature of research, confidentiality of participants' responses, participation was on a voluntary basis, and they could withdraw at any time without prejudice.

3.6. INSTRUMENTS AND DATA COLLECTION METHODS

This section presents the research instruments used in this study for both the quantitative and qualitative approaches to data collection. The quantitative approach comprises the pre-test, post-test, questionnaires for the survey, self-assessment and peer-assessment whereas the qualitative approach consists of observation, interviews and contents analysis. In addition, the implementation process, validity and reliability of these instruments are also elaborated in this section.

3.6.1. QUANTITATIVE DATA COLLECTION INSTRUMENTS

3.6.1.1 Pre-test Instrument

The instrument for the pre-tests for CNC programming lathe and milling (Appendix A-1 & A-2) was developed by the researcher for the purpose of assessing the students' cognitive skills and their prior knowledge before they start with the CNC programming course with the PBL approach. The pre-test was given to all students in the experimental groups at the beginning of every group's course (Table 3-2). The class schedule was not controlled by the researcher but it had been controlled and prepared by the students' administrative officer in the Department of Production Technology. The CNC programming courses for all groups were not started at the same time. Therefore, few precautions had been taken by the researcher to ensure that the pre-test stayed confidential for next group's pre-test. The precautions were as follows:

- The pre-test papers were handled by the researcher himself in term of distributing to the research participants, collecting and marking.
- Ensuring the numbers of pre-test papers distributed and collected were in equal quantity to prevent "sneak out" activity of pre-test papers by the participants.
- No phones or PDAs allowed to be used during the pre-test session.

3.6.1.2 Construction of Pre-tests

The researcher designed the pre-tests (CNC lathe and CNC milling programming) by adapting and reconstructing the previous years' questions and mixed them up to produce a new set of test questions in order to maintain the difficulty and standard that set by the German-Malaysian Institute (GMI). This pre-test instrument consisted of three sections including; the multiple choices, fill in the blanks and subjective questions. The content of this pre-test was based on the similar course objectives that were covered in a purely lecture-based approach previously. This pre-test was used to assess the participants' entry levels of technical reasoning, decision-making, problem-solving and critical thinking in CNC programming. It was designed with three cognitive level of Bloom's taxonomy namely: 1- knowledge, 2- understanding and 3- application. The pre-tests were reviewed by four subject matter experts at GMI in order to establish the content's clarity and validity. The subject-matter experts are the lecturers and a Section Head who have seven to twenty-four years of experience in teaching the CNC milling and lathe as well as Computer-Aided Design (CAD) and Computer Aided Manufacturing (CAM) programming. Besides the teaching, they are also responsible for verifying the examination papers of CNC milling and lathe programming and other subjects related to CNC programming at the GMI.

3.6.1.3 Post-test Instrument

The instrument for the post-tests for CNC programming lathe and milling (Appendix B-1 & B-2) were not constructed by the researcher. In fact, they were developed by the lecturers themselves, the subject matter experts, in order that the researcher has no influence on the contents. The researcher chose to use the final examination papers as the post-test instruments in this research because it does the important function of assessing the students' performance. It served the function of assessing the students' cognitive skills, learning outcomes as well as their technical competency after the CNC programming course with PBL approach. This post-tests were also used to assess the students' achievements over the course in technical reasoning, decision-making, problem-solving, and critical thinking. The post-tests were given after finishing the course to all students in the experimental groups simultaneously according to the course during the examination week (Table 3-2). The examination's schedule was also not set by the researcher. It was managed and issued by the examination administrative officer in the Department of General & Pre-University Studies. Therefore, the participants in these experimental research groups were subjected to the full examination rules and regulations of GMI. At this stage, the researcher was not involved in invigilating activities whatsoever as far as the examination is concerned. The content of this post-test (final examination) was also based on the similar course objectives that were covered in a purely lecture-based approach previously. The post-tests were cross-checked by the four subject matter experts and approved by the Head of Programme and the Examination Committee of the German-Malaysian Institute. This is a normal procedure about examination papers in GMI, so, this established the clarity and validity of the post-tests for this research.

3.6.1.4 Survey Instruments

The researcher developed three survey instruments, namely self-assessment (Appendix J-1), peer-assessment (Appendix J-2) and survey questionnaire (Appendix D-1) in order to study the studied the students' perceptions of their cognitive skills, social competency (teamwork and attitudes) and their perceptions of PBL's environment, including awareness and challenges/obstacles during the implementation of the PBL in the CNC programming courses. The step-by-step guide to developing effective questionnaires and surveys by Diem (2002) was used to develop these survey instruments. All of these instruments were developed having a 5-point Likert-type scale and were used in the quantitative section of this study. Questionnaires have several advantages over other types of survey instruments according to Ackroyd & Hughes (1981), and Popper (1959), such as a) practical and saving time in administration, b) saving cost of materials and travelling, c) less effort as compared to interviewing and d) possibility to handle a high number of respondents.

These questionnaires, namely self-assessment, peer-assessment and survey questionnaires were given to the research participants at the end of the course to each of the groups: CPT1, CPT2, CPT3, TDT1, TDT2, TDT3 and MOT, at the time of appointment for group interviews. The appointment to conduct the surveys before the group interview sessions were arranged by the researcher and agreed with all the research participants (grouping) through their respective lecturers. The researcher had ensured that the surveys were conducted within two weeks after the course ended to ensure the participants were still fresh with the PBL sessions during the CNC course.

3.6.1.5 Construction of Questionnaires

The researcher started out the construction of the instrument by writing the items himself after studied and inspired by several other instruments developed by other researchers. The items were carefully written, listed and arranged as well as possible by the researcher to avoid misinterpretation by the participants later on, during administration. These items were several times revised to get the best out of them. Then, these items were checked by four subject matter experts in Computer Numerical Control (CNC) and an English lecturer. The subject matter experts also checked for the Malay translation of the instruments. This followed some modifications of the instruments and was discussed with some lecturers in the department before having a small trial. The content validity of these instruments was evaluated and agreed among the four subject matter experts who happen to be also the PBL practitioners at the institution. Content validity is deductively established by showing that the test items are a sample of a universe in which the investigator is interested (Cronbach & Meehl, 1955). According to Joppe (as cited in Golafshani (2003)) the "validity determines whether the research truly measures that which it was intended to measure". Finally, the instruments were administrated to 132 participants and the data were analysed. Based on the data which was collected, some alterations on the items were made to increase the internal consistency of the instruments as shown in Table 3-3. Since there was no pilot test conducted, the data from the true study were used to examine the internal consistency of the instruments.

Table 3-3: Instruments, scales and no of items with Cronbach's Alpha (N = 132).

Instruments	Scales	No of Items	Cronbach's alpha	
			Before item deleted	After item deleted
Survey's questionnaire	Perception	12	0.67	0.87
	Awareness	10	0.59	0.82
	Challenges/Obstacles	5	0.88	0.88
Self-assessment	Application of knowledge	2	0.59	
	Self-Directed Learning	4	0.63	
	Technical reasoning & Decision Making Skills (i.e. contour programming).	6	0.79	
	Problem Solving & Critical Thinking Skills (i.e. contour programming techniques).	9	0.78	
	Team work	10	0.82	
	Communication Skills	6	0.77	
Peer-assessment	Attitudes	10	0.89	
	Team work	10	0.87	

The internal consistency of these questionnaires was established by Cronbach's alpha and presented in Table 3-3. According to Cortina (1993), many researchers defined internal consistency as "a measure based on the degree of correlations between different items on the same test." Also, Nunnally (1975) stated that "measurements are reliable to the extent that they are repeatable and that any random influence which tends to make measurements different from occasion to the occasion is a source of measurement error". The reliability of these instruments was established as shown in Table above, by the Cronbach's alpha analysis "before item deleted" and "after item deleted" coincided with scales of the instruments. These instruments (before item deleted) were administrated to all 132 participants in an experimental research at the end of the CNC programming courses. The Cronbach's alpha score of 0.70 is considered satisfactorily reliable for an instrument according to Bland (1997), and Wubbels (1993). Table 3-3 presents the instruments (survey questionnaire, self-assessment and peer-assessment), scales, no of items and Cronbach's alpha with 'before' and after 'item deleted'. It is notable that 'before item deleted' the subscales of: 'perception', with 12 items; 'awareness', with 10 items; 'application of knowledge', with 2 items and 'self-directed Learning', with 4 items showed (0.67, 0.59, 0.59 and 0.63) lower than 0.7 scores of Cronbach's alpha coefficients. The other scales showed good scores which were above 0.7 of Cronbach's alpha coefficients.

Table 3-4: Item Statistics for survey's questionnaire: Mean values and standard deviation for subscales before item deleted (N=132).

Perception		
Questions	Mean	Std. Deviation
1	4.1	.77
2	4.1	.72
3	4.4	3.5
4	4.2	.71
5	4.2	.73
6	4.1	.72
7	4.3	.63
8	4.1	.76
9	4.0	.81
10	4.1	.75
11	3.8	.82
12	4.0	.79

Awareness		
Questions	Mean	Std. Deviation
13	3.7	.72
14	4.1	3.56
15	3.8	.65
16	4.1	.61
17	4.0	.79
18	4.3	.65
19	4.1	.71
20	4.2	.66
21	4.0	.69
22	3.9	.95

Challengers/Obstacles		
Questions	Mean	Std. Deviation
23	3.26	1.09
24	3.18	1.22
25	3.28	1.01
26	3.33	.94
27	3.63	1.05

Cronbach's alpha is generated from the computation of standard deviations of the question items. The low Cronbach's alpha coefficients for the subscales 'perception' and 'awareness' shown in Table 3-4 above can be explained by the great difference in standard deviation for items 3 and 14. When the difference between the standard deviations for the question items of a subscale becomes greater, the Cronbach's alpha of the subscale decreases (Cortina, 1993). Items 3 and 14 also demonstrated very low item-total correlations (Table 3-5) with only 0.16 for item 3 and 0.19 for item 14. This situation happens perhaps because the participants were not so clear with these two items in terms of the meaning of "active learning" in item 3 and "competencies" in item 14, due to their translation in the Malay language. To overcome this situation, these two items (3 and 14) were removed from the subscales which resulted in an increase of the Cronbach's alpha coefficients. As a result, the item-total correlation (Table 3-3 above) and Cronbach's alpha coefficients had increased to 0.87 for scales 'perception' and 0.82 for 'awareness' (Table above). Table 3-5 exhibits the details of the Cronbach's alpha and item-total correlation for each item with 'before' and 'after' item deleted. For 'self-assessment' scales in Table 3-3, 'application of knowledge', and 'self-directed Learning' also showed (0.59 and 0.63) lower than 0.7 score of Cronbach's alpha coefficients, however this technic was not applicable as the number of items was too small (2 and 4 items) to influence the change, therefore the researcher decided not to delete any items for these scales. According to Babbie (2014), the Cronbach Alpha's value is categorized based on the reliability index in which .30 to .69 is considered moderate. Several researchers such as Clark & Watson (1995) and Briggs & Cheek (1986) discover Cronbach's alpha to be too sensitive to a number of items and prefer the use of the mean inter-item correlation as a statistical indicator for internal consistency. According to Briggs and Cheek (1986) as a rule of thumb, "The optimal level of homogeneity occurs when the mean inter-item correlation is in the .2 to .4 range" (p. 114). Clark and Watson (1995) suggest: "we recommend that the average inter-item correlation fall in the range of .15 - .50 if one is measuring a broad higher order construct such as extraversion, a mean correlation as low as .15 - .20 probably is desirable; by contrast, for a valid measure of a narrower construct such as talkativeness, a much high mean inter-correlation (perhaps in the .40 - .50 range) is needed" (p. 316). In this particular case as the mean inter-item correlation for 'application of knowledge' was .420 (2 items) while 'self-directed Learning' were .293, .195 and .370 (4 items) the researcher decided to use of the mean inter-item correlation as a statistical indicator of internal consistency as recommended by Clark and Watson (1995).

Table 3-5: The Survey's Questionnaire; Cronbach's alpha and Item-Total Correlation for 'before' and 'after' item deleted

Questions	Corrected Item-Total Correlation **(Before)**	Cronbach's Alpha if Item Deleted **(Before)**	Corrected Item-Total Correlation **(After)**	Cronbach's Alpha if Item Deleted **(After)**
1	.50	.63	.52	.85
2	.48	.63	.57	.85
~~3~~	.16	~~.86~~	-	-
4	.53	.62	.57	.85
5	.55	.62	.61	.85
6	.60	.62	.66	.84
7	.44	.64	.56	.85
8	.41	.64	.51	.85
9	.48	.63	.59	.85
10	.38	.64	.46	.86
11	.48	.62	.58	.85
12	.45	.63	.55	.85
13	.43	.53	.53	.80
~~14~~	.19	~~.82~~	-	-
15	.32	.55	.39	.82
16	.47	.53	.48	.81
17	.55	.51	.65	.79
18	.43	.54	.49	.81
19	.43	.53	.49	.81
20	.30	.55	.45	.81
21	.47	.53	.62	.79
22	.45	.51	.61	.79
23	.70	.85		
24	.75	.84		
25	.75	.84		
26	.81	.83		
27	.56	.88		

3.6.2. QUALITATIVE DATA COLLECTION INSTRUMENTS

There were two CNC programming courses with ten groups of students who were involved in this study as described in Section 3.5 of this chapter. These courses were scheduled concurrently and that made it difficult for the researcher to make the observation on the participants. The CNC milling & programming course with three groups was handled by one lecturer and the CNC lathe & programming course with seven groups was handled by three lecturers. These courses were conducted in accordance with the timetable prepared by the Students' Administrative Officer and subjected to changes in unexpected circumstances. The lesson plans for these courses originally lecture-based were modified; especially the lecture contents parts to accommodate the PBL approach.

3.6.2.1 Observations

The observations of the research participants were conducted by the researcher and the lecturers/facilitators of the respective groups in the courses who were in fact participant observers. In this study, the facilitators acted as the participant observers who observed the students from the beginning until the end of the course duration (see Table 3-2 in Section 3-5). The participant observers were introduced by the researcher to PBL implementation process as well as instructed in using the observation criteria and techniques. Generally, the observations focus on students' learning activities during the PBL sessions, which included the students' verbal interactions, discussions, problem-solving exercises and presentations. The students were observed closely by the participant observers (including the researcher himself) through their PBL activities such as discussion in group in exploring the problem, in identifying the three Ks (Know, do not Know & Need to Know), in listing the actions to be taken to solve the problem, in exchanging knowledge and listing out the possible solutions to the problem, presenting findings and question and answer, and finally the reflections. The observations were done during the PBL sessions one, two, three and four in the CNC programming Milling and Lathe courses. The PBL's problem statements for both courses can be seen in appendices M-1, P-1, -2, Q-1, -2, -3, R-1, -2, -3 and S-1, -2, -3. Table 3-6 (in Appendix H-1) illustrates the timetable of how PBL was implemented in a CNC programming course. In this course, there were four PBL sessions altogether that started in training week one (TW) and ended in TW five (Table 3-6 in Appendix H-1). In Table 3-6 (in Appendix H-1) also shows the distribution of time allocated to PBL activities, lectures and practical work. The facilitators were provided with PBL guide (Appendices I-1 and I-2) for each PBL sessions so that they did not use the time more than the time allocated. The lecture/PBL is about 40% (30 hours) of the total 75 hours course duration and 60% (45) practical work. There was a total of 32 PBL-groups were formed (informally) in both programming courses (Table 3-7). The number of members in a group ranging from three to six for students in semester three and from three to eight for students in semester four.

Table 3-6: Example of the PBL Timetable.

See Appendix H-1. Example of the PBL Timetable

Table 3-7: PBL Groupings

Course	Semester	No of Students	No. of PBL groups	No. of group members
CNC Milling Programming	Three	47	11	Ranging from 3 to 6
CNC Lathe Programming	Four	85	21	Ranging from 3 to 8
Total		132	32	

The researcher has developed the "Observational Tool" (Appendix G-1) with observation criteria and "Observational Tool Rubric" (Appendix G-2) to facilitate the participant observers as well as the researcher in the observation process during the PBL sessions in the CNC programming course. The observation's criteria of "Observational Tool" (Appendix G-1) purposely to observe the students' abilities in a) application of knowledge; b) self-directed learning; c) technical reasoning & decision-making skills; d) problem-solving & critical thinking skills; e) teamwork; f) communication skills; and g) using the CNC simulator. The "Observational Tool Rubric" (Appendix G-2) has the scale of 4 for very good, 3 for good, 2 for fair and 1 for poor. The scale helped the participants' observers to give a judgement on the students' abilities as listed in the "Observational Tool".

3.6.2.2 Interviews

Group interviews were conducted at the end of the CNC programming courses in June 2014 on ten groups of semester three and four students. The students of both semesters were from Mould Technology (MoT), Tool and Die Technology (TDT) and CNC Precision Technology (CPT) (see Table 4-3 in Chapter Four). Each interview had taken about 42 to 96 minutes per session (see Table 3-8). The interviews sessions for some of the groups (Table 3-8) were done together since the students had the constraint of the free time. The group interviews overall were smoothly executed although there were one or two students absent in a group. A set of interview's questionnaires (Appendix E-1) was used to facilitate the students' group interviews. Every interview was voice-recorded as well as writing anecdotal notes. The participants' identity was kept confidential in this research. Each group of students was coded to protect their identity and to avoid bias. Private information that might identify individual participants will not be reported in this study (Kvale, 1996). The participants' groups were coded in order to protect their identity in reporting the interviews. The interview sessions were transcribed using window media player on a computer. The voice recording was repeatedly played back to ensure every point was grasped and written. The students were given freedom to speak English or Malay language so that they can express their thought without worries of their language proficiency. The analysis of data from this instrument was described in Section 3.7.2.

Table 3-8: The group interviews dates and duration.

Semester	Group	Date	Duration
4	MOT	June 2 2014	93 mins
3	TDT & CPT	June 5 2014	96 mins
3	MOT	June 6 2014	42 mins
4	CPT1	June 5 2014	60 mins
4	CPT2 & TDT1	June 16 2014	58 mins
4	CPT3	June 17 2014	59 mins
4	TDT2	June 13 2014	50 mins
4	TDT3	June 18 2014	46 mins

3.6.2.3 Content Analysis

The content analyses were utilized to examine the patterns in documents and to obtain the insight of the students' learning so that it can be summarized and bring meaning to this research study. According to Stemler (2001), the content analysis is helpful for investigating trends and patterns in documents. Holsti (1969) defines the content analysis as a method for making inferences by objectively and systematically classifying specified characteristics of messages. Krippendorff (1980) identified content analysis as a research method for making replicable and rational inferences from data to their context.

In this research, the content analysis covering the students' CNC programming problems exercises, written CNC programming test, CNC programming solutions and simulations at the CNC simulator and the students' coursework. The contents were analysed for their degree of problem-solving, critical thinking, technical reasoning and decision making by the following features: i) the number of possible programming methods identified to the problem ii) the number of possible tools and machining strategies identified to the problem iii) the rationale for selecting the programming methods to the problem and iv) the justification for selecting the tools and machining strategies to the problem. The content analyses was carried out during the students' PBL activities in class and in the CNC simulator lab such as the CNC programming exercises, CNC programming test, and during students' working with the CNC simulator.

3.7. DATA ANALYSIS

The Statistical Program for Social Science (SPSS) version 22 and QSR NVivo 11 software were used to facilitate the quantitative and qualitative data analysis of this research and the descriptive and inferential statistics were employed to report the research outcomes. The quantitative data that comprises the pre-test, post-test, survey's questionnaire, self-assessment and peer-assessment were analysed using the SPSS and the qualitative data involved during the interviews were analysed using the Nvivo software. The researcher started the data analysis by performing 'data entry' into SPSS and by computing univariate descriptive statistics for the demographic variables. Means and standard deviations were computed for all variables with interval level of measurement. Percentages were calculated for the categorical and ordinal variables. The presentation of data analyses followed the order of the Research Questions one to six, also involving qualitative data.

3.7.1. QUANTITATIVE DATA ANALYSIS

The quantitative data analysis was started by the researcher by conducting normality tests (Shapiro-Wilk) on the pre-test, post-test, programming test one and programming test two. The tests were carried out to determine whether the data of students' pre-test, post-test, programming test one, and programming test (semester three & four) were equally normally distributed within groups. If the data was normally distributed, the SPSS's parametric tests were used, and if the data was not normally distributed, the SPSS's non-parametric tests were used. According to Shapiro & Wilk (1965) examining for distributional assumptions in general and for normality, in particular, has been a major area of continuing statistical both theoretically and practically. Razali & Wah (2011) concludes that the Shapiro-Wilk test is amongst the most powerful test for all forms of distribution and sample sizes.

The next stage of the quantitative data analysis addressed Sub Research Question one, two and three, to examine the level of awareness, motivation, perception and the challenges/obstacles of students on Problem-based Learning. The Sub Research Question one, two and three were addressed by conducting descriptive statistical analysis and Independent Samples t-test on the questionnaire items 1 to 25 of students of semester three and four, which calculates the percentage, frequency, mean and standard deviation.

The quantitative data analysis proceeded to address the sub research question four. The sub research question four investigated whether the students' prior academic performance has an effect on the learning in the PBL approach of students in semester three and four. The researcher hypothesized (H1) that students of semester three and four with above average CGPA scores have higher scores in both the pre-test and the post-test than those with below-average CGPA scores. The hypothesis was made based on researcher's observations and experiences of more than 20 years as a lecturer. The analysis first divided the students into two groups with Cumulative Grade Point above Average (CGPA) and CGPA below average. The independent-samples *t*-test performed to determine the significance between the students' pre-test and post-test scores of students' semester three & four and their last semester of CGPA.

The researcher hypothesized (H2) that students of semester four have higher scores on the pre-test than students of semester three. The assumption was made because students of semester four used to attend CNC Milling programming course during their semester three. So, the students of semester four have some prior knowledge of Computer Numerical Control (CNC) that could help them answer the pre-test questions compared to the students of semester three who attend the course for the first time. The independent-samples *t*-test executed to look at the difference in mean of the pre-test between students of semester three and students of semester four.

The above was followed by quantitative data analysis to test the researcher's hypothesis (H3) that hypothesized no difference in post-test scores between students of semester three who attending the CNC programming milling and students of semester four who attending the CNC programming lathe. For this hypothesis, the researcher's opinion was that there should be no difference in post-test scores because both groups have an equal chance of learning the CNC programming.

The quantitative data analysis continued to address the sub research question five and examined whether the CNC simulator benefits students in the PBL approach. The researcher hypothesized (H4) that students of semester three and four with above average CGPA scores have higher scores on both the programming test one and the programming test two than those having below average CGPA scores. Like the hypothesis H1, the same situation applies to the programming test one and programming test two. The independent-samples *t*-test performed to investigate the difference in mean of the students' programming test one and two scores of students' semester three and four.

The data analysis referring to hypothesis five (H5) which stated, that students of semester three and four have higher scores on the programming test two than programming test one. The students (Semester three and four) were expected to have higher scores on the programming test two because they had a CNC simulator to help them in programming, and they could verify their programming work. Whereas programming test one was 'an ad hoc' written (on a piece of paper) programming test where they could not verify their programming work. In this analysis, the paired-samples *t*-test was used to assess whether students of semester three and four have higher scores on the programming test two than programming test one.

The researcher also looked at a connection between scores on programming test one and programming test two of students semester three and four (H6). The researcher hypothesized that there would be a relation between scores on programming test one and programming test two between the students in both semesters three and four. The rationale was that the students who performed in programming test one should also be able to perform in programming test two and students who were not able to perform in programming test one should have a problem to perform in programming test two even though they had the assistance of a CNC simulator. The Pearson correlation analysis was carried out to examine the relationship between the scores of the students' programming test one and programming test two (semester three and four).

The last data analysis of this study was to address and further the main research question by focusing on the ways PBL affect the students' competencies such as learning, technical and social. The quantitative part of data analysis were the tests results from the pre-test, post-test, programming test one and programming test two. These tests results were analysed to look at the effect of the PBL approach on students' learning and technical competencies. The descriptive statistical analysis on the self-assessment and peer-assessment instruments were performed in order to have the insight of students' competencies especially the social competency.

3.7.2. QUALITATIVE DATA ANALYSIS

The qualitative data analysis of this study employed an inductive analysis with mixed methods approach. The qualitative data can come from various sources such as documents, video recorders, newspapers, letter, and books (Corbin & Strauss, 2008) and each of these sources can be coded in the same way as interviews or observations (Glaser & Strauss, 1967) and is based on a set of data that systematically related (Corbin & Strauss, 2008). This study follows the three stages of coding introduced by Corbin & Strauss (2008) for data analysis. Corbin & Strauss (2008) classify three different stages of coding namely 'open', 'axial' and 'selective'.

- The first stage: 'open coding' involves the breaking down, comparing, and categorizing the data.
- The second stage: 'axial coding' involves the placing of the data back together by making connections between the categories identified after the 'open coding' process.
- The third stage: 'selective coding' involves the selection of the main category, linking it to other categories while confirming and explaining these relationships.

According to Thomas (2006), the inductive analysis refers to an approach that "primarily use the detailed reading of raw data to derive concepts, themes, or a model through interpretations made from the raw data by the evaluator or researcher". He added that the main purpose of the inductive approach was to allow research findings to appear from the frequent, dominant, or significant themes inherent in raw data. Furthermore, according to Bogden and Biklen (2003), the qualitative data analysis involves systematic searching and arranging of data collected by various means in a study. Creswell (2007), suggests that during the analysis process, the data of interviews and observations should be brought together in order to transform into a meaningful description or into a form of summary, and the summarised data can be saved and organised in a computer and backed up for further analysis as well as descriptive writing. The Nvivo software application can be used to cluster and categorized the data by means of data coding and count codes (Creswell, 2007; Bazeley, 2007), and to see the frequency of similar codes appear in the database, according to Miles and Huberman (1994). The similar codes are considered as saturated if they were frequently emerged in the database (Corbin and Strauss, 2008) and considered as triangulated if the codes appeared from many different sources data (Creswell, 2007).

The qualitative data of this study comprise the data from the group interviews, participant observations (in the classroom and CNC simulation lab) and content analysis. The researcher processed and analysed the qualitative data with the help of QSR NVivo 11 software and Microsoft Excel 2013. The advantages of using NVivo 11 for qualitative data analysis are that it helps the researcher managing chunks of data appropriately and facilitating the process of analysis. The NVivo 11 has the abilities such as coding generation using auto coding or queries, search themes in the data, link, annotate, create relationships and able to import and process audio video files. The NVivo 11 also has the ability that allows researcher listening, coding, and simultaneously transcribing the audio file. The researcher analysed the data of the group interviews involving ten groups of students. Each group of students was coded to protect their identity and to avoid bias.

Chapter four reports all the findings of this study and presented according to the Research Questions One to Five followed by the Main Research Question.

CHAPTER 4. FINDINGS

Chapter four presents the outcomes of this research which investigated the impact of PBL on students' competencies (learning, technical and social) at the Technical Vocational Education and Training (TVET) specifically at the German-Malaysian Institute (GMI). This chapter also presents the results on awareness, motivation, perception and challenges/obstacles of students and lecturers in the PBL implementation at GMI. The research data were collected from students in semester three and four of two CNC programming courses at the German-Malaysian Institute in Kajang, Malaysia. The results of the quantitative and qualitative analysis addressed the main research question as well as the research questions one to five. Table 3-1 in Section 3.1 (Chapter three) shows the mapping of research questions and the methods, as well as the source of data and instruments used. The quantitative and qualitative data were organised according to the Research Questions to facilitate the presentation of the findings and data triangulation as well as to avoid redundancy. This chapter comprises several sections with Description of the research's subjects, Quantitative data analysis, and Qualitative data analysis, Sub Research Question One: What is the level of awareness and motivations of students at different semester about Problem-Based Learning? Sub Research Question Two: What are the students' perception of the Problem-Based Learning implementation? Sub Research Question Three: How do the students' perceive challenges/obstacles in the Problem-Based Learning implementation? Sub Research Question Four: What is the relationship between students' prior academic performance and their learning performance in the PBL approach? Sub Research Question Five: To what extent does CNC simulator benefits students in the PBL approach? Main Research Question: In what ways does PBL affect the students' competencies (Social, learning & technical) in the TVET? The findings in this chapter are discussed in Chapter Five.

4.1. DESCRIPTION OF THE RESEARCH SUBJECTS

The subjects of this research consisted of 132 students at the German-Malaysian Institute (GMI) which is located at Kajang Selangor, Malaysia who were enrolled to the CNC milling programming in semester three and CNC lathe programming in semester four. Table 4-1 and Table 4-2 below, show the gender and age of Research's subjects made up of males 122 (92%) and females 10 (8%). Their ages ranged from 19 to 25 years, with the majority aged 22 (39%), 20 (34%) and 23 (12%) years.

Table 4-1: Gender of Research's subjects.

Gender	Frequency	Percent
Male	122	92.4
Female	10	7.6
Total	132	100.0

Table 4-2: Age of Research's subjects.

Age	**Frequency**	**Percent**
19	2	1.5
20	45	34.1
21	11	8.3
22	52	39.4
23	16	12.1
24	3	2.3
25	3	2.3
Total	132	100.0

Table 4-3 illustrates the distributions of Research's subjects by groups thus; three groups (36%) were in semester three and seven groups (64%) were in semester four. The groups according to their field of specializations were: CPT, CNC Precision Technology; TDT, Tool and Die; and MOT, Mould Technology. The number of subjects in a group (Table 4-3) varied from the minimum of 7 to the maximum of 18 subjects.

The subjects enrolled at the GMI were divided into two categories as shown in Table 4-4. The subjects enrolled had to have '4 credits and lower' in Sijil Pelajaran Malaysia (Malaysian Certificate of Education) which is the minimum requirement to join any technical institutions in Malaysia. The number of subjects enrolled with '5 credits and higher' in Sijil Pelajaran Malaysia was 54 (41%) and those with '4 credits, and lower' was 78 (59%).

Table 4-3: Distribution of Research's subjects by groups in semesters as well as the frequency and percentage.

<table>
<tr><th>Semester</th><th>Group</th><th>Frequency</th><th colspan="2">Percent</th></tr>
<tr><td rowspan="3">3</td><td>CPT</td><td>18</td><td>13.6</td><td rowspan="3">35.6</td></tr>
<tr><td>TDT</td><td>16</td><td>12.1</td></tr>
<tr><td>MOT</td><td>13</td><td>9.8</td></tr>
<tr><td rowspan="7">4</td><td>MOT</td><td>16</td><td>12.1</td><td rowspan="8">64.4</td></tr>
<tr><td>CPT1</td><td>15</td><td>11.4</td></tr>
<tr><td>CPT2</td><td>12</td><td>9.1</td></tr>
<tr><td>CPT3</td><td>17</td><td>12.9</td></tr>
<tr><td>TDT1</td><td>10</td><td>7.6</td></tr>
<tr><td>TDT2</td><td>7</td><td>5.3</td></tr>
<tr><td>TDT3</td><td>8</td><td>6.1</td></tr>
<tr><td colspan="2">Total</td><td>132</td><td>100.0</td></tr>
</table>

Table 4-4: The categories of subjects' enrollment to GMI.

Subjects with:	Frequency	Percent
4 credits and lower	78	59
5 credits and higher	54	41
Total	132	100.0

4.2. QUALITATIVE DATA ANALYSIS

The qualitative data of this research study consisted of data from the group interviews, participant observations (in the classroom and CNC simulation lab) and content analysis. The researcher processed and analysed the qualitative data by the use of both the QSR NVivo 11 software and Microsoft Excel 2013. The advantages of using NVivo 11 for qualitative data analysis are because it helps the researcher managing chunks of data appropriately and facilitating the process of analysis.

NVivo 11 has the abilities such as coding generation using auto coding or queries, search themes in the data, link, annotate, create relationships and able to import and process audio video files. The NVivo 11 also has the ability which allows the researcher to listening, coding, and simultaneously transcribing the audio file analysis and the researcher analysed the data of the group interviews involving ten groups of students.

The researcher began the analysis of interviews' data by importing all the audio files of the interviews into the NVivo 11 software. The group interviews with students were conducted by the researcher in English as well as in the Malay language to give comfort to the students to speak and express their opinions without worries of their language proficiency. The audio files were transcribed according to the "edited transcription" format in which the Malay language was translated into English, and the informal speech was converted into a formally written voice. The analysis included the reviewing of the group interviews, observations as well as field notes to determine what concepts and what the data indicated. The data were broken down and compared to look for similarities, differences and general patterns for a coding generation as suggested by Corbin & Strauss (2008). At the beginning of data analysis for open coding, six major categories were identified: a) knowledge application acquiring and application, b) self-directed learning, c) technical reasoning, d) decision-making Skills, e) teamwork and f) communication skills. The data were carefully and repeatedly analysed by observing and comparing for similarities, differences and general patterns to derive categories or concepts from the data. Figure 4-1 displays the print screen of researcher's coding process with Nodes and network of items generated by the NVivo 11 software.

After a careful analysis and considerations of the first derived categories, final categories were formed by collapsing the technical reasoning, decision-making and communication skills into one category entitled as 'skills gained' and adding newly emerged categories namely; students' learning environment and students' interactions. As a result, the final analysis of the main categories from the qualitative data were a) knowledge application acquiring and application, b) self-directed learning, c) skills gained, d) teamwork, e) students' learning environment and f) students' interactions. Table 4-5 illustrates the major categories and the sub categories with some examples.

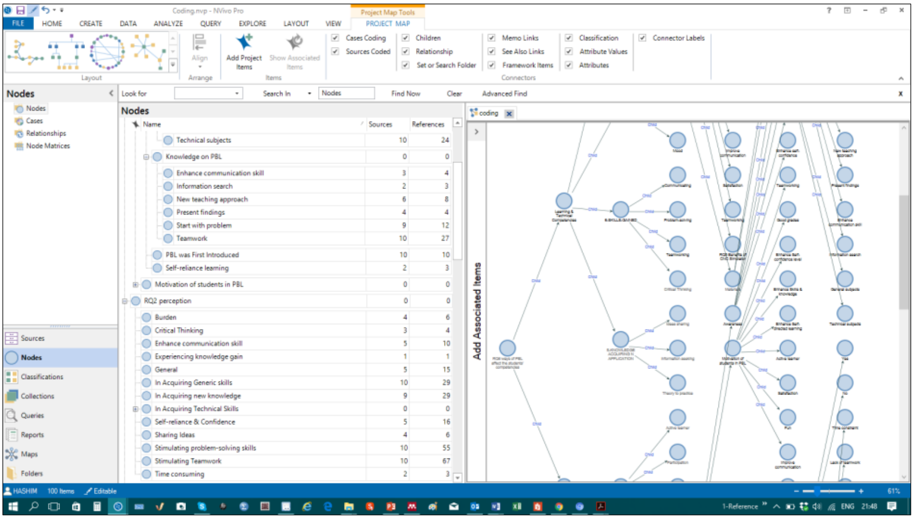


Figure 4-1: The Print Screen of coding process with NVivo 11 software.

Table 4-5: The Major Categories, Subcategories and Examples of notes and quotes for Open Coding.

Major Categories and Subcategories	Examples of notes and quotes
Knowledge Acquiring and Application:	
Ideas sharing	"Yes, by discussion, sharing the idea and prior knowledge of the members of the group."
	"Also through discussion and exchange ideas."
	"Yes, because we seek the information ourselves, and we shared the information among members of the group."
	"Yes, by discussion, sharing the idea and prior knowledge of the members of the group."
Information seeking	"Yes, we acquired new knowledge while seeking

	information to solve the problems." "Yes, because when we seek information on the internet we do not meet with information that only for the problems but much information related to the subject learnt." "Yes, it helps us because we have to solve the critical problem in a group. Thus, we need to find all the sources we need and any additional knowledge." "Yes, search information through the internet, books, programming manuals, etc. these activities contributed to new knowledge."
Theory to practice	Students were able to apply programming concept of the International Standard Organization (ISO) programming format to a new programming problem and need to be in a conversational programming format which seen through coursework assignment. Students were able to apply the concept of the International Standard Organization (ISO) programming format into practice when they worked with the CNC simulator which seen through the scores of programming test one and two.
Self-directed Learning:	
Initiative and Responsibility	Students appeared to take initiative and responsibility for their learning when the facilitator provides a problem with scaffolding.
Motivations	Students were able to set their learning objectives, activities and seen highly motivated working towards their learning objectives.
	"Working in a team is fun because it motivates learning." "Teamwork trigger active in learning and had motivated us much." "PBL educates individual to be more self-directed in

	learning, tolerant in a team to solve the problem.”
Independent and Self-reliance	CNC simulator seemed to help the students in their programming activities. They were observed to be more independent when fewer questions asked to the facilitator. The students appeared to work out with the problems by themselves. With the support of CNC simulator, the students managed to complete the exercises with the appropriate use of tools and cutting strategy. CNC simulator seemed to increase the students’ centeredness in PBL. “Yes, PBL activities encourage students to be self-reliance and a healthy working group that makes the learning easier to work on the solution.” “Yes, we can work on the programme ourselves without the involvement of the TTO. Before performing the actual machining, we can observe the part simulation and can detect the mistake in the programme and can do the correction to the programme.” “Yes, with simulator we can do analysis on our own like programme strategies and optimize the cutting strategy and technology.”
Teamwork:	
Active learning	Students were actively in the discussion, good interaction, good argument, and an effective group meeting/discussion, excellent and active interaction among the group members. “Yes, Problem-based learning gives us room to get to know our friends, practice to communicate better, speak out, share and debate the opinion.” “PBL make us an active learner.” “Fun, we like to work with teams that make us active in learning not passive.”

Participation	Group members seemed to be contributing and exchanging of ideas in the group discussion.
	"Yes, group members try to give their best idea to solve the solution."
	"Yes, PBL approach stimulated teamwork, every member of the group was given a task and needed to present in the group meeting. It was discussed in the group, thus, enhance the team spirit of the group."
	Students seemed to develop closer relationships between them in the PBL activities.
Relationships	"Yes, because PBL encourages teamwork with distributing work, share ideas and enduring relationships."
	"Yes, PBL approach stimulated teamwork, every member of the group was given a task and needed to present in the group meeting. It was discussed in the group, thus, enhance the team spirit of the group."
Learning Interest	Yes, Problem-based learning's activities generate our interest toward learning especially during the discussion in a group."
	"We have fun in learning with Problem-based learning."
Students' Interactions:	
Verbally Active	Greetings, talkative, expressing opinions, probing questions, arguments, agreements and disagreements.
Nonverbal	Body language or nonverbal expressions such as facial expressions, smiles, gestures, eye contact, handshakes, headshakes, thumb-up/down sign and attentive listening to each other's opinions and exchanging ideas.
Passive	Not much talking, low interactions, quite serious,

	isolate, low participation in group discussion, less asking questions and less suggestion given in the group discussion.
Skills Gained:	
Communicating	"Yes, because PBL is a platform for us to practice our speaking, in group interaction, communication, team working, public speaking and presentation." "Yes, we build up our confidence in our speaking, in group interaction, communication, team working, public speaking and presentation." "Yes, we enhance our confidence in our speaking, in group interaction, communication, team working, public speaking and presentation." "Yes, PBL helps us to improve our communication skills and increase our confidence level." "Enhance communication skills in the group." "To improve communication in teams."
Problem solving	"Yes, the problem had "pushed" us to think harder and search the information related to the problem-solving." "We train ourselves working in a group and enhancing our skills in problem-solving." "Yes, the given problems and with a group discussion stimulating our skills in solving problems." "Yes, the problem itself drives us to solve the problem in a team, and this had enhanced our problem-solving skills."
Team working	"Yes, because PBL promotes team working to solve problems, thus, will build up the team spirit among students." "Yes, one of the PBL criteria is for students to work in a team that makes the learning easier to work on the

	solution."
	"Yes, PBL approach stimulated teamwork, every member of the group was given a task and needed to present in the group meeting. It was discussed in the group, thus, enhance the team spirit of the group."
Critical thinking	"How cutting speed affects the cutting tool during machining?" and "What can we do to reduce the vibration of tool?" "Why we have low cutting speed at the small tool or work-piece diameter?" and "How can the earth surface speed be related to the cutting technology?" "In what ways contour programming technique of CNC Milling has in common with contour programming technique of CNC Lathe?"
Students' Learning Environment:	
Physical	Satisfactory classroom space and layout, flipchart and whiteboard for each group, reasonable computer lab space with "U" layout, adequate lighting and air-conditioned.
Resources	A workstation for each student provided with CNC simulator, ISO programming manual (pdf file), conversational programming manual (pdf file) and the internet access for external resources search.
Action	Focus, responsive, listen with judgment, asking significant questions, probing questions, discussing, explaining, share facts, taking notes, digesting each other's thoughts and ideas.

Mood	Warm behaviour, supportive, pleasant, comfortable, unstressed situation, informal, enthusiasm, curious, humour, and casual group setting.
Materials	Problem statement: "Yes, the problem statement was clear, and we were able to identify our objectives." "With only fabricated-problem, it is not sufficient because students have to deal with real problems." "Understood and cleared with problems given." "Understandable, but it takes the time to resolve." Scaffolding: "Sufficient and helpful in terms of information related to the problem." "Yes, because the scaffolding is an arrangement that can help students in problem-solving." "Sufficient and help in finding additional information." "Yes sufficient, we do not need to search some else." "Yes, it facilitates us in problem-solving." "Yes, sufficient because it can be the framework or steps to solve the problem."
Students' group composition	Mould Technology semester three (13 Males) Tool and Die Technology semester three (16 Males) CNC Precision Technology (14 Males, 4 Females) Mould Technology semester four (15 Males, 1 Female) Tool and Die Technology 1 semester four (8 Males, 2 Females) Tool and Die Technology 2 semester four (6 Males, 1 Female) Tool and Die Technology 3 semester four (7 Males, 1

	Female)
	CNC Precision Technology 1 semester four (14 Males, 1 Female)
	CNC Precision Technology 2 semester four (12 Males)
	CNC Precision Technology 3 semester four (17 Males)

The next stage of the data analysis was the axial coding where major categories were connected to their subcategories. The relationships were examined to develop more precise and complete explanations about observable facts as suggested by Corbin & Strauss (2008). The axial coding exhibited an interesting relationship between the six major categories and their subcategories. An important relationship identified was that; a structured and organized PBL setting which promotes team working also functioned as a way to motivate students to learn in a group, apply knowledge, gain skills and interact.

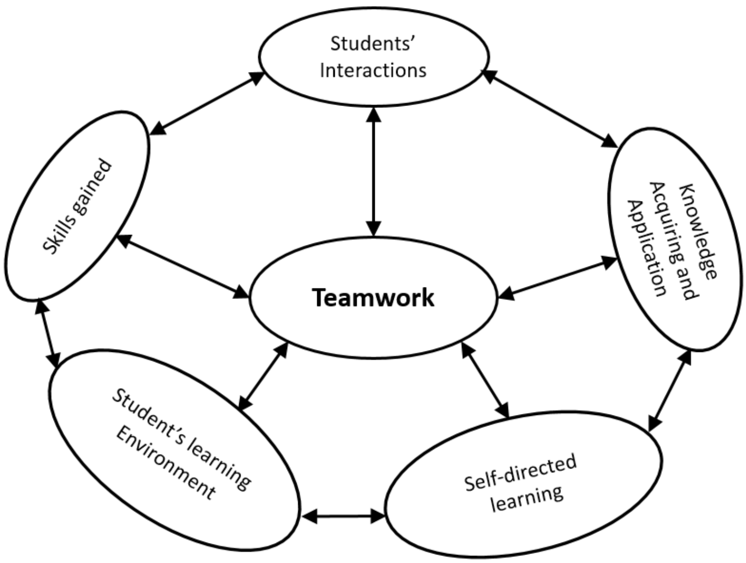


Figure 4-2: Relationship between major categories in problem-based learning with the "Teamwork" identified as the Central Theme.

Additionally, it also contributed to a constructive learning environment through self-directed learning. The next category was the students' learning environment that was set, in which the students worked in a small group with the casual, pleasant and unstressed situation. The purpose of this setting was to encourage self-direct learning, students' teamwork and interactions. Furthermore, the workstations provided with CNC simulator, ISO programming manuals and the internet for external resources search; enhanced the students' centeredness and the learning environment. The variation of students' academic background and experiences also contributed to the positive learning environment, since the sharing of knowledge and experiences fostered their interactions, acquiring of knowledge and application. Figure 4-2 demonstrates the relationships between the six major categories.

The third stage of the qualitative analysis was the selective coding which according to Corbin & Strauss (2008), is defined as; "the process of integrating and refining categories." The analysis of selective coding stressed "Teamwork" as the central theme in the enhancement of students' learning, skills and knowledge in PBL's learning environment (Figure 4-2). The researcher has positioned "Teamwork" as the central theme based on several factors such as:

1- Word frequency: The frequency of the words count generated by the NVivo software for the interviews data (see Figure 4-3). Although the word "Teamwork" in itself was not the most occurring (see Figure 4-3), it reaches the top when it is combined with related words such as "Team," "Work," "Working," "Group" and "Collaborate" as shown in Table 4-6 below.
2- Researcher's observations: The "Teamwork" of the word frequency count was further supported by the researcher's observations during the PBL sessions where students were working in team most of the time to solve problem. There was only a brief time in the PBL sessions where students needed to work alone (self-study) in search for information. The students needed to find out whatever information related to the problem individually and presented it in during the group discussion.
3- Participant observations: The data from the participant observers in Figure 4-11 of Section 4-9.1 also show that the "Teamwork" has scored relatively higher in every PBL session (PBL one to four) as compared to other elements of the observational tool. This result indicates that the participants observers have rated students have increasingly good "Teamwork" during the PBL activities.
4- Self-assessment: The data from the students' self-assessment have also showed that the "Teamwork" in Figure 4-12 of Section 4.9.1 has achieved the highest score as compared to the other elements. This result supports the data from the researcher's observations and the participant observers and seemed to be in line with the data from the interviews.

Teamwork appears to be very important in the PBL approach because it encourages students' learning through many activities especially interactions, sharing knowledge and experiences in the group. Through these activities students' acquired and applied knowledge, gained skills such as communication, problem-solving as well as team working skills. This was further affirmed by students' quotes as shown as examples in Table 4-5 (also see Appendix K-1).

Figure 4-3: The word cloud illustrates the frequency of words in the interviews' data.

Table 4-6: The Example of the word frequency query for "Work" quoted from the interviews data generated by the NVivo software.

Reference 1 - 0.06% Coverage learning that encourages students to work in a team.	Reference 1 - 0.07% Coverage solve problems and to help work in groups
Reference 2 - 0.06% Coverage and a new way to work in a group.	Reference 4 - 0.08% Coverage Yes, students can work in a group and solve
Reference 3 - 0.06% Coverage based learning is good to work in a team because we	Reference 2 - 0.09% Coverage method. It teaches us to work and collaborate in a team
Reference 5 - 0.06% Coverage it helped us learn to work in a team.	Reference 3 - 0.09% Coverage based learning, it makes us work in a team, seek for

4.3. QUANTITATIVE DATA ANALYSIS

The quantitative data were analysed using the Statistical Package for Social Sciences (SPSS) version 22 which is suitable for both parametric and non-parametric statistical procedures. There were seven instruments involved in the quantitative data analysis namely the Pre-test (Trial Exam), Post-test (Exam), Programming Test One, Programming Test two, Questionnaire, Self-assessment, and Peer-assessment. The researcher performed the Normality tests for the pre-test, post-test, programming test one, and programming test two, as will explained further in Section 4.2.1. The internal consistency for the Questionnaire, Self-assessment, and Peer-assessment were established through Cronbach's alpha which was presented in Section 3.6.1.5. The tests performed for these instruments using the SPSS were the Paired Sample T-Test, Independent Sample T-Test, and Pearson's Bivariate-Correlation. The assumption of homogeneity of variances was tested and satisfied via Levene's *F*-test. The SPSS version 22 by default provides two outputs of Levene's Test for Equality of Variances. In the normal circumstances when equal variances exist, the *t*-test result with the "equal variances assumed" will be selected, while in the case of non-equal variances exist, the "equal variances not assumed" will be used for analysis.

4.3.1. NORMALITY TEST

The research analysis examined the quantitative data and calculated the means, as well as the standard deviations. The researcher has taken into consideration of the normality of data especially of the pre-test, post-test, programming test one and programming test two. The normality tests (Shapiro-Wilk) were performed to investigate whether the data scores of students' pre-test, post-test, programming test one, and programming test (semester 3 & 4) were equally and normally distributed within groups. However, the Shapiro-Wilk's tests showed mixed results with $p > .05$ for pre-test and post-test while $p < .05$ for programming test one and two. According to Coakes (2005), if the data is of a normal distribution the independent sample t-test (parametric) is best employed and the Mann-Whitney U-test if the distribution is not normal and having a small number of samples. According to Pallant (as cited in Ghasemi & Zahediasl, 2012) the violation of the normality assumption should not cause major problems with large enough sample sizes (> 30 or 40). In addition, with large sample size (40 or more), the central limit theorem (CLT) can be invoked to justify using parametric procedures even when the data are not normally distributed (Elliott & Woodward, 2007). According to a research carried out by Norman (2010), it is suggested that parametric statistics can be used with Likert data, small samples sizes, unequal variances, and non-normal distributions and the findings are consistent with empirical literature dating back 80 years. Therefore, based on these facts and also as the subjects of this study were more than 40, the parametric statistical tests were employed for data analysis in this study.

4.4. SUB RESEARCH QUESTION ONE

The quantitative data of "questionnaire" with 25 items (Appendix D-1) provided information about the students' "perception", "awareness" and "challenges/obstacles" of the PBL implementation in the two CNC programming courses that addressed Sub Research Question (SRQ) One, below. The motivational issues were analysed and derived from items in the questionnaire and the data of group interviews. As reported in Chapter Three of Section 3.6.1.5, the Cronbach's alpha (after item deleted) for the questionnaire's scales were 0.87 for 'perception', 0.82 for 'awareness' and 0.88 for the 'challenges/obstacles'.

SRQ1: What is the level of awareness and motivations of students at different semester about Problem-Based Learning?

The first research question examined the level of awareness and motivation of students in semester three and four about Problem-based Learning, and the quantitative and qualitative instruments namely Questionnaire and Interview were employed to investigate these issues.

Results of Students' Awareness and Motivation on PBL from the Questionnaire

The overall (Table 4-7 in Appendix L-1) feedback from the students (semester three, N = 47) showed a students' score of 59.3% for 'agree with' and a score of 22.2% 'strongly agree with' of items listed referring to students' 'awareness' on PBL. On the other hand, 0.5% to 0.7% of students 'disagreed' and 'strongly disagreed' respectively and 17.3% of students were 'undecided'. The items' mean (M) scores ranging from M = 3.17 to M = 4.43 and overall M = 3.91.

As for students in semester four (N = 85), the overall (Table 4-8 in Appendix L-1) feedback showed a students' score of 53.5% for 'agree with' and a score of 28.5% 'strongly agree with' of items listed referring to students 'awareness' on PBL. Whereas, 2.6% to 0.7% of students 'disagreed with' and 'strongly disagreed with', respectively and 14.8% of students were 'undecided'. The items' mean (M) score ranging from M = 3.81 to M = 4.29 and overall M = 4.07.

Table 4-7 and Table 4-8: Awareness on PBL: Percentages and Frequencies of Students' Responses of Likert-Scale Questionnaire.

See Appendix L-1. Awareness on PBL: Percentages and Frequencies of Students' Responses of Likert-Scale Questionnaire.

The analysis of the data demonstrate that the implementation of the PBL approach for the two CNC programming courses (the lathe and milling), the majority of students (81.5% from semester three and 82% from semester four) were highly 'aware' of the advantages of PBL approach, and only less than 3% of students were perhaps not convinced with PBL approach. Therefore the PBL approach is a very useful learning tool.

The independent samples *t*-test was conducted to determine whether a statistically significant difference existed between groups of semester three and four students of questionnaire items 12 to 20. The data were analysed by the parametric Levene's Test for equality of variances assumed (Table 4-10).

Box-and-whisker plot (Figure 4-4) shows the data distribution on questionnaire's items 12 to 20 about the awareness and motivation of students in semester three and four in PBL. A box-and-whisker plot is a tool utilised to graphically show the data distribution and patterns including the range, symmetry, and central tendency of a distribution (Bryman & Cramer, 2005; Lewandowski & Bolt, 2010). According to Sheskin (2010), an outlier is an observation in a set of data that is inconsistent with the majority of the data and is usually labelled if it is significantly higher or lower than most of the observations. The Box-and-whisker plot (Figure 4-4) shows two different outliers with a small circle for "out" values and a star for "far out" or "extreme values" according to the SPSS analysis. The data set shows outliers with "far out" or "extreme values" by the group of semester three students, especially students 2 at Mark 1 (Strongly disagree) of the scale of items 15, 17 and 20. The outliers with "extreme values" also demonstrated by the group of semester three students in items 19 at Mark 3 (Undecided) and Mark 5 (Strongly agree) of the scale. Instead, the data set by the group of semester four students displays outliers with "out" for questionnaire items 15 to 20 and only item 14 shows outliers with "extreme values".

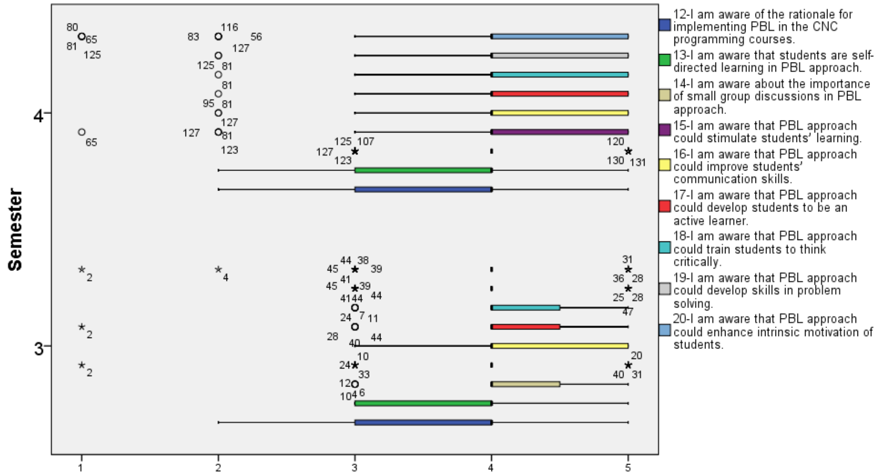


Figure 4-4: Box and whisker plot of semester three and four students' awareness and motivation in PBL.

The dataset also shows no outliers to questionnaire items 12 and 13 for both groups which indicated that the majority of the subjects were aware of the rationale for implementing PBL in the CNC programming courses and also aware that students are self-directed learning in the PBL approach. Overall, the box plots illustrate the data distribution are skewed to the right-hand side with the observations are concentrated at Mark 4 (Agree) of the scale. This situation indicated that the majority of students were aware of the benefits of PBL.

Table 4-9: The summary of the Independent samples t-test compares the difference means of semester three and four students' awareness and motivation in PBL.

	Semester	N	Mean	Std. Deviation
12- I am aware of the rationale for implementing PBL in the CNC programming courses.	3	47	3.70	.689
	4	85	3.81	.748
13- I am aware that students are self-directed learning in PBL approach.	3	47	3.77	.560
	4	85	3.85	.699
14- I am aware about the importance of small group discussions in PBL approach.	3	47	4.17	.564
	4	85	4.08	.640
15- I am aware that PBL approach could stimulate students' learning.	3	47	3.98	.737
	4	85	4.12	.822
16- I am aware that PBL approach could improve students' communication skills.	3	47	4.43	.617
	4	85	4.29	.669
17- I am aware that PBL approach could develop students to be an active learner.	3	47	4.09	.747
	4	85	4.14	.693
18- I am aware that PBL approach could train students to think critically.	3	47	4.15	.589
	4	85	4.24	.701
19- I am aware that PBL approach could develop skills in problem solving.	3	47	3.98	.608
	4	85	4.14	.742
20- I am aware that PBL approach could enhance intrinsic motivation of students.	3	47	3.91	.830
	4	85	3.92	1.026

Table 4-9 and Table 4-10 show the summary results of the independent samples t-test (equal variances assumed) between students of semester three and four on awareness and motivation in PBL. Table 4-10 displays Sig. (2-tailed) $p > 0.05$ for all questionnaire items (12 to 20). These results indicate that there were no statistically significant differences between students of semester three and four on the awareness and motivation about PBL. The results suggest that the level of students' awareness and motivation in PBL were not influenced by the level of students in the semester.

Table 4-10: The summary of the Independent samples t-test evaluates the significance of the different means of semester three and four students' awareness and motivation in PBL.

	Levene's Test for Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
12-I am aware of the rationale for implementing PBL in the CNC programming courses.	.012	.913	-.829	130	.409	-.110	.132	-.371	.152
13-I am aware that students are self-directed learning in PBL approach.	.463	.497	-.683	130	.496	-.081	.119	-.316	.154
14-I am aware about the importance of small group discussions in PBL approach.	.150	.699	.787	130	.433	.088	.112	-.133	.309
15-I am aware that PBL approach could stimulate students' learning.	2.331	.129	-.963	130	.337	-.139	.144	-.424	.146
16-I am aware that PBL approach could improve students' communication skills.	.053	.818	1.110	130	.269	.131	.118	-.103	.366
17-I am aware that PBL approach could develop students to be an active learner.	.414	.521	-.433	130	.666	-.056	.129	-.312	.200
18-I am aware that PBL approach could train students to think critically.	3.884	.051	-.716	130	.475	-.086	.121	-.325	.152
19-I am aware that PBL approach could develop skills in problem solving.	4.870	.029	-1.281	130	.203	-.162	.127	-.413	.088
20-I am aware that PBL approach could enhance intrinsic motivation of students.	1.585	.210	-.016	130	.987	-.003	.175	-.348	.343

Results of Students' Awareness and Motivations on PBL from the Qualitative Data

The semester three and four students' feedback from the group interview to the questions "when PBL was first introduced to you?" and "what are the courses/subjects that you have experience with PBL approach?" shows that most of the students have experienced PBL before attending CNC programming course. They experienced PBL from their previous colleges (one or two students in a group), technical institutes (one or two students in a group) and from the German-Malaysian Institute as well.

The interviews also revealed that the students experienced PBL in general subjects such as Mathematics, English, German, Malaysian Studies, Material Science and Industrial Management. They also practised PBL in technical subjects like Electric & Electronic Technology (semester two), CNC milling and programming (semester three) and Geometry Dimensional & Tolerances (semester four) at the German-Malaysian Institute. The situation indicated that the students have some ideas of what PBL is all about and how it works.

In responses to the question "Do, you feel the PBL approach helps you in acquiring new knowledge? If yes, how? If not, why?" the interview revealed the following quotes:

> "When we seek information on the internet we do not meet with information that only for the problems but much information related to the subject learnt."
>
> "PBL give me more knowledge during information retrieval."
>
> "When we search for information through various ways, the internet, book, journal, etc. and exchange opinions and knowledge."
>
> "Seek for information alone."
>
> "Through discussion with the team."
>
> "By discussion, sharing the idea and prior knowledge of the members in the group."
>
> "Information search, discussion and exchange idea in the group."
>
> "We acquired new knowledge while seeking information to solve the problems."

> "We work for the knowledge through information search and group discussion and presentation by other groups."
>
> "We worked for the knowledge through journals, technical books and group discussion and presentation by other groups."
>
> "We started to search and compare and gain as much information as possible and some information we cannot learn in the class."
>
> "By identifying the problem, much information related to the problem searched and discussion in the group."
>
> "Search information through the internet, books, programming manuals, etc. these activities contributed to new knowledge."

The analysis of the interviews indicated that all students in the groups are of the opinion that the PBL approach helped them in acquiring new knowledge. A majority of students indicated that the PBL approach "helped" them in acquiring new knowledge while seeking information related to problems, group discussion, knowledge sharing and presentation by other groups. Besides the knowledge related to the problems, they also acquired much more knowledge related to the subject learnt during information search.

In answers to another question "Do you feel the PBL approach helps you in acquiring technical skills? If yes, how? If not, why?" the interview produced the following comments:

> "Not helpful, as technical skills were practical-based and skill-based to operate a machine or even to work with hand tools like files, chisels, hacksaws, hand reamers, hand taps etc. because proper technique and proper use of these tools are important for effectiveness and safety reason".
>
> "No, this PBL is not suitable in the technical subject because of it unable to improve our technical skills by only reading and understand."
>
> "Less, because PBL is only suitable to apply in class and not in a workshop where machines and tools are dangerous to use without properly trained and supervision."
>
> "No, this PBL is not suitable in the technical subject because of it unable to improve our technical skills only by reading."

> "Yes and No, because Problem-based learning makes the team members be independent and giving ideas in solving the machining problem but when working with machines and tools, skilled trainer needed to demonstrate the proper method and for safety reasons".

> "Yes and No, with Problem-based learning we were able to know more about the subject during information search but to master skills we need practice."

> "Yes, if each of every member of the group has their distinctive technical skills that we can learn."

> "Yes, possible for the theoretical matter, but we need to practice hands-on to acquired technical skills."

> "Yes, by discussion in the group we learned the skills through our teammates who have experience in CNC lathe machining that gained from their previous technical schools."

The analysis of the interviews above indicated that almost all students in the groups are of the opinion that PBL approach does not help them in gaining technical skills. They have the view that technical skills can only be gained by practising with much hands-on and not by reading and understanding. The technique and proper use of machine or tools need to be practically demonstrated by a skilled trainer as it involves safety.

However, some students in the groups of Sem4TDT1 and Sem4TDT2 responded to "yes" to this question, they learned skills through their teammates who had experience in CNC lathe machining which was gained from their previous technical schools.

In reactions to the next question "Do you feel PBL approach helps you in acquiring generic skills (communication, problem-solving, and teamwork)? If yes, how? If not, why?" the interview discovered the following remarks:

> "Yes, every member of the team need to speak in the discussion and explain and present the ideas."

> "Yes, because we have to communicate in the group and present our solution to the problem. Thus, it helps us become more confident and increases our generic skills".

> "Yes, through group interaction, presentation, public speaking, seeking information to solve the problem."

> "Yes, because PBL is a platform for us to practice our speaking, in group interaction, communication, team working, public speaking and presentation."

> "Yes, we enhance our confidence in our speaking, in group interaction, communication, team working, public speaking and presentation."

> "Yes, because we can practice and improve our communication and presentation skills during PBL sessions."

The interviews indicated that all students in the groups are of the opinion that PBL approach does help them in gaining generic skills. They have the view that generic skills can be acquired and improved with many practices. PBL is an approach that provides a platform for them to practice their speaking, interaction in the group, communication, team working, public speaking and presentation that indirectly improve their self-confidence and generic skills.

<u>Results of Students' Motivation on PBL from the Qualitative Data</u>

The semester three and four students' feedback to the group interview to question "What are your motivations for learning through PBL approach?" showed that most students found PBL motivated them in learning. This fact was affirmed by the following students' statements in the interviews such as:

"This way it can foster the spirit of cooperation among the group members and also exchange the ideas".

> "Yes, PBL make the team discussed and thought critically about solving problems".

> "To increase our generic skills, technical skills and knowledge".

> "Fun, we like to work with teams that make us active in learning not passive".

> "Working in a team is fun because it motivates learning".

> "Drilling through discussion for the best solution to the problem given".

> "When we have successfully presented the solution, we felt very satisfied".

> "Working together in a group is fun, and we assume the problem as challenges for us to solve it".
>
> "We have chances to learn in a group that better than learning alone and challenge to solve problems".
>
> "PBL educates individual to be more self-directed in learning, tolerant in a team to solve the problem".
>
> "It motivated us very much in learning and make us an active learner".
>
> "Working in a team is fun because it has very much motivated our learning".

The interviews' analysis revealed that the teams' working and style of active learning which were promoted in the PBL approach have motivated most of the students. Other factors that were identified to contribute to the students' motivations were PBL's activities, such as group discussion and presentation which enabled to enhance students' generic skills as well as technical skills.

4.5. SUB RESEARCH QUESTION TWO

SRQ2: What are the students' perception of the Problem-Based Learning implementation?

Sub Research Question two of this study was especially concerned with the students' perception on the PBL implementation in the CNC Lathe and Milling programming courses at the GMI and with this question, the researcher was trying to discover the students' point of view on the PBL implementation in order to get a clear picture of its implementation at GMI.

<u>Results of Students' Perception on PBL from the Quantitative Data</u>

The feedback is presented in Table 4-11 in Appendix L-2 and was obtained from the students of semester three (N = 47), the results of the listed items which represented the students' perception on PBL in CNC programming courses were: 49.9% of the students 'agreed' and 35.2% 'strongly agreed' with the statement. However, 0.4% to 0.8% of students 'disagree' and 'strongly disagree' respectively with the statement and 13.7% of students were 'undecided'. Thus the ten items scored mean (M) was above 4.00, except for item number 10 having a score of M = 3.85 and overall M = 4.8.

The responses shown in Table 4-12 in Appendix L-2 was obtained from the students of semester four (*N* = 85) and the results showed that the listed items which represented the students' perception on PBL in CNC programming courses were: 52.7% of the students 'agreed' and 30.2% 'strongly agreed' with the statement. However, 2.8% to 0.5% of students 'disagree' and 'strongly disagree' respectively with the statement and 13.7% of students were 'undecided. Thus the eight items scored mean (*M*) was above 4.00, except for items number 8, 10 and 11 having a score lower than *M* =4.00 and overall *M* = 4.09.

The results above strongly indicates that majority of students (85.1% from semester three and 82.9% from semester four) have a good perception on the PBL approach and only less than 3% of students have negative perception on PBL when it was implemented in two CNC programming courses (lathe and milling).

The independent samples *t*-test was performed to determine whether a statistically significant difference in perception (questionnaire items 1 to 11) existed between groups of semester three and four students. The data were analysed by the parametric Levene's Test with equality of variances assumed in (Table 4-14).

Table 4-11 and Table 4-12: Perception on PBL: Percentages and Frequencies of Students' Responses of Likert-Scale Questionnaire.

See Appendix L-2. Perception on PBL: Percentages and Frequencies of Students' Responses of Likert-Scale Questionnaire.

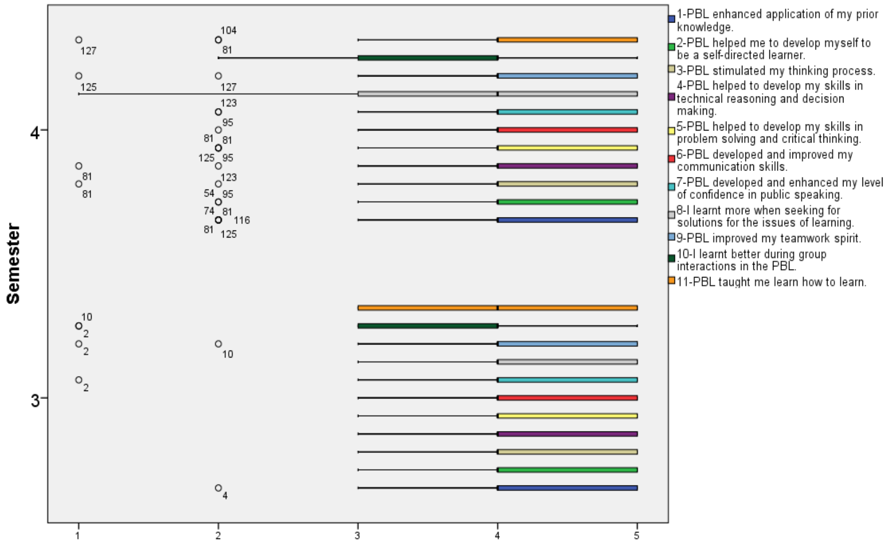


Figure 4-5: Box and whisker plot of semester three and four students' perception on PBL.

A Box-and-whisker plot (Figure 4-5) displays the data distribution on questionnaire's items 1 to 11 about the perception of students in semester three and four in PBL. The Box-and-whisker plot demonstrates outliers with a small circle of "out" values for both groups. The outliers seem to be more in a group of semester four than semester three that at the low end 1 (Strongly disagree) and 2 (Strongly agree) of the scale. The Box-and-whisker plot indicates that the students of semester four have a more negative perception on PBL than students of semester three. Students 2, 81 and 95 were having quite a negative perception on PBL with three or more questionnaire items were at mark 2 (disagree) and 1 (Strongly disagree). Overall, the box plots illustrate the data distribution are skewed to the right-hand side with the observations are concentrated at Mark 4 (Agree) of the scale. The data set suggested that majority of the subjects have a positive perception on PBL.

Table 4-13: The summary of the Independent samples t-test compares the difference means of semester three and four students' perception on PBL.

	Semester	N	Mean	Std. Deviation
1-PBL enhanced application of my prior knowledge.	3	47	4.19	.680
	4	85	4.12	.822
2-PBL helped me to develop myself to be a self-directed learner.	3	47	4.13	.679
	4	85	4.13	.753

3-PBL stimulated my thinking process.	3	47	4.32	.629
	4	85	4.22	.762
4-PBL helped to develop my skills in technical reasoning and decision making.	3	47	4.17	.670
	4	85	4.24	.766
5-PBL helped to develop my skills in problem solving and critical thinking.	3	47	4.19	.680
	4	85	4.06	.746
6-PBL developed and improved my communication skills.	3	47	4.40	.614
	4	85	4.24	.648
7-PBL developed and enhanced my level of confidence in public speaking.	3	47	4.28	.877
	4	85	4.13	.686
8-I learnt more when seeking for solutions for the issues of learning.	3	47	4.23	.598
	4	85	3.93	.897
9-PBL improved my teamwork spirit.	3	47	4.21	.806
	4	85	4.08	.727
10-I learnt better during group interactions in the PBL.	3	47	3.85	.932
	4	85	3.88	.762
11-PBL taught me learn how to learn.	3	47	4.04	.779
	4	85	3.99	.809

Table 4-13 and Table 4-14 show the results of the independent samples t-test (equal variances assumed) on the perception of PBL among students of semester three and four. Table 4-14 displays Sig. (2-tailed) $p > 0.05$ for all questionnaire items (1 to11). These results indicate that there were no statistically significant differences between students of semester three and four on the perception about PBL. Therefore, the hypothesis two: There is no difference in perception on the PBL implementation in the CNC programming course between students of semester three and four is not rejected. The results suggest that the students' perception in PBL were not influenced by the level of students in the semester.

Table 4-14: Independent samples t-test evaluates the significance of the different means of semester three and four students' perception on PBL.

	Levene's Test for Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
1-PBL enhanced application of my prior knowledge.	1.375	.243	.524	130	.601	.074	.141	-.205	.353
2-PBL helped me to develop myself to be a self-directed learner.	.406	.525	-.013	130	.989	-.002	.132	-.263	.260
3-PBL stimulated my thinking process.	.194	.660	.733	130	.465	.096	.130	-.162	.354
4-PBL helped to develop my skills in technical reasoning and decision making.	.604	.438	-.488	130	.626	-.065	.133	-.329	.199
5-PBL helped to develop my skills in problem solving and critical thinking.	.210	.647	1.009	130	.315	.133	.131	-.127	.393
6-PBL developed and improved my communication skills.	.342	.560	1.461	130	.146	.169	.116	-.060	.398
7-PBL developed and enhanced my level of confidence in public speaking.	5.967	.016	1.066	130	.288	.147	.138	-.126	.420
8-I learnt more when seeking for solutions for the issues of learning.	2.596	.110	2.085	130	.039	.305	.146	.016	.594
9-PBL improved my teamwork spirit.	.881	.350	.949	130	.344	.130	.137	-.141	.402
10-I learnt better during group interactions in the PBL.	1.516	.220	-.208	130	.835	-.031	.150	-.328	.266
11-PBL taught me learn how to learn.	.544	.462	.374	130	.709	.054	.145	-.233	.341

Results of Students' Perception on PBL from the Qualitative Data

The responses of the semester three and four students to the group interview revealed the following perception on PBL. Students found communication and teamwork as the most positive aspects of their PBL experience. This was affirmed by the fact that several of the feedback to a simple question, "What do you feel/think about PBL?" were remarks such as:

> "This helps improve communication,"

> "Helpful because it can create teamwork spirit and encourage the students to think outside the box,"

> "Yes, PBL is very helpful in thinking critically to solve problems and to help work in groups,"

> "We feel that Problem-based learning is good to work in a team because we can give ideas to solve problems,"

> "Problem-based learning is an exciting way of learning approach and useful,"
>
> "Problem-based learning is a good way of learning by discussion and interaction in the group,"
>
> "Yes good, the good thing about Problem-based learning, it makes us work in a team, seek for information and doing presentation on the solution to the problem,"
>
> "Very good because we share ideas, learn new knowledge from each other members in the group," and
>
> "Yes good and enjoyable, the discussion in a group can generate good ideas to solve the problem and improve our communication skills".

Other aspects which students found also to be positive in their PBL experience were remarks such as:

> "Stimulating individuals mind for not to depend on the notes given but to search more information on the subject,"
>
> "We think it can help students to solve a critical problem,"
>
> "Great type of learning, improve self-knowledge and self-confidence,"
>
> "PBL is good because it opens students' mind that students need to think good to solve problems,"
>
> "Problem-based learning is a fun way of learning and it helps us to think and work on the problem ourselves, some of the information that we cannot get in the class,"
>
> "Problem-based learning has made us understand better the subject at hand because we experience the gain of knowledge," and
>
> "Great type of learning approach, improve self-knowledge and self-confidence."

The responses of the semester three and four students to the group interview also revealed some students' negative perception on PBL. Students found time constraint and many other PBL assignments as the most negative aspects of their PBL experience. This was supported by several of the students' comments such as:

> "PBL consumes much time and we cannot get any hands-on skills (technical) with it,"
>
> "we still need the TTO (Instructor) to teach us as time constraint and PBL is not suitable when we have very limited time, and we are overloaded with another assignment,"
>
> "PBL consumes much time and we can't get any skills with it,"
>
> "But we have many assignment and time constraints,"
>
> "But it consumes time and a bit burden" and
>
> "PBL burdens students because we have many PBL assignment given by other TTO at the same time".

A couple of students found other negative issues in their PBL experience were noted such as:

> "In my opinion, PBL is a burden to me because the subject matter was not taught from the beginning," and
>
> "Sometimes we feel hard to find appropriate resources to the problem"

(Appendix K-1 consists of all of students' responses to the questionnaire).

4.6. SUB RESEARCH QUESTION THREE

SRQ3: How do the students' perceive challenges/obstacles in the Problem-Based Learning implementation?

Sub Research Question Three of this study was concerned with the students' challenges/obstacles faced during the PBL implementation in the CNC Lathe and Milling programming courses. With this question, the researcher was trying to discover and to understand the challenges/obstacles during PBL implementation from both the students' and lecturers' perspective.

Results of Students' challenges/obstacles in PBL from the Quantitative Data

The section referring to the 'Students' challenges/obstacles on PBL' in the questionnaire provides five items in a 'negative form' type of questions. The 'negative form' of questions was purposely designed by the researcher to look at the trend of participants in answering this questionnaire; whether they read, understood and answered the questions appropriately. The data were then reverse-scored to give the correct computation and interpretation of data analysis. The feedback (Table 4-15 and Table 4-16 in Appendix L-3) from the students (semester three, N = 47 and semester four, N = 85) overall indicated that they answered the questionnaire appropriately. These results indicate the percentages declined in columns 'agree' and 'strongly agree' with 26.8% and 6.8% respectively for semester three, and 28.9% and 20.9% respectively for semester four. Also, the percentages increased in columns 'disagree' and 'strongly disagree' with 17.9% and 3% respectively for semester three and 16.5% and 5.6% respectively for semester four. However, the majority of students in semester three were 'undecided' with 45.5% and 28% respectively of students in semester four. The data scores seem to be almost balanced in both groups with an overall mean (M) of 2.83 for semester three students and 2.57 for semester four students.

Table 4-15 and Table 4-16: Challenges/obstacles on PBL: Percentages and Frequencies of Students' Responses of Likert-Scale Questionnaire.

See Appendix L-3. Challenges/obstacles on PBL: Percentages and Frequencies of Students' Responses of Likert-Scale Questionnaire.

The results indicated that the students faced some challenges/obstacles in the CNC programming courses which employed PBL for the very first time. The sum of 49.8% (N = 42) students of semester four responded 'agree' and 'strongly agree' to challenges/obstacles compared to students of semester three with only 33.6% (N = 16) responded 'agree' and 'strongly agree'.

Results of Students’ challenges/obstacles on PBL from the Qualitative Data

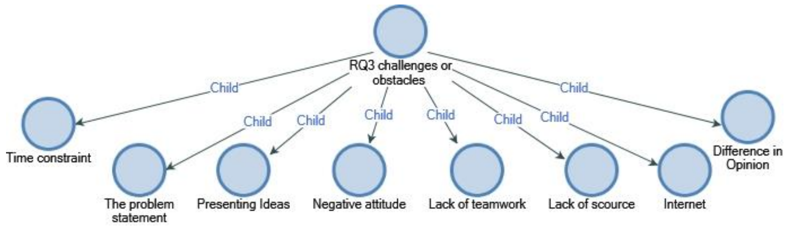


Figure 4-6: The elements that emerged from the qualitative data (group interviews) analysis for students’ challenges/obstacles in PBL.

Figure 4-6 shows the elements that emerged from the qualitative data analysis of group interviews about the students’ challenges/obstacles in PBL. The students’ responses to the group interview question which asked, “What you feel the challenges/obstacles for you as a student to adopt PBL approach in your learning?” comprised the following quotes:

> “Time, because too many subjects with PBL in a semester,”
>
> “The challenge is the time and when doing the presentation to get the audience understand,”
>
> “To solve the problem given in the problem statement in a limited time,”
>
> “Time constraint to gather information from the group members and to solve problems,”
>
> “Don’t have enough time, due date too short and team members that did not participate and cooperate in the discussion,”
>
> “Lack of time, the difference in opinion, lack of teamwork, the lack of sources,”
>
> “Time constraint because we also have other PBL assignment in the same week given by other TTO,” “time constraint to solve problem and presentation in English,”
>
> “The challenge when group members did not cooperate,”

> "Language during the presentation,"
>
> "Some of the group members did not cooperate, no contribution and materials found by some members were not appropriate and difficult to understand," and
>
> "The internet is not consistent."

The interviews' answers indicated that students encountered challenges/obstacles during the learning with the PBL approach. The majority of students stated that "time constraint" was the obstacle when learning with PBL approach because at the same time they also had other assignments given by other lecturers. The students mentioned that subjects adopted in the PBL approach were too many in a semester which they had to cope with. Other challenges/obstacles encountered by the students were the lack of sources, the internet was inconsistent, the difference in opinion, lack of teamwork and importantly some team members who did not participate and cooperate in the discussion. The interviews also indicated that some students faced a problem with the English language, especially during the presentation. These responses provided further insight into what students considered to be the challenges/obstacles in the PBL implementation and supported by the quantitative data.

4.7. SUB RESEARCH QUESTION FOUR

SRQ4: What is the relationship between students' prior academic performance and their learning performance in the PBL approach?

The Sub Research Question four of this study investigated the extent of students' prior academic performance influence has on the learning using the PBL approach for the students in semester three and four. The quantitative instrument namely Pre-test, Post-test and Students' academic records were employed to investigate this issue. In this investigation, Researcher hypothesized that:

H1: Students of semester three and four with above average CGPA scores should have higher scores in both the pre-test and the post-test; than those with below average CGPA scores.

H2: Students of semester four should have higher scores in the pre-test than students of semester three.

H3: There is no difference in post-test scores between students of semester three who attending the CNC programming milling and students of semester four who attending the CNC programming lathe.

Researcher's hypothesis one:

H1: Students of semester three and four with above average CGPA scores should have higher scores in both the pre-test and the post-test; than those with below average CGPA scores.

The independent-samples *t*-test was conducted to determine the significance between the students' pre-test, post-test scores of students' semester three & four and their last semester of Cumulative Grade Point Average (CGPA) in order to address the SRQ four. The SRQ four asked: To what extent does students' academic performance influence the learning with the PBL approach? Research hypothesis one was: Students of semester three and four with above average CGPA scores should have higher scores in both the pre-test and the post-test; than those with below-average CGPA scores.

The researcher arranged the data according to the students CGPA scores in two groups, one having high CGPA scores and the other low CGPA scores to test for significance. The researcher considered the CGPA with equal and above mean as high CGPA and the CGPA with below mean as low CGPA. The means of CGPA for students in semester three ($\bar{x}$ = 2.72) and four ($\bar{x}$ = 2.70) were calculated.

For semester three, the assumption of homogeneity of variances was tested and satisfied via Levene's *F*-test, $F(45) = .01$, $p = .913$ (pre-test) and $F(45) = .18$, $p = .672$ (post-test). Whereas for semester four, the assumption of homogeneity of variances was tested and satisfied via Levene's *F*-test, $F(83) = .32$, $p = .573$ (pre-test) and $F(83) = 3.03$, $p = .085$ (post-test).

Tables 4-17 and Table 4-18 show the outcomes of the independent samples t-test of students' CGPA versus the students' pre- and post-test. The outcomes revealed that the group of students in both semesters three and four with high CGPA scored higher than those having low CGPA in both the pre-test and post-test. However, the mean differences for pre-test (Table 4-17 and Table 4-18) were not significant in both semesters three and four. Nevertheless, the independent samples *t*-test was associated with a statistically significant in the post-test for both semester three with $t(45) = -6.55$, $p = 0.00$ and semester four with $t(83) = -6.75$, $p = 0.00$. The findings indicated that there was some relationship between the students' CGPA and the performance of students learning in the PBL approach. Therefore, the hypothesis one: students of semester three and four with good CGPA above average have higher scores in both the pre-test and the post-test than the ones with CGPA scores below average is not rejected.

Table 4-17: CGPA versus pre-test and post-test of semester three students.

Tests	CGPA	N	Mean	Std. Deviation	t	df	Sig. (2-tailed)	Mean Difference
Pre-Test	Below Mean	25	9.24	3.03	-1.90	45	.063	-1.81
	Above Mean	22	11.05	3.47				
Post-Test	Below Mean	25	35.00	14.12	-6.55	45	.000	-27.96
	Above Mean	22	62.95	15.12				

Table 4-18: CGPA versus pre-test and post-test of semester four students.

Tests	CGPA	N	Mean	Std. Deviation	t	df	Sig. (2-tailed)	Mean Difference
Pre-Test	Below Mean	44	16.66	5.18	-1.51	83	.136	-1.80
	Above Mean	41	18.46	5.86				
Post-Test	Below Mean	44	35.16	10.06	-6.75	83	.000	-16.26
	Above Mean	41	51.41	12.11				

Researcher's hypothesis two:

H2: Students of semester four should have higher scores in the pre-test than students of semester three.

This hypothesis investigates whether there was a significant difference in performance scores between students of semester four and semester three in the pre-test. The independent-samples *t*-test was conducted to determine whether students of semester four would achieve higher scores on the pre-test than students of semester three.

The assumption of homogeneity of variances was tested and satisfied via Levene's *F*-test, $F(130) = 12.67$, $p = .001$ (pre-test). However, the test was significant, therefore, the t-value from equal variance not assumed was used by equalizing the sample size. Random sampling was conducted on a group of semester four students (85) to equalize with the number of semester three students (47) as shown in Table 4-19.

The results from the independent samples t-test (Table 4-19) on pre-test indicated that the students of semester four scored higher mean ($M = 17.55$, $SD = 5.12$, $N = 47$) than semester three students ($M = 10.09$, $SD = 3.34$, $N = 47$). The difference was statistically significant ($t(79.12) = -8.38$, $p = .000$). Therefore, the hypothesis two: students of semester four would achieve higher scores on the pre-test than students of semester three, is not rejected.

Table 4-19: Independent samples t-test on Pre-test between students of semester three and four.

	Semester	N	Mean	Std. Deviation	Std. Error Mean
Pre-Test	3	47	10.09	3.335	.486
	4	47	17.55	5.115	.746

Researcher's hypothesis three:

H3: There is no difference in post-test scores between students of semester three who attending the CNC programming milling and students of semester four who attending the CNC programming lathe.

This hypothesis investigates whether there was a significant difference in performance scores between students of semester four and semester three in the post-test. The independent-samples *t*-test was conducted to determine whether there was a difference in post-test scores between students of semester three who attending the CNC programming milling and students of semester four who attending the CNC programming lathe.

The assumption of homogeneity of variances was tested and satisfied via Levene's *F*-test, $F(130) = 8.13$, $p = .005$ (post-test). However, the test was significant, therefore, the t-value from equal variance not assumed was used (Table 4-20).

Table 4-20: Independent Samples t-test on Post-test between students of semester three and four.

	Semester	N	Mean	St d. Deviation	Std. Error Mean
Post-Test	3	47	48.09	20.179	2.943
	4	85	43.00	13.727	1.489

The results from the independent samples t-test (Table 4-20) on post-test showed that the students of semester three scored higher mean (M = 48.09, SD = 20.18, N = 47) than semester four students (M = 43.00, SD = 13.73, N =85). However the difference was not statistically significant (t (130) = 1.54, p = .128). Therefore, the hypothesis three: there is no difference in post-test scores between students of semester three who attending the CNC programming milling and students of semester four who attending the CNC programming lathe is not rejected.

4.8. SUB RESEARCH QUESTION FIVE

SRQ5: To what extent does the CNC simulator benefit students in the PBL approach?

The fifth Sub Research Question of this study examined the extent of the CNC simulator benefits students when using the PBL approach. The quantitative (programming test one and two) and qualitative (interviews, observations and content analysis) instruments were employed to examine this issue. In this research study hypothesized four was made by the researcher:

H4: Students of semester three and four with above average CGPA scores should have higher scores in both the programming test one and the programming test two than those with below average CGPA scores.

H5: Students of semester three and four should have higher scores on the programming test two than programming test one.

H6 There will be a relation between the scores of programming test one and programming test two of students semester three and four.

Researcher's Hypothesis four:

H4: Students of semester three and four with above average CGPA scores should have higher scores in both the programming test one and the programming test two than those with below-average CGPA scores.

The independent-samples *t*-test was performed to determine the significance of the students' programming test one and two scores of students' semester three and four. The researcher arranged the data according to the students CGPA scores in two groups, one having high CGPA scores and the other low CGPA scores to test for significance. The researcher considered the CGPA with equal and above mean as high CGPA and the CGPA with below mean as low CGPA. The means of CGPA for students in semester three ($\bar{x} = 2.72$) and four ($\bar{x} = 2.70$) were calculated.

For semester three, the assumption of homogeneity of variances was tested and satisfied via Levene's *F*-test, F (45) = .35, p = .558 (programming test one) and F (45) = 21.45, p = .000 (programming test two). However, the test was significant for programming test two, and therefore, the t-value from equal variance not assumed was used. While for semester four, the assumption of homogeneity of variances was tested and satisfied via Levene's *F*-test, F (83) = 3.12, p = .081 for programming test one and F (83) = 3.75, p = .086 for programming test two.

Table 4-21: Programming test one and two of semester three students.

Tests	CGPA	N	Mean	Std. Deviation	t	df	Sig. (2-tailed)	Mean Difference
Program Test One	Below Mean	25	6.06	1.45	-2.32	45	.025	-.95
	Above Mean	22	7.01	1.35				
Program Test two	Below Mean	25	7.75	1.05	-3.05	38	.004	-.74
	Above Mean	22	8.49	.57				

Table 4-22: Programming test one and two of semester four students.

Tests	CGPA	N	Mean	Std. Deviation	t	df	Sig. (2-tailed)	Mean Difference
Program Test One	Below Mean	44	7.69	1.16	-1.37	83	.175	-.32
	Above Mean	41	8.01	.97				
Program Test two	Below Mean	44	8.03	.85	-.66	83	.509	-.11
	Above Mean	41	8.14	.61				

Tables 4-21 and Table 4-22 show the outcomes of the independent samples t-test for students' programming test one and two (semester three and four). The results discovered that the group of students in both semesters three and four with high CGPA scored higher than the low CGPA in both the programming test one and two. However, the mean differences were significant only in programming test one $t(45) = -2.32$, $p = 0.025$ and two $t(38) = -3.05$, $p = 0.004$ of semesters three (Table 4-21). The mean differences for programming test one $t(83) = -1.37$, $p = 0.175$ and two $t(83) = -.66$, $p = 0.509$ (Table 4-22) were not significant for semester four students.

The results were only significant for semester three students and not significant for semester four students. Although there was no concrete evidence to support hypothesis four nevertheless the results were somewhat inclined to the expected direction of the study hypothesis (four). The results somehow indicated that the students' CGPA influenced the performance of students learning in PBL approach although the data were not statistically significant for students of semester four. Therefore, the hypothesis four: students of semester three and four with above average CGPA scores should have higher scores in both the programming test one and the programming test two than those with below average CGPA scores, is partially not rejected.

Researcher's Hypothesis five:

H5: Students of semester three and four should have higher scores in the programming test two than programming test one.

The objective of this hypothesis was to investigate whether there was a significant difference between programming test one and programming test two of students in the semester three and semester four. Programming test one and two were given to the students in a CNC programming course. The programming test one (given earlier) was a CNC programming test, writing on a piece of paper without the aid of CNC simulator. Whereas for the CNC programming two (which was the same question as programming test one), was a test of CNC programming, but in this case the students had to key-in the programme in the CNC simulator and the software program could then simulate the geometry paths, tool paths and detect any errors in the program. With that, the students could check the error and make appropriate remedies to the program until the required geometrical paths were achieved without errors. The CNC programming two test was given immediately after the CNC programming one test and was the continuation of CNC programming one. With this, the students were able to verify the programme that they have written on paper with the CNC simulator. Therefore the CNC simulator has enabled students to work and solve problems by identifying the errors on their own and encourage them to be more self-directed in learning.

Table 4-23: Paired samples t-test of programming test one and two of semester three and four students.

		Programming test one		Programming test two		
Semester	**N**	*M*	*SD*	*M*	*SD*	Sig. (one-tailed)
3	47	6.51	1.47	8.09	0.93	.000
4	85	7.85	1.08	8.08	0.74	.012

The paired-samples *t*-test was conducted to determine whether students of semester three and four had higher scores in the programming test two than programming test one. The results in Table 4-23 shows that there was highly statistically significant difference between the scores of programming test one and programming test two. From Table 4-23 it can be seen that the score of the students in semester three for programming test two; had an average of (M = 8.09) which was a higher score than for programming test one (M = 6.51) and with the *p*-value of .000. One-tailed paired samples *t*-test revealed that students' (semester three) scores were higher in programming test two (M = 8.09, SD = 0.93) compared to programming test one (M = 6.51, SD = 1.47), t (46) = -8.41, $p \leq .05$.

Also, the students in semester four had an average score for the programming test two of (M = 8.08) which was a higher score than the programming test one (M = 7.85) and with the *p*-value of .012 (Table 4-23). One-tailed paired samples *t*-test revealed that students' scores were higher in programming test two (M = 8.08, SD =.74) compared to programming test one (M = 7.85, SD = 1.08), t (84) = -2.32, $p \leq .05$.

The results showed that the students in semester three and four have higher scores in programming test two than programming test one. Therefore, the hypothesis five: students of semester three and four should have higher scores in the programming test two than programming test one, is not rejected.

Researcher's Hypothesis Six:

H6: There will be a relation between the scores of programming test one and programming test two; for students in both semesters three and four.

The Pearson correlation analysis was conducted to examine whether there was a relationship between the scores of the students' programming test one and programming test two (semester three and four).

Table 4-24 and Table 4-25 show the outcomes of the Pearson's correlation analysis of students' programming test one and programming test two. The results shows that, for students in both semester three and semester four there were moderate-to-close to a high, positive correlations between the students' programming test one and programming test two of students of semester three having: r = .49, N = 47 and $p \leq .001$, and similarly for students of semester four having: r = .53, N = 85 and $p \leq .001$. Both correlations were significant at the 0.01 level.

The results revealed that the programming test one and programming test two were correlated in the sense that the students were able to apply their theoretical knowledge in the programming test one and into practice in the programming test two using the program simulation. The results also revealed that students with a good score of programming test one were correlated with a good score in the programming test two.

Table 4-24: Pearson Correlation programming test one versus programming test two of semester three students.

		Programming Test Two
Programming Test one	Pearson Correlation	.493
	Sig. (2-tailed)	.000
	N	47

Correlation is significant at the 0.01 level.

Table 4-25: Pearson Correlation programming test one versus programming test two of semester four students.

		Programming Test Two
Programming Test One	Pearson Correlation	.528
	Sig. (2-tailed)	.000
	N	85

Correlation is significant at the 0.01 level.

The above results indicate that the CNC simulator has benefited the students in assisting them to solve the programming test two; which is the main objective of having the simulator as a learning tool. Furthermore, the results indicated that the students in both groups have achieved the level of learning and technical competencies as required in the learning outcomes of the CNC programming courses (CNC milling programming and CNC lathe programming) at the GMI.

Results of Students' Opinion on CNC simulator from the Interview Data

The semester three and four students' feedback to the group interview referring to the question "Do CNC simulator benefits you in the CNC programming course adopting PBL approach?" revealed that the students have given positive comments on the use of CNC simulator in the CNC programming courses. The objective of this question was to seek their view on whether CNC simulator has benefitted them in the CNC programming course with PBL approach. If yes, how CNC simulator has benefitted and if not why?

The interviews indicated that all students in the groups agreed that CNC simulator has benefitted them in the CNC programming course with PBL approach. They have stated that the CNC simulator is one of the programming tools for beginners that could help them to get used to the CNC machine without any worries of injury or damaging the machine. They have also stated that with the CNC simulator, learning of programming has become more efficient and effective. They have had the hands-on experiences in programming and handling the simulator that resemblance to the actual CNC machine controller. They were of the opinion that the CNC simulator can simulate the geometrical path of the programme and simulate the physical function of an actual CNC machine controller. Besides, it can detect mistakes, and make the necessary correction to the programme before performing the actual machining. They also were of the opinion that with the CNC simulator they can do analysis on the programming to optimise the cutting strategy and technology and make them more independent by learning by themselves.

The group interview revealed the following quotes:

> "Yes, besides reading books, learning about programming will become more efficient, productive and more knowledge gained."
>
> "Yes is crucial for the beginners in CNC programming and when students start working with CNC machine."
>
> "Yes, because CNC simulator is one of the programming tools that could help students understand the functions of CNC machine."
>
> "Yes, simulation on the physical function of the actual CNC machine controller."
>
> "Yes, it is critical to CNC programming as a beginner for each student to familiar with CNC controller."
>
> "Yes, CNC simulator enables students to plan in term of making the programme, and we can observe the errors and make remedies."
>
> "Yes, because the simulator is like the exactly CNC controller at the CNC machine."
>
> "Yes, because it helped the students to practice and experience like an actual CNC controller."
>
> "Yes, because it helps us imagine the real machining process on the machine thus avoid any error."
>
> "Yes, before performed the actual machining, we can observe the part simulation and can identify problems in the programme and can do corrections to the programme."
>
> "Yes, we can workout the programme ourselves without the involvement of the TTO."
>
> "Before performing the actual machining, we can observe the part simulation and can detect the mistake in the programme and can do the correction to the programme."

> "Yes, with simulator we can do analysis on our programme strategies and optimise the cutting strategy and technology."
>
> "Yes, it can improve our programming skill before we go the real machine."
>
> "Yes, because simulation will detect the error in programming."
>
> "Yes, because the simulator can show the graphic of the machining process that shows what happen."
>
> "Yes, because simulation will show what happens to our programme, and we can do 'trial and error' until we get the right programme that we want".
>
> "Yes, because the simulator can show the graphic of the machining process that shows what happen."
>
> "Yes, we experience programming like doing at the actual CNC machine controller and avoid any collision if wrongly programmed."

During the observations carried out by the researcher in the third and fourth PBL sessions which were held in the CNC simulator labs of CNC Milling and Lathe programming courses, the students also seemed to develop an informal group relationship in terms of showing a friendly and warm behaviour toward each other in a learning environment which appeared to be conducive, supportive and peaceful. Also during the PBL sessions, the students took the initiative and responsibility for their learning when the facilitator provided a programming problem including a scaffold. They were able to set their learning objectives, activities and seen to be very motivated working towards their learning objectives and they appeared to be able to search for the relevant information from various learning resources independently. Also, it appeared that they were empowered and more independent because fewer questions were asked to the facilitator when working with the CNC simulator and able to work out the problems by themselves.

The observation data showed that students very focused when working with the CNC simulator. They were observed discussing the problems that they faced during programming at the CNC simulator. The problems discussed seemed to be very technical such as the function keys of the CNC simulator, programming structure, CNC coordinate system, the work piece zero point and the machine zero point, metal cutting technology, programming codes, geometry definitions, programming plane, graphic definition, programming cycles and cutting strategy. During the group discussions to solve a programming problem, several workable solutions were proposed by the members of the group. The students seemed to make the appropriate decision to the problems given and able to provide a technically good reason to the decision that they have made. They were also seen exchanging ideas on their programming style and probe questions of each other and gave explanations and shared their own perceptions. The students seemed to manage to complete the exercises with the appropriate use of tools and cutting strategy during programming exercises given; with the help of the simulator. This fact affirmed by the quantitative data in Section 4.8 that exhibited the students' good performance in their programming test one and programming test two which also showed students were capable to use their knowledge and apply it into practice when they work with the CNC simulator. They seemed to be very self-reliant and confident when working with the CNC simulator.

The content analysis of students' programming exercises at the CNC simulators also demonstrated a high degree of problem-solving skills, decision-making skills as well as critical thinking ability by the students. They were seen trying many possible methods with the simulator to come out with the best programming solution and able to produce several ways of programming strategies and contour programming format to the same problem. Examples were programming a corner radius (Figure 4-7) and a chamfer (Figure 4-8) as shown in Table 4-26 and Table 4-27. With the knowledge of ISO programming option one, the students were observed to be capable of exploring more programming functions at the CNC simulator and come up with two, three and four other programming options (Table 4-26 and 4-27). They were also able to adapt the concept of ISO programming to a new problem (part drawing) with the Conversational programming format without much interference from the lecturer or the facilitator.

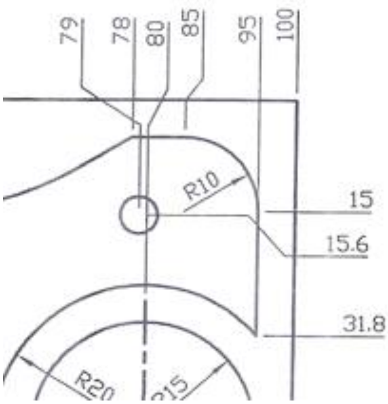


Figure 4-7: Programming a corner radius of R10

Table 4-26: Programming options of the corner radius of R10

Programming Options		Programming Format
1	G1 X85 Y5 G2 X95 Y15 R10	ISO
2	G1 X85 G2 X95 Y15 I85 J15	ISO
3	G1 X85 G25 R10	ISO with controller's special function
4	L X85 RND R10	Conversational

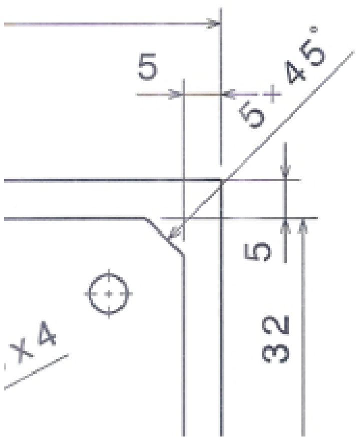


Figure 4-8: Programming a chamfer of 5x45 degrees

Table 4-27: Programming options of the chamfer of 5x45 degrees.

Programming Options		Programming Format
1	G1 X90 Y5 G1 X95 Y10	ISO
2	G1 X55 G24 R5	ISO with controller's special function
3	L X55 CHF R5	Conversational

The content analysis of students' coursework assignments also showed that students were able to apply programming concept of the International Standard Organization (ISO) programming format that they have learned to a new programming problem and need to be in a Conversational programming format. An individual coursework was given to each student that need them to programme with a Conversational programming format and worked with the CNC simulator. The coursework was given in the seventh week of the course, and the students were given two weeks to complete their assignment. The content analysis shows they seemed able to apply programming concept from the International Organization for Standardization (ISO) of CNC programming format to a conversational programming format in new CNC programming problem. The students of semester four (CNC Lathe Programming) scored an average of 8.34 out of 10 in the assignment and 8.2 out of 10 for students of semester three.

4.9. MAIN RESEARCH QUESTION

In what ways does PBL affect the students' competencies (learning, technical & social)?

The main research question of this study explored the ways of the PBL affects the students' learning, technical & social competencies. Triangulation of qualitative data analysis (Section 4.3) indicated that "Teamwork" was a major category and as the central theme (Table 4-5; Figure 4-2) of importance in fostering PBL among students in CNC programming courses. The Triangulation of qualitative data analysis (Section 4.3) also suggested that other elements in making the PBL a meaningful learning experience for the students were the "students' interactions," "self-directed learning," and the "students' learning environment." This finding also suggested that these elements anchored with "teamwork" had contributed to "knowledge acquiring and application" and "skills gained" by the students as evidenced by the collected data of the researcher's and participants' observations, group interviews and content analysis (see Table 4-5, Figure 4-2, and Appendix K-1).

Figure 4-9 shows the overview of the relationship between the main and sub-categories that emerged from the qualitative data analysis which explained the ways PBL could affect the students' learning, technical and social competencies. The researcher divided the competencies into two main categories namely a) Social Competency, and b) Learning and Technical Competencies. From the qualitative data analysis, two sub-categories emerged for the Social Competency (Students' Interactions and Teamwork) and four sub-categories for Learning and Technical Competencies (Students' Learning Environment, Self-directed Learning, Skills Gained and Knowledge Acquiring & Application).

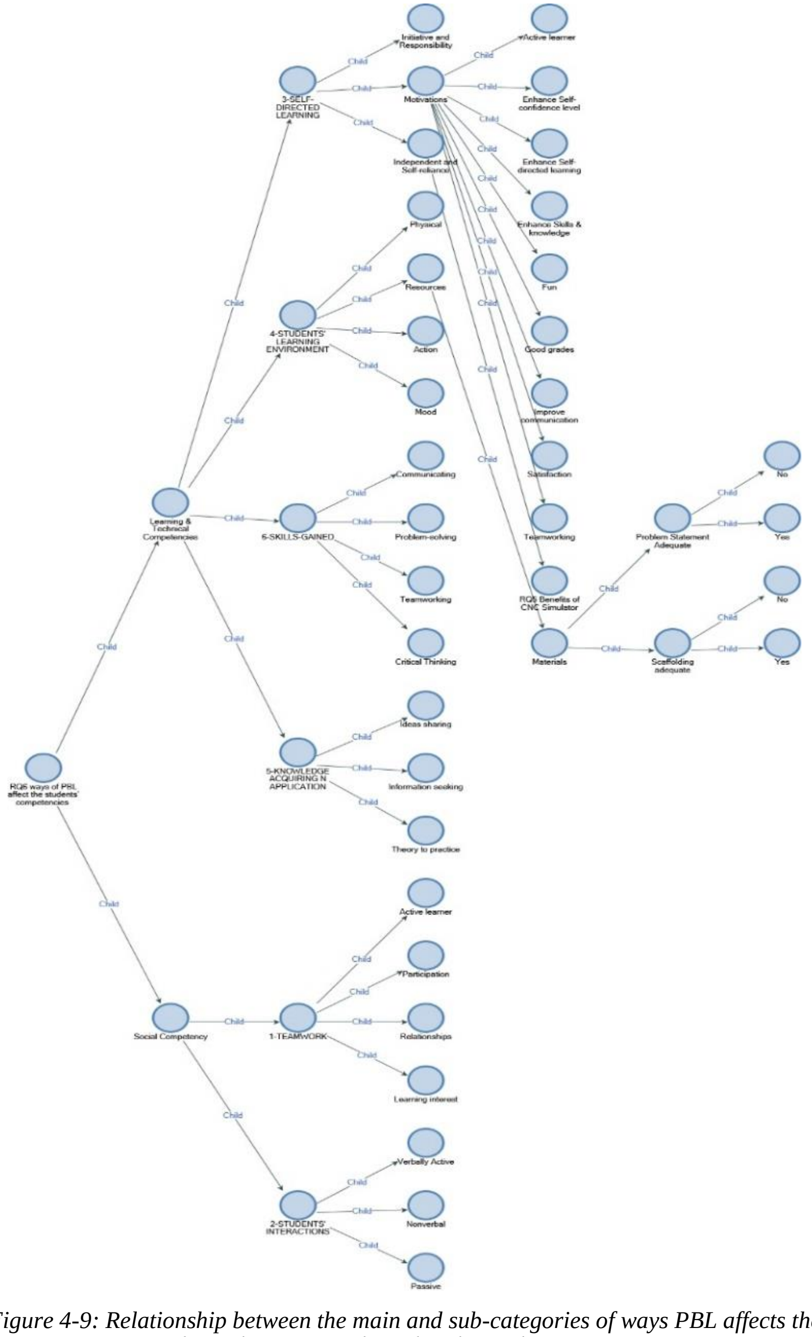


Figure 4-9: Relationship between the main and sub-categories of ways PBL affects the students' learning, technical and social competencies.

4.9.1. THE WAYS PBL AFFECTS THE STUDENTS' SOCIAL COMPETENCY

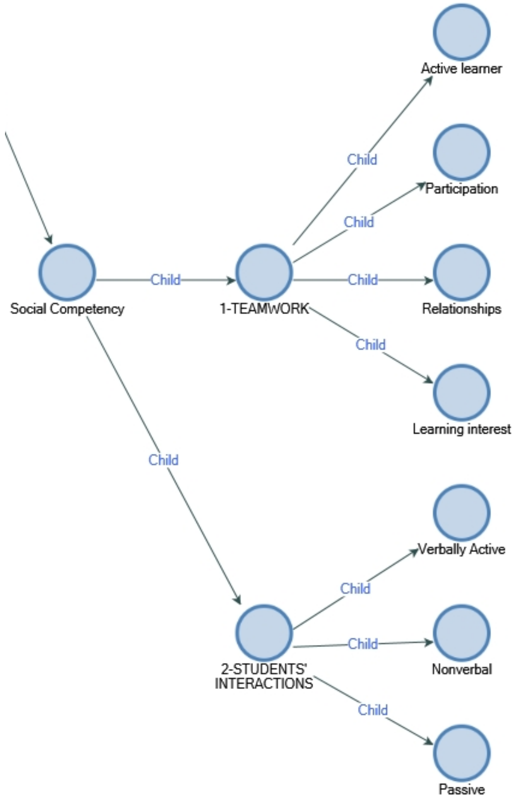


Figure 4-10: Relationship between the main and sub-categories of ways PBL affects the students' social competency.

<u>Students Interactions</u>

The observation data showed that, in every PBL session, the students seemed to develop an informal grouping and exhibited friendly and supportive behaviour among them. Figure 4-10 shows the relationship between the main and sub-categories of the ways PBL affects the students' social competency. Every group of students appeared to be focused in their discussion on their learning issues and tried to grasp each other's opinion by ignoring distractions of noise and physical activities by others. The students continued to give views to and questioned each other, and they gave feedback and explanations to each other. Various sorts of questions were posed by the students in a group; some were raising new and catchy questions such as:

"What is the difference between cutting speed and the circumferential speed?"

"How cutting speed affects the cutting tool during machining?" and

"What can we do to reduce the vibration of tool?"

Some questions were probing and asking for explanations such as:

"Why we have low cutting speed at the small tool or work-piece diameter?" and

"How can the earth surface speed be related to the cutting technology?"

Some questions asked about the CNC programming concepts between Milling and Lathe:

"Why we need to programme the feed in millimetre per minute in CNC Milling programming and not in millimetre per revolution as in CNC Lathe programming?"

"Why we do not need to programme the constant cutting speed as in the CNC Lathe programme?" and

"In what ways contour programming technique of CNC Milling has in common with contour programming technique of CNC Lathe?"

The feedback from the students were also a variety with some of them showed the application of their prior knowledge:

"Actually, the cutting speed and the circumferential speed is the same thing where the cutting always occurs at the circumference of the tool or, at the circumference of a work-piece."

"Using wrong cutting speed will damage the tool earlier than it supposed to be because every tool material performs at different cutting speed."

"Cutting speed is the ability of a certain tool to machine a work-piece."

"The vibration of the tool can be reduced by decreasing the overhang length of the tool or lessen the depth of cut or reducing the number of tool rotation."

"We have low cutting speed at the small tool or work piece diameter is because it relates with the circumference of the tool or work piece where smaller diameter with lower circumference and bigger diameter with a larger circumference."

> "The earth surface speed is the work piece or tool cutting speed and the location of the countries' represents the various work piece or tool diameters."
>
> "We programme the feed in millimetre per minute when the tool is rotating and millimetre per revolution when the work piece is rotating."
>
> "In Milling, the cutting speed is always constant because the tool is rotating with a diameter while in Lathe, the work-piece is rotating and machine with a range of diameters."
>
> "Generally, if the controller is the same for both CNC Milling and Lathe, the contour programming technique is very much the same."

Generally, the variation of questions and answers that resulted from students' group discussions seemed to provide to the fruitfulness of the answers and solutions to the learning issues. The students used their prior knowledge of machining to relate with a new problem. For example, students identified other factors that were causing the vibration during machining were the rigidity of machine itself, the tool used, the shape of the work-piece and material of the work-piece. Furthermore, the students showed to be giving compliment and support to each other's opinions and efforts in solving the problems. Comments for instance, "Point taken" "Good idea", "Yes, you are right", "I have the same opinion", "good search", "I agreed", "Good job" and "Right, right, right." Some of the students exhibited a positive body language or nonverbal expressions such as smiles, handshakes, thumbs-up sign, and attentive listening to each other's opinions were examples of positive manners that existed among the students within the groups during the discussion of learning issues. They seemed to enjoy and have fun with their learning activities and showed humour and deep interest as they worked to solve the problem. This observation by the researcher was further backed by the students' remarks in Table 4-5; Appendix K-1.

It was interesting to observe that some students in the groups were rather passive and not very much verbally interactive. This situation was expected mainly in the first PBL session. Some of the possible reasons for this probably was due to the new approach of learning in which the students still needed some time to adapt, their anxiety, shyness and uncomfortable in speaking, presenting or in expressing themselves in English. For most of the students, English was the second language for them. The observation made by the researcher was further supported by the data of participants' observations which shows mean score of 2.61 (Figure 4-11) on "Communication skills" at the beginning of PBL session (PBL-1). The criteria observed by the participants' observers on "Communication skills" were as the following:

- Demonstrating the ability to speak clearly, proficient with language in group discussion and presentation.

- Demonstrating the ability to explain and present confidently in the group meeting and oral presentation.
- Demonstrating the ability to deliver the content very well and understood by the audience.
- Demonstrating the ability to place the appropriate words to the thoughts that want to explain.
- Demonstrating the ability to listen and answer the questions very well.

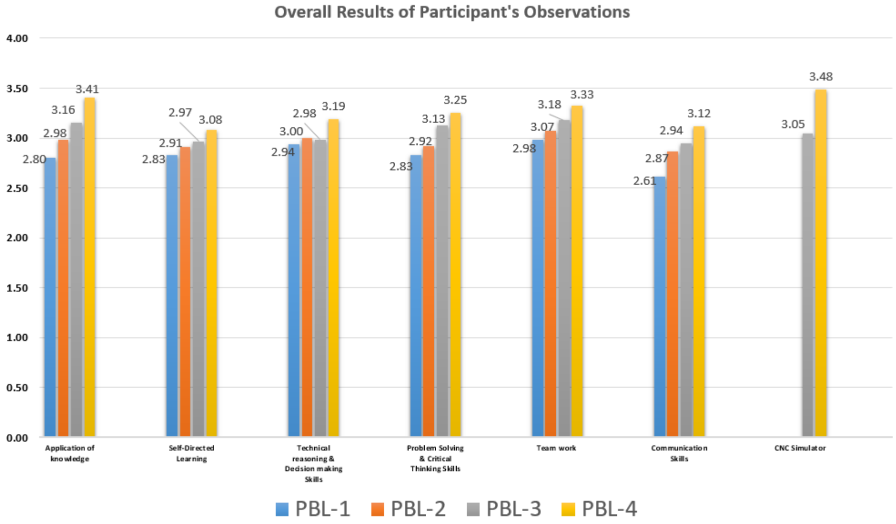


Figure 4-11: The results of the participants' observers on PBL sessions one, two, three and four of students semester three and four.

It is also possible that at the beginning these students were not used to or not comfortable when participating in the "heavy" group discussion. However, after the first PBL session, the interaction among passive students increased, and they seemed to be more relaxed and got used to the PBL learning approach. The reflection by the students and comments by the facilitator at the end of the PBL sessions might contribute to this positive change. Some of the questions posed by the facilitator to the students during the reflection in order for them to be aware and improve in the next PBL sessions included the following:

> "What you have experienced during the discussion of the learning objective, know, don't know, what need to find out?"

> "What you have experienced during the self-study and seeking for information?"
> "What you have experienced during the group discussion and presentation?"
> "What you have experienced during the group presentation?"
> "What about the group members?" "Teamwork?" "Cooperation?" and "Individuals' contribution?"

The verbal interaction among students in the groups during the first PBL session seemed to be increased and improved in the following sessions two, three and four. This can be observed through the result of "Communication skills" in Figure 4-11. The "Communication skills" of students scored $M = 2.61$ for PBL-1, $M = 2.87$ for PBL-2, $M = 2.94$ for PBL-3 and $M = 3.12$ for PBL-4., and confirms that there was an increase of "Communication skills" by students in PBL sessions one to four and it is reflected by an increase of about 0.51 from PBL-1 to PBL-4. It was interesting to observe that at the beginning of PBL session the students with good English proficiency dominated the group discussions, however, in the third and fourth PBL sessions the students who were at the beginning passive and less English proficiency started to take active participation in the group discussions and some of them even lead the discussion.

Teamwork

The observation data also showed that students were very much involved in team working, and they seemed to have an active discussion, good interaction, and good argument. This observation was also affirmed by some of the students' comments in the group interviews as presented below;

> "Yes, Problem-based learning gives us room to get to know our friends, practice to communicate better, speak out, share and debate the opinion";
>
> "PBL makes us an active learner"; and "Fun, we like to work with teams that make us active in learning not passive."

During the group discussions, the students exhibited good participation developed good relationships and teamwork among them. They seemed to contribute and exchange ideas in the group discussions. This observation was supported by some of the statements:

> "Yes, because PBL encourages teamwork with distributing work, share ideas and enduring relationships" and

> "Yes, PBL approach stimulated teamwork, every member of the group was given a task and needed to present in the group meeting. It was discussed in the group, thus, enhance the team spirit of the group."

The students seemed to show interest in learning and enjoy with their learning activities. This observation was backed by some of the students' feedback:

> "Yes, Problem-based learning's activities generate our interest toward learning especially during the discussion in a group" and

> "We have fun in learning with Problem-based learning."

The group interviews also revealed some of the students' negative comments on teamwork regarding the question "What you feel the challenges/obstacles for you as a student to adapt PBL approach in your learning?"

Some of the negative comments are given below:

> "Team members that did not participate and cooperate in the discussion."
> "Lack of teamwork."
> "The challenge when group members did not cooperate."
> "Teammate busy with other PBL assignment."
> "Some of the group members did not cooperate, no contribution and materials found by some members were not appropriate and difficult to understand."
> "Can't find the information."
> "Some members of the group were not doing their job."
> (See Table 4-5; Appendix K-1 for more comments).

The data from the participants' observers (see Section 3.6.2.1 of Chapter Three) in Figure 4-11 indicated that the "Teamwork" of students scored $M = 2.98$ for PBL-1, $M = 3.07$ for PBL-2, $M = 3.18$ for PBL-3 and $M = 3.33$ for PBL-4. The results showed that there was an increase of "Teamwork" by students in PBL sessions one to four. The increase was about 0.35 from PBL-1 to PBL-4.

The criteria observed by the participants' observers on "Teamwork" were as the following:

- Demonstrating the ability to conduct an effective group meeting/discussion.
- Demonstrating a good and active interaction among the group members.

- Demonstrating the ability to contribute and exchange of ideas in the group discussion.
- Demonstrating the ability to work towards the attainment of the team's learning objectives.

The quantitative data of students' self-assessment (Figure 4-12) of both semester three and four students scored the overall mean of M = 4.15 and M = 4.24 for "Teamwork". This result seems to support the qualitative data and the participants' observers on "Teamwork." See Appendices N-1 and N-2 for the detail results of the students' self-assessment.

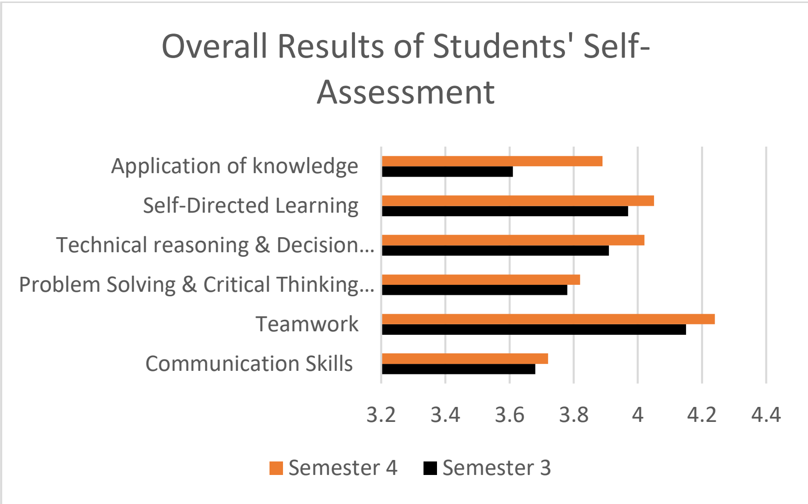


Figure 4-12: The overall results of students' self-assessment of students' semester three and four.

Table 4-28, Table 4-29, Table 4-30, Table 4-31, Table 4-32 and Table 4-33: Percentages and Frequencies of self-assessment by semester three students.

See Appendix N-1. Percentages and Frequencies of Students Semester Three's Responses of Likert-Scale Self-Assessment.

The self-assessment on “Teamwork” (Tables 4-32 in Appendix N-1) from the students of semester three (N = 47) overall showed ‘agree’ with 53.6% to ‘strongly agree’ with 33.2% of items listed (22 to 31). This result indicates the students’ insight on “Teamwork” during the PBL sessions in CNC programming courses. However, 1.9% to 1.5% of students were ‘disagree’ and ‘strongly disagree’ with 9.8% of students were ‘undecided’. Nine items scored mean (M) above 4.00, except for item number 31 “I supported group decisions although I was not totally in agreement” scored M = 3.51.

Table 4-34, Table 4-35, Table 4-36, Table 4-37, Table 4-38 and Table 4-39: Percentages and Frequencies of self-assessment by semester four students.

See Appendix N-2. Percentages and Frequencies of Students Semester Four’s Responses of Likert-Scale Self-Assessment.

The self-assessment on “Teamwork” (Table 4-38 in Appendix N-2) from the students of semester four (N = 85) overall showed ‘agree’ with 47.5% to ‘strongly agree’ with 39.3% of items listed (22 to 31). Nevertheless, 1.2% of students were ‘disagree’ and 0.7% ‘strongly disagree’ with 11.3% of students were ‘undecided’. Seven of ten items scored mean (M) above 4.00, except for items number 22, 29, and 31 scored slightly M lower 4.00 and overall M = 4.24. The data above overall reveal that majority of students (86.8% from semester three and also 86.8% from semester four) have a good “Teamwork” on PBL approach and only less than 3.4% of students have negative “Teamwork” feedback on PBL that has been implemented in two CNC programming courses (lathe and milling).

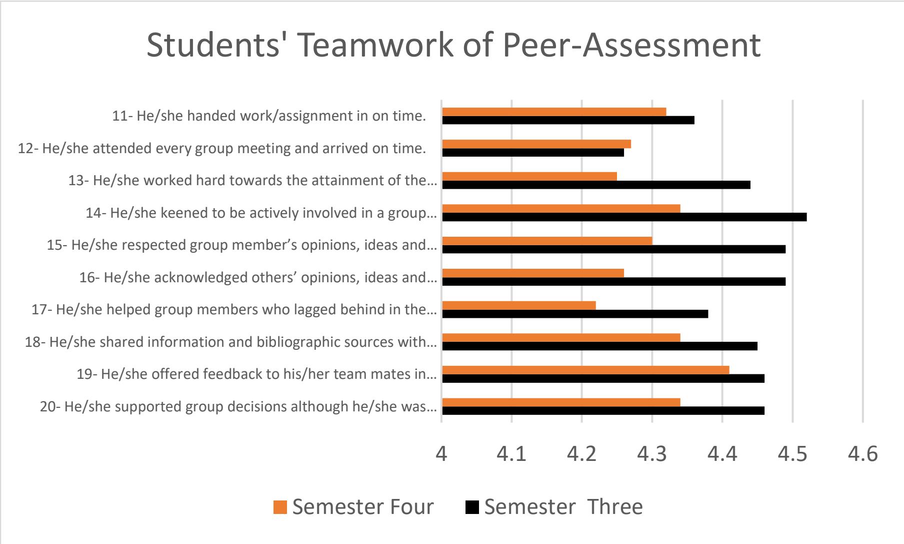


Figure 4-13: The results of students' peer-assessment of students' semester three and four on teamwork.

The quantitative data of students' peer-assessment (Figure 4-13) of both semester three and four students scored the overall mean of M = 4.43 and M = 4.38 for the "Teamwork". This result is consistent with the qualitative data of group interviews and the participants' observers on the "Teamwork" as well as the self-assessment. See Appendices O-1 and O-2 for the detail results of the students' Peer-assessment. The results of peer-assessment on "Teamwork" in Figure 4-13 by the students of semester three (N = 47) and four (N=85) overall indicated that students were satisfied with their teammates during the PBL sessions in CNC programming courses. All items from number 11 to 20 scored mean (M) above 4.00. The results in Figure 4-13 suggest that students of semester four seem to be more positive than students of semester three in "Teamwork" especially for items 13, 14, 15, 16, 17, 18 and 19.

The observation that in the self-assessment the Semester 4 students rated themselves better than their peers (peer-assessment) on teamwork and the Semester 3 students rated their peers higher, this situation might be explained by several factors such as; 1- The students of semester 4 were basically more matured than students of semester 3, especially with respect to learning, experience and knowledge as well as learning to work with the PBL approach. 2- As their own knowledge increases (students of semester 4) the appreciation of what others know to becomes more critical. 3- The Semester 4 students understand better than the Semester 3 students and semester 3 students have less understanding and consequently they may have overestimated the performance of their peers.

The quantitative data of students' peer-assessment (Figure 4-14) of both semester three and four students scored the overall mean of M = 4.23 and M = 4.31 for "Attitude". This result appears to support and complement the qualitative data of group interviews and the participants' observers on the "Teamwork" as well as the self-assessment.

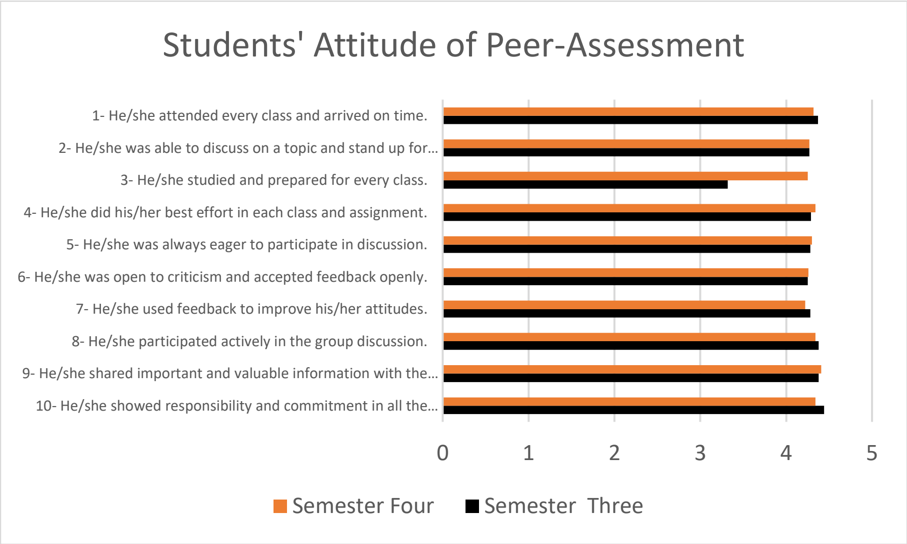


Figure 4-14: The results of students' peer-assessment of students' semester three and four attitudes.

See Appendices O-1 and O-2 for the detail results of the students' Peer-assessment. The results of peer-assessment on "Attitude" in Figure 4-14 by the students of semester three (N = 47) and four (N=85) overall revealed that students were happy with the "Attitude" of their teammates during the PBL sessions in CNC programming courses. All items from number 1 to 10 scored mean (M) above 4.00 except for item 3 of semester three. The results in Figure 4-14 indicate that students of semester three and four were equally positive on their teammates "Attitude" during the PBL sessions in CNC programming courses.

4.9.2. THE WAYS PBL AFFECTS THE STUDENTS' LEARNING AND TECHNICAL COMPETENCIES

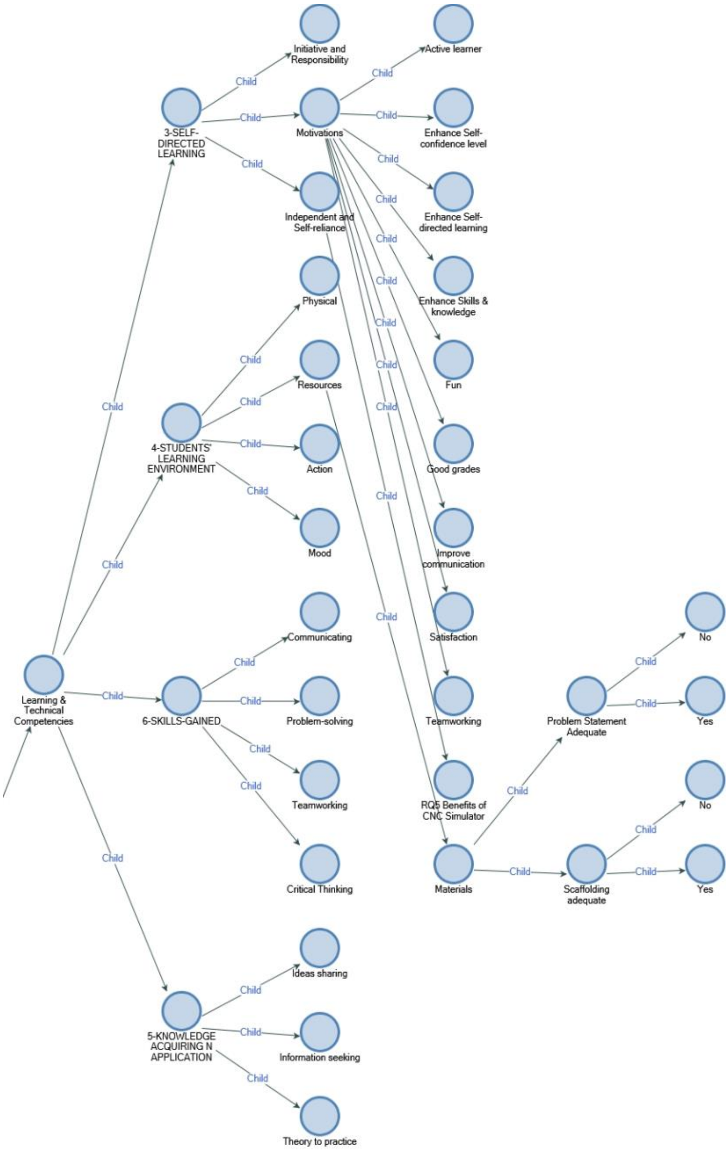


Figure 4-15: Relationship between the main and sub-categories of ways PBL affects the students' learning and technical competencies.

Students' Learning Environment

The observation data showed that the Students' Learning Environment appeared to be pleasant with satisfactory classroom space and layout, flipchart and whiteboard for each group, reasonable computer lab space for CNC Milling and Lathe, adequate lighting and air-conditioned. Each student was given a workstation with CNC simulator installed, ISO programming manual (pdf file), conversational programming manual (pdf file) and the internet connection for external resources search. Figure 4-15 displays the relationship between the main and sub-categories of ways PBL affects the students' learning and technical competencies.

The students displayed a warm behaviour, supportive, pleasant, comfortable, unstressed situation, informal, enthusiasm, curious, humour, and casual group setting. They seemed to focus, responsive, listen with judgement, asking significant questions, probing questions, discussing, explaining, share facts, taking notes, digesting each other's thoughts and ideas.

The materials such as the "Problem statements" and "Scaffoldings" were clear, understandable, sufficient and helpful. This observation was also affirmed by some of the students' comments:

> "Yes, the problem statement was clear, and we were able to identify our objectives"
>
> "Understood and cleared with problems given"
>
> "Understandable, but it takes time to resolve"
>
> "Sufficient and helpful in terms of information related to the problem"
>
> "Yes, because the scaffolding is an arrangement that can help students in problem-solving" and
>
> "Sufficient and help in finding additional information."

There was a comment from a student in the group interview who felt that the "Problem statement" is not adequate:

> "With only fabricated-problem, it is not sufficient because students have to deal with real problems."
>
> There were also comments from two students in the group interview who felt that the "Scaffoldings" is not sufficient:
>
> "No, not sufficient" and
>
> "No, because we still have to find out more information on the internet, etc."

Self-Directed Learning

The observation data also revealed that the students were more self-directed in learning. They seemed to take initiative and responsibility for their learning when the facilitator provides a problem with scaffolding. They were able to set their learning objectives, activities and seen highly motivated working towards their learning objectives.

This observation was supported by the results of Sub Research Question one (Section 4.4) and some of the students' comments in the group interviews as described in Section 4.4 such as:

> "Working in a team is fun because it motivated learning"
>
> "Teamwork trigger active in learning and had motivated us much" and
>
> "PBL educates individual to be more self-directed in learning, tolerant in a team to solve the problem."

The observation data further discovered that the students were more independent and self-reliant especially when they worked with the CNC simulator. The CNC simulator seemed to help the students in their programming activities. They were observed to be more independent and fewer questions were asked to the facilitator. The students appeared to work and solve the problems by themselves. With the support of CNC simulator, the students managed to complete the exercises and programming test two with the appropriate use of tools and cutting strategy.

This observation was supported by the quantitative results of Sub Research Question five in Section 4.8 which showed students scored higher marks in programming test two by using CNC simulator than programming test one that was only writing on a piece of paper. This observation was also supported by some of the students' comments in the group interviews as described in Section 4.8 such as:

> "Yes, PBL activities encourage students to be self-reliant and a healthy working group that makes the learning easier to work on the solution"
>
> "Yes, we can work on the programme ourselves without the involvement of the TTO. Before performing the actual machining, we can observe the part simulation and can detect the mistake in the programme and can do the correction to the programme" and
>
> "Yes, with simulator we can do analysis on our own like programme strategies and optimise the cutting strategy and technology."

The data from the participants' observers (see Section 4.9.1 of Chapter Four) in Figure 4-11 shows that the "CNC simulator" of students' scores were $M = 3.05$ for PBL-3 and $M = 3.48$ for PBL-4. The "CNC simulator" was not applied for PBL-1 and PBL-2. The results showed that there was an increase of "CNC simulator" by students in PBL sessions three to four. The increase was about 0.43 from PBL-3 to

PBL-4. The CNC simulator seemed to increase the students' centeredness in PBL approach. The criteria observed by the participants' observers on "CNC simulator" were as the following:

- Demonstrating the ability to help students in decision-making & problem-solving.
- Demonstrating the ability to be more self-directed with the help of CNC simulator.

The data from the participants' observers in Figure 4-11 also shows that the "Self-Directed Learning" of students' scores were $M = 2.83$ for PBL-1, $M = 2.91$ for PBL-2, $M = 2.97$ for PBL-3 and $M = 3.08$ for PBL-4. The results suggested that there was an increase of "Self-Directed Learning" by students in PBL sessions one to four. The increase was about 0.25 from PBL-1 to PBL-4. The criteria observed by the participants' observers on "Self-Directed Learning" were as the following:

- Demonstrating the ability to set and achieve the learning objectives.
- Demonstrating the ability to search relevant information from various learning resources independently.

The quantitative data of students' self-assessment (Figure 4-12) of both semester three and four students scored the overall mean of M = 3.97 and M = 4.05 for "Self-Directed Learning". This result seems to support the qualitative data and the participants' observers on "Self-Directed Learning." See Appendices N-1 and N-2 for the detail results of the students' self-assessment.

Skills Gained

The observation data discovered that, through the PBL approach, the students have more chance in speaking, expressing their ideas to the members of the group as well as team working in which they would enhance their skills in communicating and team working. This observation was backed by some of the students' responses to a question during the group interviews "Do you feel PBL approach help you in acquiring generic skills (communication, problem-solving, teamwork)? If yes, how? If not, why?" The comments were presented in the sub research question one of Section 4.4:

> "Yes, because PBL is a platform for us to practice our speaking, in group interaction, communication, team working, public speaking and presentation"

> "Yes, because we have to communicate in the group and present our solution to the problem. Thus, it helps us become more confident and increases our generic skills" and
>
> "Yes, because we can practice and improve our communication and presentation skills during PBL sessions."

The interview data showed that students seemed to agree that PBL approach could help them in acquiring generic skills (See Table 4-5; Appendix K-1 for comments).

However, in the responses to another question in the group interviews "Do you feel PBL approach help you in acquiring technical skills? If yes, how? If not, why?" most of the students seemed to be sceptical about acquiring technical skills through PBL approach. This was evident by some of the students' comments:

> "Not helpful, as technical skills were practical-based and skill-based to operate a machine or even to work with hand tools like files, chisels, hacksaws, hand reamers, hand taps, etc. because proper technique and proper use of these tools are important for effectiveness and safety reason."
>
> "Yes and No, because Problem-based learning makes the team members be independent and giving ideas in solving the machining problem but when working with machines and tools, skilled trainer needed to demonstrate the proper method and for safety reasons."
>
> "Yes, possible for the theoretical matter, but we need to practice hands-on to acquired technical skills."
>
> "No, because technical skills need to be demonstrated by a skilled person, hands-on practice."
>
> "No, technical skills can only be acquired by doing a lot of hands-on."
>
> "No, technical skills good to be learned by demonstration from an expert and we need to practice to master the skills."

The observation data also found that the students seemed to be more hardworking, busy and very focus in discussing the problem. The content analysis of students' programming exercises at the CNC simulator and during their presentations showed a high level of problem-solving as well as critical thinking skills. They seemed to produce several solutions as well as their rationale for each decision to the problem. This observation was backed by the qualitative data that presented in the sub research question five (Section 4.8).

The data from the participants' observers in Figure 4-11 also shows that the "Problem-solving and critical thinking skills" of students' scores were *M = 2.83* for PBL-1, *M = 2.92* for PBL-2, *M = 3.13* for PBL-3 and *M = 3.25* for PBL-4. The results showed that there was an increase of "Problem-solving and critical thinking skills" by students in PBL sessions one to four. The increase was about 0.42 from PBL-1 to PBL-4. The criteria observed by the participants' observers on "Problem-solving and critical thinking skills" were as the following:

- Demonstrating the ability to solve problems in an appropriate manner.
- Demonstrating the ability to think critically about the issues in the problem.

The data from the participants' observers in Figure 4-11 furthermore shows that the "Technical reasoning and Decision making skills" of students' scores were *M = 2.94* for PBL-1, *M = 3.00* for PBL-2, *M = 2.98* for PBL-3 and *M = 3.19* for PBL-4. The results showed that there was an increase of "Technical reasoning and Decision making skills" by students in PBL sessions one to four. The increase was about 0.25 from PBL-1 to PBL-4. The criteria observed by the participants' observers on "Technical reasoning and Decision making skills" were as the following:

- Demonstrating the ability to make the appropriate decision to the problem.
- Demonstrating the ability to give technical reasoning to the decision made.

The data from the participants' observers in Figure 4.11 also displays that the "Communication skills" of students' scores were *M = 2.61* for PBL-1, *M = 2.87* for PBL-2, *M = 2.94* for PBL-3 and *M = 3.12* for PBL-4. The results exhibited that there was an increase of "Communication skills" by students in PBL sessions one to four. The increase was about 0.51 from PBL-1 to PBL-4. The criteria observed by the participants' observers on "Communication skills" were as the following:

- Demonstrating the ability to speak clearly, proficient with language in group discussion and presentation.
- Demonstrating the ability to explain and present confidently in the group meeting and oral presentation.
- Demonstrating the ability to deliver the content very well and understood by audience.
- Demonstrating the ability to place the appropriate words to the thoughts that want to explain.
- Demonstrating the ability to listen and answer to the questions very well.

The quantitative data of students' self-assessment (Figure 4.12) of both semester three and four students scored the overall mean of *M* = 3.78 and *M* = 3.82 for

"Problem -solving and critical thinking skills". While for "Technical reasoning and Decision making skills" with M = 3.91 and M = 4.02 and lastly the "Communication skills" with M = 3.68 and M = 3.72 of students semester three and four. These results seem to support the qualitative data and the participants' observers and should reflect the insight of the students in the implementation of PBL at the CNC programming courses at GMI. See Appendices N-1 and N-2 for the detail results of the students' self-assessment.

Knowledge Acquiring and Application

The observation data discovered that students sought information to the problem in the group as well as individually. They seemed to seek information through several means such as books, programming manual which was available in the workstation and the internet. They seemed to discuss and exchange information that they found with the group members. There were also some students in the group who engaged in the defence of their findings and ideas and some of them arguing about the information or the findings and some of the other students and asked them just to "agree to disagree." This situation was expected to be seen during the discussion for the selection of a good machining strategy and the tools that should be used for a particular area of machining of the component.

In responses to a question in the group interviews "Do you feel PBL approach help you in acquiring new knowledge? If yes, how? If not, why?" the students seemed to agree that PBL approaches help them in the acquisition of new knowledge by several means; such as during seeking information through books, the internet, group discussions, exchanging/sharing ideas and knowledge, exchanging information and during a presentation by other groups. Some of the students' comments were presented in Section 4.4 Sub Research Question One.

The observation data also revealed that students seemed to apply what they have learned or experienced during the PBL sessions. This situation was observed by their questions posed and feedback during the group discussion. Some of the students used their prior knowledge that they have learned from semester one and two in machining or cutting technology by giving ideas and feedback during the group discussion. The examples of students' posed questions and feedback were presented in Section 4.9.1.

The content analysis of students' programming test one that was done in writing and programming test two at the CNC simulator exhibited that students were able to apply the programming concept of International Standard Organization (ISO) programming format. The students were able to apply the concept of the ISO programming format into practice when they worked with the CNC simulator as shown by the scores of programming test one and two (Tables 4.20 and 4.21) as presented in Section 4.8, Sub Research Question Five.

An individual coursework was given to each student which required them to programme with a Conversational programming format and worked with the CNC simulator. The coursework was given in the seventh week of the course, and the students were given two weeks to complete their assignment. The content analysis of students' coursework assignments also showed that students were able to apply the programming concept of the International Standard Organization (ISO) programming format that they have learned to a new programming problem and needed to be changed in a Conversational programming format. The students of semester four (CNC Lathe Programming) scored an average of 8.34 out of 10 in the assignment and 8.09 out of 10 for students of semester three.

Furthermore, the data from the participants' observers in Figure 4-11 also exhibited that the "Application of Knowledge" of students' scores was $M = 2.80$ for PBL-1, $M = 2.98$ for PBL-2, $M = 3.16$ for PBL-3 and $M = 3.41$ for PBL-4. The results indicated that there was an increase of "Application of Knowledge" by students in PBL sessions one to four. The increase was about 0.61 points from PBL-1 to PBL-4. The increase of "Application of Knowledge" was expected in PBL-4. This increase was perhaps because in PBL-4 the students worked a lot with CNC simulator and applied the knowledge into practice. The criteria observed by the participants' observers on "Application of Knowledge" were as the following:

- Demonstrating the application of prior knowledge.
- Demonstrating the ability to adapt and apply relevant concepts.

CHAPTER 5. DISCUSSION AND CONCLUSION

Chapter 5 is subdivided into five Sections of Discussion, Methodological Reflections, Conclusion, Implications and Recommendations. Section 5.1 presents a detailed discussion of the findings referring to the main research question and sub research questions with the hypotheses.

5.1. DISCUSSION

The first section of the discussion refers to the research findings of this study and focus on answering the main research question: In what ways does PBL affect the students' competencies (learning, technical & social)?" The presentation first discusses the findings from the qualitative data of students' group interviews, observations and content analysis (see Table 4-5, Figure 4-2, and Appendix K-1) followed by the sub research question four: "SRQ-4: What is the relationship between students' prior academic performance and their learning performance in the PBL approach?" and explorative sub research question five: "SRQ-5: To what extent does the CNC simulator benefits students in the PBL approach?" The second section; discusses the research questions one, two and three which investigate the students' awareness, motivations and perception as well as the challenges/obstacles in the Problem-Based Learning implementation at the CNC programming courses. Sub research question one and two are discussed simultaneously as the concepts awareness, motivations and perception were very much interrelated and the discussion is then followed by the sub research question three which explore on "how do the students' perceive challenges/obstacles in the Problem-Based Learning implementation?"

Main Research Question:

In what ways does PBL affect the students' competencies (learning, technical & social)?

The main research question explored the ways of PBL affects the students' learning, technical & social competencies. The research findings reported in section 4.9 of Chapter 4 revealed that PBL affects the students' competencies in many ways.

As described in Section 4.9, the triangulation of qualitative data analysis suggested that "Teamwork" appears to be the central theme of importance in promoting PBL among students in CNC programming courses. And also indicated that other elements in making the PBL a meaningful learning experience for the students were: the "students' interactions," "self-directed learning," "students' learning environment," "knowledge acquiring and application" and "skills gained". This latter statement is supported through data of researcher's and participants' observations, group interviews and content analysis (see Table 4-5, Figure 4-2, and Appendix K-1).

The research findings of the qualitative data of this study showed that students' learning were encouraged and enhanced through their team working and interactions and supported by the conducive learning environment. This situation can be seen as students participated actively in the group discussion, debated issues, raised and probed questions, and responded each other's questions. According to Schmidt et al. (1992), problem-based learning does seem to provide a friendlier and more inviting educational climate that facilitates the emergence of positive attitudes toward learning.

These findings are in line with the work by Graaff and Kolmos (2003) and Kolmos et al. (2004) who have suggested three common approaches characterizing PBL; which are learning, content and social approaches.

Learning approach: The learning which was organized around problems had developed the students' motivation and comprehension as reported in Section 4.4 (see also Table 4-5, Figure 4-2, and Appendix K-1). The problem serves as the foundation for the learning because it determines the direction of the learning process and places weight on the formulation of a question rather than an answer.

Content approach: Theory-practice means that the students gain abilities to analyse problems by using theories. They learn the skill of analysis as they are required to analyse problems, analyse solutions, develop solutions, and analyse the impact of given solutions.

As reported in Section 4.8 of Chapter 4, the students were able to apply their theoretical knowledge into practice when they have used the CNC simulator to work on the programming test two. The results of the programming tests (Table 4-21 and 4.22) shows they scored higher in programming test two than programming test one which they had done on paper. The content analysis of students' coursework assignments revealed that students were also able to apply the programming concept of the International Standard Organization (ISO) programming format which they have learned how to convert the new programming problem that needed to be in a Conversational programming format (see page 142).

Social approach: Team-based learning is where the majority of the learning processes take place through conversation and communication in groups and teams.

The students learn from each other, learn to share knowledge and organize the process of collaborative learning that implicitly developed the generic skills.

As reported in Section 4.3 as well as 4.9 of Chapter 4, the qualitative data analysis suggested that "Teamwork" was a major category and as the central theme (Table 4-5; Figure 4-2) of importance in fostering PBL among students in CNC programming courses. Teamwork was considered crucial to stimulate learning among students in PBL. Through teamwork, students were able to work on the problems with less "burden" because they worked cooperatively with many interactions and discussions.

These research findings also support Sibley et al. (2014) who stated that team-based learning is a special form of small-group learning that effective, bring more fun, energy, and deep learning to the students. Advocates of team-based learning likewise suggest that student learning is enhanced and deepened through continuous collaborative interactions with team members, often while engaged in solving the study problem (Michaelsen, 2002).

These research findings seem to support the theories of constructivism which state that learning environment as a place where students work together and support each other in their problem-solving activities and their effort to achieve the learning goals (Wilson, 1995). In the constructivist learning environment, students are educated to be self-directed and play an active role in learning activities (Bruning et al., 2004).

These findings also appear to support Vygotsky (1978) who suggested social interaction leads to knowledge construction in which communication serves as the main instrument that promotes thinking, develops reasoning and supports activities like reading and writing. According to Vygotsky (1978) whose principal proponent in social constructivism, language, and interactions with others such as family, peers, and teachers play a primary role in the construction of meaning from experience.

These findings also seem to support Orlich et al. (2004) who stated that constructivism provides student-centred activities which allow students to participate in their learning process by engaging them in collaborative activities with their team members and become more self-directed and thus, encourage the social interactions, communication among students, and teamwork in learning. Furthermore, the findings seem to support the Thinking Curriculum Model which is based on the cognitive theories' principles by Resnick and Klopfer (1989) which stresses that social interaction as an important element in enhancing the thinking process. They believe that the social setting provides occasions for modelling effective thinking strategies, and students can scaffold complicated performances for each other. Each one will do a part of the task and by exchanging knowledge and information and through team work, the students can achieve solutions for problems that could not be done by a student alone. However, most importantly, the social setting may let students know that all the elements of critical thinking, for instance probing question, interpretation, attempting several possibilities, and asking reasonable justification are socially valued (Resnick and Klopfer, 1989).

The observational data indicated that some students were passive and not verbally interactive during the first PBL session. This may perhaps have been due to several reasons. For instance, some students might be naturally a passive learner whose learning style is more individualistic; some students might not have had enough prior knowledge and experiences to speak about the issue discussed; some might not have been very comfortable or shy in expressing their ideas within the group perhaps because of their low English proficiency.

The fact that most of these students became more active and interactive in learning after the first PBL session can be credited to the reflection done at the end of the first PBL session. The facilitators had played a major role in commenting the each group' performance during the first PBL session such as how they supposed to do and not to do, what were their weakness and strength as well as the positive and negative elements of each group had. The facilitators had also stressed and encouraged the students to be more active and interactive in learning and advised them not to put language (English) as a barrier for them to communicate and express their ideas during the PBL sessions. The facilitators had succeeded in convincing the students that nothing to lose and to be ashamed of because they are all friends and course mates who also have the strength and weakness. All of these elements might have contributed to the students' sense of relieving in the following PBL sessions, and they seemed to have active participation in the discussion, teamwork and be more serious in their learning. These findings support Barrows and Tamblyn (1980) in their statement that PBL usually meets the needs of a heterogeneous group of students and will eventually take full responsibility for their own learning. These findings also support Bruner (1986) and Vygotsky (1978) in their argument that Constructivism drives students to be active learners, think critically, reflectively, responsible for their own learning and construct knowledge on their own besides determining their own learning outcomes.

Sub Research Question Four:

SRQ-4: What is the relationship between students' prior academic performance and their learning performance in the PBL approach?

In this investigation, the Researcher hypothesized that:

H1: Students of semester three and four with above average CGPA scores should have higher scores in both the pre-test and the post-test; than those with below average CGPA scores.

The fact that the group of students in both semesters three and four with high CGPA scored greater than the low CGPA in both the pre-test and post-test (Table 4-17 and Table 4-18) indicates that the students' CGPA seemed to have some influence on the performance of students learning in the PBL approach. The fact that the mean differences for pre-test between high and low CGPA students (Table 4-17 and Table 4-18) were not significant in both semesters three (MD = -0.81) and four (MD = -0.80), indicated that the prior knowledge of students of high and low CGPA was about equal before the CNC programming courses started. While for post-test, the mean differences between high and low CGPA students were associated with a statistically significant for both semester three (MD = -27.96), $p = 0.00$ and semester four (MD = -16.26), $p = 0.00$. This situation indicated that the learning through the PBL approach was more appreciated by students with a high CGPA as compared to students with low CGPA. This situation might be due to the fact that the students with high CGPA had more characteristics that are compatible with the PBL approach, such as 'more motivated', 'self-reliance' and 'student-centred learning skills'. While students with low CGPA perhaps had less of these features and were inclined to prefer the traditional teaching approach. Perhaps the results of 47% (N = 40) of semester four students and 31.9% (N = 15) of semester three students suggests that satisfaction with the traditional learning approach (see research question 3) is connected with a low CGPA. Adnan et al. (2011) revealed that differences of CGPA resulted in various effects on students learning in PBL. Hwang and Jang (2005) reported that the positive effect of the PBL approach on good grades students was linked with the high motivation of these students. Hwang and Jang (2005) also observed that students with good grades felt encouraged by the integrative learning and interactions with group members as well as with the tutor which may have contributed to their stronger motivation. According to Dahlgren & Dahlgren (2002), the nature of students' motivation in PBL is influenced by their academic or professional discipline of study. According to Krutetskii (1976), the memory of lower-achieving students is different from high achievers, where high-achieving learners remember the general characteristics in problem-solving while lower-achievers only remember the problems' specific data. This is connected to the fact that several students had difficulty in solving the problem during the PBL sessions. It can be concluded that the PBL approach is more successful for students with a good CGPA than for students with a low CGPA.

H2: Students of semester four should have higher scores in the pre-test than students of semester three.

The fact that the students of semester four scored (Table 4-19) higher mean (M = 17.55) than semester three students (M = 10.09) and the difference was statistically significant (*t*(79.12) = -8.38, *p* = .000); the higher score perhaps was due to the students of semester four who had answered the pre-test based on their prior knowledge of CNC programming. This is because students of semester four had attended the CNC milling programming during their third semester. Theory and the basic concept of CNC programming of milling and lathe programming are more or less the same and enable the semester four students to use that knowledge in the pre-test.

H3: There is no difference in post-test scores between students of semester three who attending the CNC programming milling and students of semester four who attending the CNC lathe programming.

The result that there was no statistically significant difference in post-test scores (see Table 4-20) between students of semester three who had participated in the CNC programming milling and students of semester four who participated in the CNC lathe programming; this may have been due to the fact that the students had equal opportunity in learning through the PBL setting or it might also happen by chance.

Sub Research Question Five:

SRQ-5: To what extent does the CNC simulator benefit students in the PBL approach?

In this investigation, the Researcher hypothesized that:

H4: Students of semester three and four with above average CGPA scores should have higher scores in both the programming test one and the programming test two than those with below average CGPA scores.

The results reported in Section 4.8 (Table 4-21 and Table 4-22) show that the students in both semesters three and four with the higher CGPA; scored higher than the low CGPA in both the programming test one and two. However, the results were only significant for semester three students and not significant for semester four students. Although there was no concrete evidence to support hypothesis six, however, the results leaned towards the expected direction of the hypothesis H6 of this study. The results somehow indicated that the students' CGPA influenced the performance of students learning in the PBL approach although the data were not statistically significant for students of semester four. Perhaps, these results proved once again that the PBL approach is more applicable and successful for students with good CGPA than students with low CGPA. These results also indicate that the students with good CGPA had benefited from the CNC simulator more than students with low CGPA.

H5: Students of semester three and four should have higher scores in the programming test two than programming test one.

The paired-samples *t*-test results in Table 4-23 showed that there were highly statistically significant difference between the programming test one and programming test two scores by students of both semesters three and four. The fact that students in semester three and four have higher scores in programming test two than programming test one, perhaps this may have been due to several factors, for example:

1) The programming test one that was given earlier to the students was a CNC programming test students had to write on a piece of paper without the aid of CNC simulator; thus, they have no chance to check and verify their programming whether it was correctly done or not.

2) The CNC programming two (actually the same question as programming test one), was a test of CNC programming that students can use in the CNC simulator to check and verify their programming and make the appropriate remedies to the program until the required geometrical paths were achieved without error; The CNC simulator has enabled students to work and solve problems on their own therefore encourage them to be more self-directed in learning.

These results indicated that the students in both groups have achieved the level of learning and technical competencies as required in the learning outcomes of the CNC programming courses (CNC milling programming and CNC lathe programming). The results also revealed that the CNC simulator has benefited the students in assisting them to solve the programming test two as required.

Additionally, this finding was confirmed by the qualitative data of students' group interviews, researcher's observation, and content analysis (see Table 4-5, Figure 4-2, and Appendix K-1). The group interviews indicated that all students in the groups agreed that CNC simulator has benefitted them in the CNC programming course with the PBL approach. They have stated, "Yes, it is critical to CNC programming as a beginner for each student to familiar with CNC controller" because the CNC simulator is one of the programming tools for beginners that could help them to get used to the CNC machine without any worries of injury or damaging the machine. They have also stated "Yes, besides reading books, learning about programming will become more efficient, productive and more knowledge gained" and that with the CNC simulator, learning of programming has become more efficient and effective. Therefore they have had the hands-on experiences in programming and handling the simulator which resemblance the actual CNC machine controller. They were also of the opinion that with the CNC simulator they can do analysis on the programming to optimise the cutting strategy and technology and make them more independent in learning. Below are some of the feedback from the group interviews:

> "Yes, because the simulator is like the exactly CNC controller at the CNC machine."
>
> "Yes, we can work out the programme ourselves without the involvement of the TTO."
>
> "Before performing the actual machining, we can observe the part simulation and can detect the mistake in the programme and can do the correction to the programme."
>
> "Yes, we experience programming like doing at the actual CNC machine controller and avoid any collision if wrongly programmed."

The above conclusion was further supported by the qualitative data (Section 4.8) of researcher's observations (see Table 4-5, Figure 4-2, and Appendix K-1) which revealed that students were very focused when working with the CNC simulator; they were observed discussing the very technical problems that they face during programming at the CNC simulator; they were also seen exchanging ideas on their programming style and probe questions to each other and gave explanations and each other perceptions; they managed to complete the exercises with the appropriate use of tools and cutting strategy during programming exercises given with the help of the simulator; they were able to apply programming concept from the International Organization for Standardization (ISO) of CNC programming format to a conversational programming format in new CNC programming problem; they seemed to make the appropriate decision to the problems given and able to provide a technically good reasons to the decision that they have made. The content analysis of students' programming exercises at the CNC simulators also demonstrated a high degree of problem-solving skills, decision-making skills as well as critical thinking ability by the students; they were seen trying many possible methods with the simulator to come out with the best programming solution and able to produce several ways of programming strategies and contour programming format to the same problem. Examples such as programming included a corner radius and a chamfer (Figure 4-7 and 4-8).

From the results and discussion of the quantitative and qualitative data highlighted above it can be concluded that, the CNC simulator seemed to benefit students in the PBL approach in six ways; 1) to help the students in checking and verifying their programme, 2) to give students the hands-on experience of working on the actual CNC machine controller, 3) to enhance the students' technical reasoning and decision-making skills 4) to enhance the students' problem-solving and critical thinking skills, 5) to encourage self-directed in learning, become more engaged and increase the students' centeredness, and 6) to increase students' motivation in learning because the simulator makes learning more interactive, interesting and fun. A study by Dunlap (2005) discovered substantial increases in self-efficacy after a 16-week PBL session in computer engineering. According to Smith (1992), "hands-

on experiments are essential to an engineer's education" (p. 41). According to Neo & Neo (2009); Seng & Mohamad (2002) students are capable of working more independently when utilising computers and engaging in online learning activities. These findings support Sahin (2006) who states that states computer simulation has a great potential in the PBL process because it provides students with the chance to observe a real world experience and interact with it. These findings also support Araz & Sungur (2007) who argue that computer simulation might contribute to conceptual change, provide open-end experiences, tools for scientific inquiry and problem-solving experiences that increase the effectiveness of PBL.
H6: There will be a relation between the scores of programming test one and programming test two; for students in both semesters three and four.

The fact that there was a moderate correlation and also a nearly high moderate positive correlation (Table 4-24 and Table 4-25) between the students' programming test one and programming test two for students in both semester three and four, and both correlations were significant at the 0.01 level, these results indicate that, if the students are unable to perform in the programming test one, most likely they will also not able to perform well in the programming test two. This is because programming test one was to test the knowledge and comprehension of students in CNC programming and programming test two was to test the students' ability to apply their knowledge and comprehension into practice by using CNC simulator. The CNC simulator will not benefit the students if they do not have the knowledge and comprehension of CNC programming.

Sub Research Question One and Two:

SRQ-1: What is the level of awareness and motivations of students at semester three and four about Problem-Based Learning?

SRQ-2: What are the students' perceptions of the Problem-Based Learning implementation?

Sub research question one and two explored the level of awareness and motivation as well as the perceptions of students at semester three and four about Problem-based Learning that had been implemented in the CNC Lathe and Milling programming courses. The quantitative and qualitative instruments namely Questionnaire (Appendix D-1) and Interview (Appendix E-1) were employed to investigate these issues.

Students' Awareness and Motivation

The quantitative data analysis (Table 4-7 and Table 4-8 in Appendix L-1) revealed that the majority of students (81.5% from semester three and 82% from semester four) were highly 'aware' of the advantages of the PBL approach, and only around 1.2% to 3.3% of students were perhaps not convinced with the PBL approach which was implemented in two CNC programming courses (lathe and milling). The group interviews revealed that the students experienced PBL in general subjects such as Mathematics, English language, German language, Malaysian Studies, Material Science and Industrial Management. They also practised PBL in technical subjects like Electric & Electronic Technology (semester two) and Geometry Dimensional & Tolerances (semester four) at the German-Malaysian Institute. The results showed that the students were very much aware of "what is PBL?" and "the advantages of the PBL approach" although they perhaps did not know in detail the PBL process. This awareness was perhaps because the students have experienced the PBL in other courses or subjects before this study as discovered when obtaining the qualitative data (group interview data). Considering the number of subjects that the students had experienced with PBL and feedback from the group interviews, supported by the survey results on the students'level of awareness and motivation (quantitative data - Questionnaire) which showed that 81.5% of semester three and 82% from semester four, this indicated that students were pretty much aware of the PBL process. This awareness and motivation were perhaps due to the PBL orientations conducted by the facilitators at the beginning of each course and because some of the students even had experienced PBL before entering GMI. In a PBL orientation normally the facilitator will explain what PBL is; the rationale for implementing PBL in the course; what and how PBL could benefit the students?; moreover, what are the PBL activities. The PBL orientation was also introduced by the facilitators for the CNC programming courses.

The fact that the around 3% of students (three to four students) seemed to be very negative about PBL approach may have been due to various factors such as, their negative attitude towards learning in general. They may resent that the PBL method demanded that they should work for their knowledge; they might have been too complacent or used to the traditional teaching approach that provides all the information (spoon-feeding) and even the solutions to the problems and therefore found it difficult to change and adapt to the new learning approach. A Study by Mohd-Yusof et al. (2013) on students' perception of Cooperative Problem-Based Learning (CPBL) revealed that many students may not initially like the drastic transformation from the usual "spoon-feeding" culture to learning inductively through CPBL. However, most of them were slowly swayed with the learning approach when they realized the improvement in skills and knowledge that they gained through the technique (Mohd-Yusof et al., 2013). According to Dahl (2004), learning can be difficult if the students cannot adapt to a new teaching style. This situation implies that the learners' learning history on how the students previously have been taught, influences how they can learn later on (Dahl, 2004). It might also be possible due to the students' particular individualistic learning style.

The independent samples *t*-test conducted to determine whether a statistically significant difference existed between students' groups of semester three and four indicated that there were no statistically significant differences between students of semester three and four on the awareness and motivation about PBL. The results suggest that the level of students' awareness and motivation in PBL were not influenced by the level of students in the semester although they have a different level of PBL experience.

The qualitative data (Group interviews) indicated that students of semester three and four have the positive feeling that PBL approach helps them in acquiring new knowledge. This may be possibly due to various aspects. For example, in the PBL approach, students need to seek for information and solution in order to solve the problem. In seeking and digging for information and solution to the problem, they would certainly have found new information complementary to the information which could probably be the solution to the problem; students exchanging of information and ideas could also have been possible for the students to gain new knowledge from their group members; sharing experience and prior knowledge by senior students might also contribute to new knowledge to the junior students.

The qualitative data (Group interviews) also revealed that students of semester three and four were of the opinion that PBL approach helps them in acquiring generic skills. The positive views were probably due to various factors. One of the factors that can be drawn from the group interviews was deduced from the following comment, "PBL is a platform for us to practice." The activities in PBL approach which foster active learning, interactions, discussions, team working and presentation had created a platform and a chance for the students to practice their public speaking, communication, presenting, problem-solving, and team working skills. Through many repeating processes of these activities in many PBL sessions, students were able to enhance their generic skills as well as their level of self-confidence.

The results of qualitative data (Group interviews) analyses have also shown that almost all students in the groups have the opinion that the PBL approach does not help in gaining technical skills. Their view is that technical skills can only be gained by practising many times with hands-on and not only by reading and understanding. They believed that the technique and proper use of machines or tools need to be practically demonstrated by a skilled trainer as it involves safety. This finding showed that the students prefer the technical parts in Technical Vocational Training and Education (TVET) especially in mastering the technical skills which they said should be taught by a skilled trainer. They believed the technique and proper use of machines or tools need to be demonstrated by a skilled trainer for several anticipated situations and conditions because a) if the students were to learn on their own they might have many different opinions or interpretations, working styles and techniques related to issue, b) the lack of adequate manuals or books that describe in details on mastering techniques of certain machine or tool, c) longer time might be needed for the students to figure out on the correct technique in mastering the machine or tool, and d) students might face the safety issue when working with the machine or tool without knowing the proper technique. Perhaps the students had misunderstood PBL and thought that PBL means the absence of a supervisor or a facilitator. In PBL, a supervisor or a facilitator does not meet the students only on the first day and then disappear and comes back only for group presentations. A supervisor or a facilitator actually will facilitate the students not only throughout the process of solving the problem but also in mastering the skills of using tools or machines especially when it involves safety. It is also part of Vygotsky's scaffolding and zone of proximal development (Figure 1-4; Section 1.5). However, some students in the groups of Sem4TDT1 and Sem4TDT2 were of the opinion that the PBL approach does help them in gaining technical skills. However, they learned skills through their teammates who had experienced in CNC machining which was gained from their previous technical schools. In this situation, the students still need somebody who had the experience to show them the techniques.

The qualitative data analysis presented in Section 4.3 also revealed that the "team working" and style of "active learning" that promoted in the PBL approach as well as "fun" have motivated most of the students learning. This conclusion was based on the frequency of students' responses in the group interviews. Furthermore, Triangulation of qualitative data suggested that "teamwork" was a major category and the central phenomenon of importance in fostering PBL among students in CNC programming courses (see Table 4-5 in Section 4-2). This finding suggested that other elements in making the PBL a meaningful learning experience for the students were the "students' interactions," "self-directed learning," and the "students' learning environment." This finding also suggested that these elements anchored with "teamwork" had contributed to "knowledge acquiring and application" and "skills gained" by the students. This finding was further discussed in the Main Research Question in this chapter.

The fact that the students were having good interactions among the group members which could be seen (Researcher's observations) by their verbal and nonverbal expressions as well as their feedback in the group interviews (see Table 4-5 and Appendix K-1) indicated; that they were enjoying learning with the PBL approach. The students seemed to have fun in learning where they enjoy learning in teams although there were some students in the groups not performed accordingly as needed by the group members. This finding supports Bridges (1992) that states the PBL approach triggers the students' learning, and they become highly motivated and enjoy the activities they are doing. The research by Schmidt & Moust (2000) indicates that learning in small cooperative groups through PBL approach seems to foster students' cognitive learning processes and motivation. The qualitative data suggested that the "fun" in learning might have been the motivating factor due to various aspects. For examples working in teams itself was fun because learning in a group made the learning much easier than learning alone, and the "burden" of learning was distributed among the group members; learning was much easier when the problem was discussed in a group of students and sharing their ideas, information, and knowledge with the group members; PBL activities such as group discussion and seeking for information to solve the problem that had relevance to their field of study had pushed the students to be active learners and self-directed in learning; the problems that were given to the students were like a puzzle that trigger their mind to think critically and create a curiosity and challenge for them to solve the problems. This finding supports Graaff and Kolmos (2007a) that mention problem-based learning is an educational strategy and a method to structure the learning process in such a manner that the students are actively engaged in finding answers by themselves. This finding backs McLoughlin & Oliver (1999) who state that students perceived the various PBL activities did contribute substantially to their learning and they considered the environment to be enjoyable and stimulating. According to Sanson-Fisher & Lynagh (2005) students claim that PBL gives a more satisfying learning experience than traditional teaching approaches. This finding also supports the findings of Gackowski (2003) who suggests that problem-based learning inspires greater motivation which brings into the practice elements of excitement, active participation, and involvement. Other factors that identified to contribute to students' motivations in PBL approach were, their satisfaction when successfully solving the problem and presenting the solution, in enhancing their self-confidence, generic skills, and knowledge. This finding appears to concur with Norman & Schmidt (1992) and Hmelo-Silver (2004) who argue that PBL is able to assist students in fostering intrinsic motivation, and this can be attained when students work on a task motivated by their interests, challenges, or sense of satisfaction. Barrows and Tamblyn (1980), state "that students' learning is motivated by personal satisfaction which will always be present even when grade and passing exams are no longer an issue" (p. 16).

Students' Perceptions

The students' perceptions have a very close connection with the students' awareness and motivation on PBL. The quantitative data analysis of the questionnaire (Table 4-11 and Table 4-12 in Appendix L-2) has shown that the majority of students (85.1% from semester three and 82.9% from semester four) had a positive perception on PBL that had been implemented in the CNC Lathe and Milling programming courses. The number of students with negative perception was only around 0.4% to

0.8%. These results demonstrate some consistency in term of percentages between students' awareness/motivation and perceptions. The results show that students of semester three were more positive in perception than students of semester four. However, the independent samples t-test indicated that there were no statistically significant differences between students of semester three and four regarding the perception about PBL. These results suggest that the students' perception in PBL were not influenced by the level of students in the semester or the type of programming courses they attended. The fact that students of semester three were more positive in perceptions towards PBL than students of semester four, perhaps this might be due to a fact that most of them (students of semester three) had an earlier experience of the PLB process and therefore led them to a higher level of satisfaction and benefit from the PBL than students of semester four.

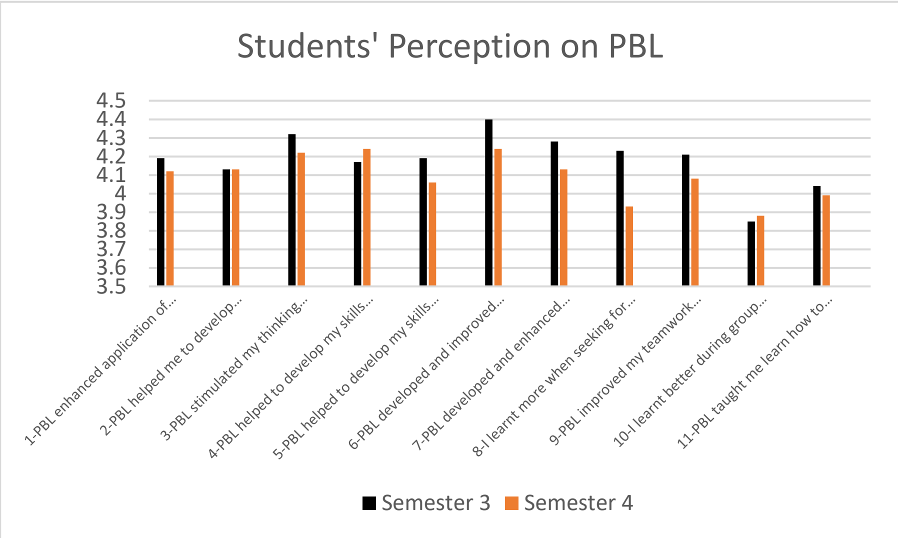


Figure 5-1: The comparison between semester three and four of students' perceptions on PBL.

Figure 5-1 shows the comparison of students' perceptions on PBL in the CNC programming courses. The pattern of feedback by students of semester three and four to items 1 to 11 in Figure 5-1 illustrate some consistency. The consistency of feedback by the two groups of students could be considered as validating each other responses in the group interviews. The reason for the highly positive scores in perceptions, in particular for items 6, 3, 4, 7, 1, 2 and 9, could be due to the students' experience and who felt the positive changes and improvement towards the end of the CNC programming course with the PBL approach.

This finding seemed consistent with the qualitative data analysis from the group interviews (Table 4-5 in Section 4.2) which also exhibit a positive trend in perceptions over PBL. The fact that students found communication and teamwork as the most positive aspects of their PBL experience, perhaps because they had a lot of communication and teamwork in a group and had benefited them in learning as well as improved their generic skills. This was affirmed by the students' comments such as:

> "This helps improve communication,"

> "Yes good and enjoyable, the discussion in a group can generate good ideas to solve the problem and improve our communication skills".

> "Helpful because it can create teamwork spirit and encourage the students to think outside the box,"

> "Yes, PBL is very helpful in thinking critically to solve problems and to help work in groups,"

> "We feel that Problem-based learning is good to work in a team because we can give ideas to solve problems,"

> "Problem-based learning is an exciting way of learning approach and useful,"

> "Problem-based learning is a good way of learning by discussion and interaction in the group,"

> "Yes good, the good thing about Problem-based learning, it makes us work in a team, seek for information and doing presentation on the solution to the problem,"

> "very good because we share ideas, learn new knowledge from each other members in the group,"

Students also found other positive elements in their experience with PBL such as opening and stimulating their mind, fun, improve self-knowledge and self-confidence. This was supported by the students' comments such as:

> "Stimulating individuals mind for not to depend on the notes given but to search more information on the subject,"

> "We think it can help students to solve a critical problem,"

> "PBL is good because it opens students' mind that students need to think good to solve problems,"
>
> "Problem-based learning is a fun way of learning, and it helps us to think and work on the problem ourselves, some of the information that we cannot get in the class,"
>
> "Problem-based learning has made us understand better on the subject because we experience the gain of knowledge," and
>
> "great type of learning approach, improve self-knowledge and self-confidence".

The fact that there was also some negative perception on PBL by students such as "time constraint", "burden", and "overloaded with another assignment" as discussed above could be seen as the PBL implementation as a whole need to further improved and fine-tuned.

Sub Research Question Three:

SRQ-3: How do the students' perceive challenges/obstacles in the Problem-Based Learning implementation?

The sub research question three investigated how students' perceived challenges/obstacles in the Problem-Based Learning implementation in the CNC Lathe and Milling programming courses. As for sub research question one and two, the quantitative and qualitative instruments specifically Questionnaire and Interview were also employed to investigate this element.

The results of the quantitative data analyses (Table 4-16 in Appendix L-3) has shown that 49.8% (N = 42) of students semester four responded 'agree' and 'strongly agree' to challenges/obstacles compared to students of semester three with only 33.6% in Table 4-15 (N = 16). The result indicated that almost half of the semester four students who had attended the CNC Lathe programming experienced more challenges/obstacles in PBL implementation as compared to students of semester three with only 33.6%. The results in Table 4-16 show that 47% (N = 40) of semester four students seemed to "agree" and "strongly agree" that they have been complacent with the traditional learning approach than the PBL approach when compared with only 31.9% (N = 15) of semester three students. One of the reasons may be due to the fact that students of semester four were introduced to PBL a bit later than students of semester three at GMI, especially in CNC programming. The mind-set held by the students of semester four (45.9%; N = 39) that "PBL is actually putting the burden of educating the students" perhaps also related to the students who were complacent with traditional learning. This can be seen by the percentage score and the number of students responded to items 21 and 22 which were very close (see Table 4-15 and Table 4-16 in Appendix L-3). However, this finding supports the study by Hwang & Jang (2005) who suggested that students negatively perceived PBL as a burden because it took additional time than traditional learning tasks.

Learning objectives: The quantitative data analysis on the Questionnaire also revealed that some students in both semester three (34.1%; N = 16) and four (44.7%; N = 38) were having difficulties to determine their learning objectives. This situation might be due to the possibility that some students who were still not capable of getting used to the new way of learning during which they needed to determine their learning objectives on their own. The researcher's observation data affirmed this matter, especially during the first PBL session. Some students seemed not sure with their learning objectives because they were observed to be asking the facilitator for clarification a few times although the facilitator had given a briefing on that matter prior the PBL session. This finding addressed a common criticism of PBL namely that student lack of control over their learning and ways to make sure that students have covered all the important content including the central importance relevant to the given theme (Swanson et al., 1989). The same thing could have happened to students in the CNC programming courses; because they might not have been conscious of all the important information and concepts that were essential to the problem. However, they seemed to improve in the subsequent PBL sessions perhaps due to the reflection session at the end of the PBL-1 conducted by the facilitator.

The results from the quantitative data (Questionnaire) had further indicated that the resources concerning Technical Vocational and Education Training (TVET) were not adequate, and was one of the challenges/obstacles faced by both the groups of students semester three (29.8%; N = 14) and four (37.1%; N = 38). This finding was supported by the results from the qualitative data of the group interviews mentioned previously regarding the lack of source. The fact that some of the students claimed inadequate resources concerning TVET might be due to several factors. For example, some students might have expected to get the exact solution for the problem through the internet or textbooks in the library. According to Blumberg and Michael (1992), the PBL students were more likely to utilise textbooks whilst non-PBL students are more likely to depend on lecture notes. However, the observational data (Table 4-5 in Section 4.2) shows that each student was provided with a workstation which was equipped with CNC simulator, ISO programming manual (pdf file), conversational programming manual (pdf file) and the internet access for external resources search. Every problem given to the students was unique and could be solved with the software material which was saved in the workstation especially the programming. Therefore, the question of resources concerning TVET that it was not adequate, really it was not an issue at all. Another factor perhaps might have been due to some students who were not able to determine their objectives and felt that the resources available were not enough.

Time constraint: The last item no. 25 of the questionnaire (Table 4-15 and Table 4-16 in Appendix L-3) indicated that students of semester three (42.5%; N = 20) and four (64.7%; N = 55) encountered the inadequate amount of time to work on solving the problem. This result affirmed by the qualitative data of group interview during which the students seemed to have the issue of time constraint during their PBL sessions (see section 4.6). This matter might have been due to several factors:

1- The CNC programming course originally was a lecture-based or a traditional teaching approach with 75 teaching units which was equivalent to 75 hours. In this study, the 75 hours were allocated for both the PBL-lecture approach and for practical works and perhaps this was the reason for the students to state that the time was not enough, also because during the PBL sessions the students tended to work based on their own pace although time was set for every PBL activities. From the total 75 hours, only 23 hours were hours for PBL sessions (see Table 5-1 below), and the rest were for students' practical works. From the researcher's observations, most of the students seemed to take more time than the time allocated to complete a particular PBL activity.

Table 5-1: Time allocation for lecture and PBL sessions.

PBL Sessions	Lecture Hours	PBL Hours
PBL-1	0.5	4.5
PBL-2	1.5	5
PBL-3	2	8.5
PBL-4	5	5
Total hours	**9**	**23**

2- The fact that some students in the group spent time with another assignment during the PBL as claimed by the students in the group interviews could also contribute to insufficient time since fewer members were working. The issue of students having too many subjects with PBL in a semester which also faced the time constraints had propelled some students to spend the time with another assignment.

It might also be the fact that the problem given to the students were new to them and that they really needed more time to digest. The fact that PBL is less efficient and time-consuming than the lecture-based or traditional approach has been a debated issue. According to Barrows and Tamblyn (1980) when students are confronted with an unfamiliar problem or a new study area, they need a considerable amount of time to understand and to solve the problem. A study by Al-Naggar & Bobryshev (2012) shows 39.7% of the study participants agreed that PBL strategy consumes more time than conventional lectures. In another finding reported that participants feel that PBL is very time-consuming (Nandi et al., 2002). Time-consuming and distrust are associating with PBL as reported by Chakravarthi et al. (2010). According to Schwartz et al. (1993), PBL is less efficient for the reason that the PBL students have to invest more time learning the subject matter on their own. A study by Dodd (2007) also indicates that time restrictions in PBL influenced students' information seeking behaviour. Perhaps time constraints in PBL is really an issue. However, time is a very subjective matter that cannot be determined by how much is enough by the students. Perhaps the Vygotsky's zone of proximal development (ZPD) (see Figure 1-4 in Section 1.5) as the concept of scaffolding could be refined to balance up this issue. For example, the scaffolding could be structured according to the time that the students have and their ability to solve the problem.
Some other elements of students' challenges/obstacles also emerged from the results of qualitative data from group interviews as shown in Figure 4-6 (Section 4.6) which were said to be; the lack of teamwork, the difference in opinion, poor internet connection, the problem statement, presenting ideas and the negative attitude.

Lacking teamwork: The fact that there were some negative feedback about lacking teamwork and negative attitude from students in the group interviews such as:

- A teammate was busy with other PBL assignment.
- Team member did not participate in the discussion.
- A teammate did not do their homework or job.
- Team member did not give cooperation.
- No contribution by a teammate; materials found by some members were not appropriate and difficult to understand.
- Team member gave the excuse of "Can't find the materials/information."

These scenarios were possibly due to several reasons. Concerning the "teammate was busy with other PBL assignment," was among of the reasons were students had too many PBL classes which were implemented within the training week. This situation was perhaps due to the difficulties in PBL implementation using the traditional teaching curriculum at the German-Malaysian Institute (GMI). GMI is in the process of changing from teaching approach to the PBL approach although it is not in fully implemented yet. GMI perhaps had overlooked the burden experienced by students when the PBL approach is applied to all subjects without changing the traditional teaching curriculum to a PBL curriculum and possibly combine several subjects into one. Thus, the students could have a reasonable amount of time for a particular PBL. Perhaps, GMI needs to consider aligning the curriculum and structured it in thematic blocks according to learning principles mentioned by advocators of PBL as cited in Graaff & Kolmos (2003). The shift toward innovative and meaningful curricula is essential at this moment to attract the Generation-Y into not only in engineering (Mohd-Yusof et al., 2015) but also in TVET.

The fact that some of the students did not participate in the discussion might be due to several factors. For example, the students had not done the homework to study the particular issue which was going to discussed and consequently they could not talk about the issue in the discussion; it might also be the student's personalities that inhibit his/her participation; students might not have experience or shy to participate in a discussion; students' English proficiency inhibit them to argue or express their ideas in the discussions.

The difference in opinion and presenting ideas: Students also looked at the difference in opinion and presenting ideas were considered to be challenges/obstacles in PBL approach. The students should expect the difference in opinion and present ideas in every team working or a discussion. The researcher looked at this as a positive aspect of PBL approach because students will learn to "agree to disagree," negotiating; convincing people as well as presenting that would their skills.

Problem statement: Only two of 21 small PBL groups of semester four students claimed that the problem statement was difficult to understand. Perhaps, the problem statement that difficult to understand refers to PBL-2 based on the researcher's observations in four PBL sessions. Some students seemed to struggle a bit in understanding the problem statement in PBL-2 (see appendix Q-2). Looking at the small number of groups (two groups) that claimed the problem statement was difficult to understand, it can be concluded that the problem statement was fairly easy to understand since the majority of the groups (19 groups) had no problem to understand it. The fact that only two groups were having difficulty in understanding the problem statement, perhaps due to their inability to relate or grasp the similarity of the surface speed of the earth with the cutting technology. In the problem statement of PBL-2 (see appendix Q-2), students need to understand the surface speed of the earth and need to why the speed is different at different places of the world such in London, Hong Kong, and Australia. They can then relate the finding with the cutting technology especially the cutting speed that has the same concept.

Internet connection: The internet connection at GMI has been an issue for a year or two since the capacity of students increased as well as staffs. The internet seemed to be unstable during the peak hours between 9.00 am to 3.00 pm. However, during the PBL sessions especially for PBL-1 and PBL-2, the students still managed to use the internet but a bit slow. This situation also perhaps contributed to longer time taken by the students to work with the problem.

5.2. METHODOLOGICAL REFLECTIONS

The aim of this study is to examine the impact of PBL on Students' competencies in Technical Vocational Education and Training (TVET). The design of this study, which was an experimental research approach that employed a mixed methods design with a concurrent triangulation strategy, has helped the researcher in conducting the research successfully although the complexity of the applied research has been an issue throughout the research study.

The mixed methods approach demand the researcher to be able to work and process the quantitative as well as the qualitative data which have a totally different approach in processing and interpreting. This researcher felt more at home with the processing of the quantitative data than with the processing and analysis of the qualitative data.

The researcher has used the Statistical Package for the Social Sciences 22 (SPSS) software to process as well as running the tests on the quantitative data whilst QSR NVivo 11 software was utilized for the qualitative data. The SPSS software was employed to conduct tests such as normality test (on the pre-test, post-test, programming test one and programming test two), Independent samples t-test (on the questionnaire, pre-test, post-test, programming test one and programming test two and students' Cumulative Grade Point above Average (CGPA)), paired-samples t-test (on the programming test one and programming test two), Pearson correlation analysis (on the programming test one and programming test two) and the last test was the descriptive statistical analysis (self-assessment and peer-assessment data). The NVivo 11 software helped the researcher in managing the qualitative data such as interviews data and field notes (researcher's observation data). Besides that, the NVivo enable the researcher to create nodes, categories and themes as well as importing articles, pictures, audios and videos for analysis.

The most challenging part of this study was to process the qualitative data of observations, group interviews and content analysis as well as interpreting the results. By comparison the analysis of the quantitative data was much more straightforward. The students' group interviews were successfully conducted with 32 PBL groups of semester three and four students. The students had given full cooperation during the interviews that took between 42 minutes to 96 minutes although they had a very tight class schedule. However, some of the students were quite passive during the interview sessions, which needed the researcher to ask them for feedback. In order to grasp the right message from the group interviews, the students were allowed to respond to the interview's questions in English or Malay language so that they were able to express their thought without fears of their language proficiency. The students seemed happy with the option set, and they have given positive and negative feedback without any problem.

As described in Section 3.3 of chapter 3, the quantitative design of this study employed a quasi-experimental approach in which the subjects were assigned to the experimental group based on their natural setting such as the students' semester, area of specialization, number of students and the researcher has no control over where and when the courses should take place. Throughout the research, the researcher needed to follow the class that scheduled by the department (see Table 3-2 in Section 3.5). A pre-test was administrated by the researcher at the beginning of each class and the post-test was administrated during the examination week by the examination unit. The programming test one and two were administered during the course to evaluate their learning performance while the questionnaire, self-assessment and peer-assessment were administrated at the end of the course to have their insight over the PBL approach.

The qualitative research design was inspired by the ethnographic approach which enabled the researcher not only to conduct the group interviews but also observations on the students' interactions, behaviour as well as on the learning environment. The ethnographic method has specific ideas about how to look at the subjects which usually apply in purely qualitative research that usually studies a group of people in their own environment. In the ethnographic approach, the ethnographer will engage him- or herself in the environment being studied to observe the daily life of the subjects and also conducting the unstructured interviews to gather the information.

In this research context, the researcher followed the principle of the ethnographic approach to study group of students in the classroom and used it as part of a mixed methods design approach. In this study, the observations by the researcher were much on the students to students' interactions and students with the facilitator interactions, their activities in the classroom as well as the activities in the computer lab where they worked with the CNC simulator. In these circumstances, the researcher should be sensitive and should be able to "read" the actions by the students and make some judgment on their actions.

The observations were also done by four facilitators (participant observers) on their students during the CNC programming course so that the data could be compared by the researcher. However, the observations by participant observers were guided by the observational tool provided by the researcher. It means that besides their function as facilitators they also needed to observe the students using the observational tool (see Appendix G-1). The facilitators (participant observers) needed to observe and rate their students from PBL-1 to PBL-4 using a rubric

(Appendix G-2). The observational data from the participant observers were then processed by the researcher and triangulated with other Research's data for verification.

As described in Section 3.7, the content analysis including the students' CNC programming problems exercises, written CNC programming test, CNC programming solutions, and simulations at the CNC simulator and the students' coursework. Most of the content analyses was carried out during the students' PBL activities in class especially when the students worked with the CNC simulator. The content analyses was carried out while students worked with the CNC simulator in order to get their direct feedback on their programmings such as technical reasoning, the rationale for selecting the programming methods to the problem and the justification for selecting the tools and machining strategies to the problem. The students were also subjected to the researcher's probing questions in order to get their opinion and look at their skills in problem-solving, critical thinking, technical reasoning, and decision making. In this way, the researcher could judge the students' ability in solving the CNC programming problems.

Lastly, the results of the quantitative and qualitative of this study were compared to determine if there were congruence or divergence and the triangulated to give a better picture of the data collected as well as providing the validity and reliability to the data.

5.3. CONCLUSIONS

A number of important conclusions can be drawn from this study such as; The PBL approach has been successfully implemented at the GMI and had a positive impact on the students' learning when implemented in the CNC Milling and Lathe programming courses, although there were some issues that still need attention for further improvement and fine-tuning. The “Teamwork” is selected as the central theme of importance in promoting the students' learning in the CNC programming courses in the PBL approach. The choice is based on the triangulation of qualitative as well as the quantitative data analysis and on the fact that in PBL, students were always working and studying in groups, fostering interactions among students and self-directed learning supported by a conducive learning environment. The students seem to have benefited from the team working and they were able to gain knowledge from the group discussions and sharing of idea and knowledge. The students appear to have gained and enhanced their skills such as communication, teamwork, presentation, problem-solving and critical thinking through the PBL activities. The success of the implementation of the PBL approach can be said to be for the following reasons:

1. This study demonstrated that students' learning was encouraged and enhanced through their teamwork and interactions and supported by the encouraging learning environment. This situation could be seen as students participated actively in the group discussion, debated issues, raised and probed questions, and responded each other's questions. These findings indicate that the PBL approach has a positive impact on the students' social competence. This fact was evident through students' feedback from the group interviews and researcher's observations.
2. Students were observed to enjoy learning through the PBL approach which showed their motivation. This fact was evident through students' feedback from the group interviews and researcher's observation.
3. Students seemed to be more active and verbally interactive in the second PBL session after the reflection session conducted by the facilitator. This fact was evident through the researcher's observation.
4. Students of both semester three and four scored higher mean in post-test than the pre-test and the difference was statistically significant and this result confirmed that students have learned and gained knowledge from the PBL approach. This fact was evident from the quantitative data of paired sample t-test.
5. This finding also indicated that students in both semesters three and four have achieved the level of learning and technical competencies as required in the learning outcomes of the CNC programming courses (CNC milling programming and CNC lathe programming). This fact was evident from the results of the analyses of the quantitative data of students post-test, programming test one and programming test two results.
6. Students were able to apply the learning obtained from theory into practice when they had used the CNC simulator to work on the programming test two. This can be seen from the results of the programming tests which shows that they scored higher in programming test two than programming test one. The results also indicated that the CNC simulator has benefited the students in assisting them to solve the programming test two as required.
7. The content analysis of students' coursework assignments also revealed that students were also able to apply the programming concept of the International Standard Organization (ISO) programming format that they have learned to a new programming problem which was required to be in a Conversational programming format.
8. Students had given positive perceptions about the PBL approach, this indicated that they had a good experience during the PBL sessions. Perhaps they had experienced the changes and improvement by the use of the PBL approach and hence their positive attitude towards the end of the CNC programming course. This fact was evident through students' feedback from the group interviews.

This research finding also revealed that students having a high score in CGPA had benefited more from the learning through PBL than the students having a low score in CGPA. This research also indicated that the students with good CGPA had benefited from the CNC simulator more than students with low CGPA. This situation indicated that the students' CGPA scores seem to have some relationship with the performance of students learning in the PBL approach. This situation might be due to the reason that the students with high CGPA had the characteristics of PBL approaches such as more motivated, self-reliance and student-centred learning that suit their learning style. While students with low CGPA perhaps had less of these features and inclined toward traditional teaching approach.

In conclusion, the overall research findings have strongly indicated that the PBL approach had a positive impact on the students' learning, technical and social competencies, it also has the potential to enhance the generic skills and attitudes of the students as well as improving the students' attributes for a better workforce in organisations.

5.4. IMPLICATIONS

This study supports that it is possible to implement PBL approach in Technical Vocational Education and Training (TVET) specifically in the curriculum of the CNC programming courses although hands-on experience should also be given more emphasis. As noted at the beginning of this study's thesis, in the era of globalization and the new and emerging technologies, the need for knowledge manpower with generic attributes is essential in order for the individual to cope with the rapid changes in technology. Furthermore, there have been a lot of discussions locally and internationally concerning graduates lacking in attributes of generic skills as needed by the labour market which has led to a low employability rate. As mentioned in Section 2.5, the Government of Malaysia through the Ministry of Higher Education has been aware on this problem and insisted that higher education institutions embed graduate attributes into the curriculum and training system. In addition, it has been the vision and aspirations of the Malaysian government to enhance education systems that are capable of developing skills and attributes needed for the 21st century. The question is, how to embed the intended attributes such as communication, teamwork, problem-solving and critical thinking skills into the curriculum and training system can stimulate generic skills effectively among students?

Therefore, this study confirms that PBL approach also has a great potential to be implemented in the TVET system which is well-known to be well practised especially in the medical field. The findings of this research also support the literature study reported by Sada et al. (2015) that PBL is an essential tool for educating students in technical and vocational fields. They argue that employing the PBL approach in TVET will enhance the students' skills in communication and information retrieval, which will enable individuals to gain and apply new knowledge and expertise as required.

Although there were several issues revealed from the findings of this study, however, two issues are essential and need serious consideration in implementing the PBL approach in TVET that is, "Constraint of time" and "Students overloaded with other assignments." These two issues are strongly related to each other. As shown clearly in the discussion of above section, these issues were due to the fact that PBL was implemented in many subjects or courses in a semester. It seems that just simply changing from lecture-based to PBL for every subject or course without changing the curriculum to PBL curriculum will lead to the issues mentioned above. Many studies found that time-consuming always associating with PBL (Barrows and Tamblyn, 1980; Al-Naggar & Bobryshev, 2012; Nandi et al., 2002; Chakravarthi et al., 2010; Schwartz et al., 1993). This study suggested that, in order to have more effective PBL, the training institutions like GMI need to change its curriculum to PBL curriculum and will need to consider the students' learning and training holistically. According to Graaff & Kolmos (2007c), the total curriculum change can be observed from many different perspectives such as at an institutional level, a faculty, a department, or a programme. Combining several subjects such as material science I and II, English I and II, Maths I and II, CNC Programming of Milling and Lathe can increase the time allocated for a certain subject. For example, the CNC Milling and Lathe Programming when combined will have 150 hours instead of only 75 hours and the content can also be optimised as well. However, time is a very subjective matter because students seem to study at their own pace and because the students' style of learning also varies as well as their academic performance. Perhaps the Vygotsky's zone of proximal development (ZPD) (see Figure 1-3) as the concept of scaffolding could be refined to balance up this issue. For example, the scaffolding could be structured according to the time that the students have and their ability to solve the problem. According to Walker and Leary (2009), PBL can be in many different forms that are worth exploring including variations in how much learning is directed by teachers or students within a particular problem or across the whole course or curriculum.

Nowadays the internet has played a major role in everyday life as well in education. In this matter, a good internet connection is essential for the PBL approach in which the time for students to seek information can be extensively reduced because all the information can be accessed at one place. The computer simulation or specifically the Computer Numerical Control (CNC) simulator used in the CNC programming courses appeared to play an important role in learning with PBL setting. As mentioned in the discussion above, the CNC simulator seemed to have a positive impact on the students learning through the PBL approach. Several studies showed that computer simulation beneficial the students' learning (Neo & Neo, 2009; Seng

& Mohamad, 2002; Sahin, 2006; Araz & Sungur, 2007). Therefore, this research study suggests that computer simulation should be used in order to enhance the effectiveness of students' learning in the PBL setting.

5.5. RECOMMENDATIONS

For Future Study:

From this research study, the following recommendations are presented for any future study on the PBL approach implementation specifically in CNC programming courses or generally in the TVET.

a) Further study should be carried out to support the finding of this research study that concludes students with above average CGPA scores had benefited the learning through PBL approach more than the students with below average CGPA scores or in other words the students' prior academic performance influence the learning in PBL approach.
b) A study to compare the performance of students with different learning styles and characteristics and how the PBL approach influences their learning.
c) More studies should be carried out to investigate further on how the PBL approach can effectively benefit the teaching of Technical Vocational Education and Training (TVET) because it involves hands-on and technical skills that students need to master.
d) Further studies should be carried out to support the finding of this research study which concludes the CNC simulator seemed to benefit students in the PBL approach in six ways:
    I. help the students in checking and verifying their programme,
    II. give students the hands-on experience of working on the actual CNC machine controller,
    III. enhance the students' technical reasoning and decision-making skills
    IV. enhance the students' problem-solving and critical thinking skills,
    V. encourage self-directed in learning, become more engaged and increase the students' centeredness, and
    VI. increase students' motivation in learning because the simulator makes learning more interactive, interesting and fun.

PBL Framework

The German-Malaysian Institute (GMI) is a Technical Vocational Education and Training (TVET) institution that provide skill workforces to fulfil the industry needs in Malaysia. Adopting a new learning approach such as Problem-based Learning from a traditional learning approach like GMI is rather a very complex changing process. According to Graaff & Kolmos (2007c), the change from traditional to PBL approach can be observed in many different levels such as a faculty, a department, a programme or a course. Fullan (2001), emphasises that change is a process, not an event and that change does not occur overnight. He adds that the outcome of an educational change process is not only a change in student learning but also the organisational capacity. However, at GMI currently, the change occurred only at courses or subjects level. This PBL framework developed as a guideline for GMI as well as other TVET institutions that wish to change their learning approach to PBL approach.

Three levels that need attention in order to implement the PBL at the institution.

1- Organisation level:
   - Set a vision and mission in implementing PBL in the organisation.
   - Set a short-term and long-term plan for implementing PBL in the organisation.
   - Provide the infrastructure orientated to PBL approach to creating a conducive learning environment such as:
   - The good internet connection where it could enhance the effectiveness of PBL implementation and it could also reduce the time for students to search for information as seeking of information could be done at the workstation.
   - Setup a conducive PBL classrooms and computer labs in which students could comfortably work in groups and present their findings.
   - Equipping the physical and virtual library with a variety of PBL books to enhance the knowledge of staffs as well as students.
   - Provide an attractive landscape around the department or faculty so that the students could have their PBL activities such as group discussion outdoor to foster learning.

2- Management:
   - Organise awareness programme on PBL to all level of staffs.
   - Organise a PBL orientation on all teaching staffs.
   - Provide training on facilitation skills to all teaching staffs.
   - Provide training on problem crafting to all teaching staffs.
   - Provide training on developing of PBL assessment to all teaching staffs.

- Provide training on developing the PBL curriculum to all teaching staffs.
- Establishing the PBL curriculum and PBL assessment scheme.

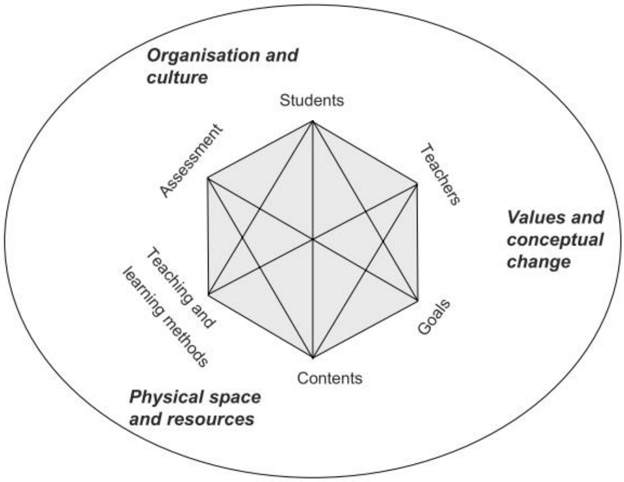


Figure 5-2: Curriculum model for change

Source: Adapted from Graaff & Kolmos (2007c).

Restructuring or grouping the interrelated subjects such as CNC technology, CNC lathe programming and CNC milling programming accordingly in order to establish an effective PBL approach. In this way, the students will have more reasonable time to workout on the problems. Avoid implementing PBL on one single subject to prevent the burden on students. GMI may apply the model of curriculum change (as shown in Figure 5-2) that according to Him & Hippe and Kolmos (as cited in Graaff & Kolmos, 2007c) constructed on the didactics relationship which includes all of the educational elements in order to achieve the change.

3- Teaching Staffs:

- Form teams to develop the PBL curriculum and PBL assessment scheme.
- Form teams of problem crafters to develop a problem statements for the subject matter.
- Establish PBL community among teaching staffs to discuss issues on PBL.
- Organise awareness and orientation programme on PBL to the first semester students.
- Use the Moodle/ASK-LMS to enhance learning and stay connected with students and other teaching staffs after class.

The PBL session starts with a problem statement given by the facilitator (see the PBL flowchart in Figure 5-3). The facilitator can give a brief on the problem statement if he/she feels necessary. At this stage, the students with their knowledge they had, need to comprehend what the problem is all about. Then they need to define and list out the issue/s in the problem statement. After they have identified the issue/s, they need to formulate the learning objective/s. The facilitator needs to make sure the students' learning objectives are appropriate and in line with the learning objectives of the course. Next, the students should analyse the issue/s and identify what they know, what they do not know and what they need to find out. The facilitator should facilitate the students in analysing the issues in the problem through a series of probing questions.

The students distribute the tasks among them on what they need to find out so that each student has their responsibility toward solving the problem. At this point, the students worked individually (self-study) on what they need to find out. They search for information by all means that they think possible. Next, they will share and discuss as well as debate what they have found out to solve the problem. The facilitator should facilitate the students in the discussion through a series of probing questions so that they did not off track from the objectives they want to achieve. They will then need to get a consensus from the group members on the findings or solutions to the problem. After the discussion and consensus from the group members, they need to prepare a presentation slide to present their findings and solutions to the problem. The students are expected to defend their solutions to the problem with the reasons behind the decision made. Other groups are reminded to focus on the presentation and should ask questions at the end of the presentation.

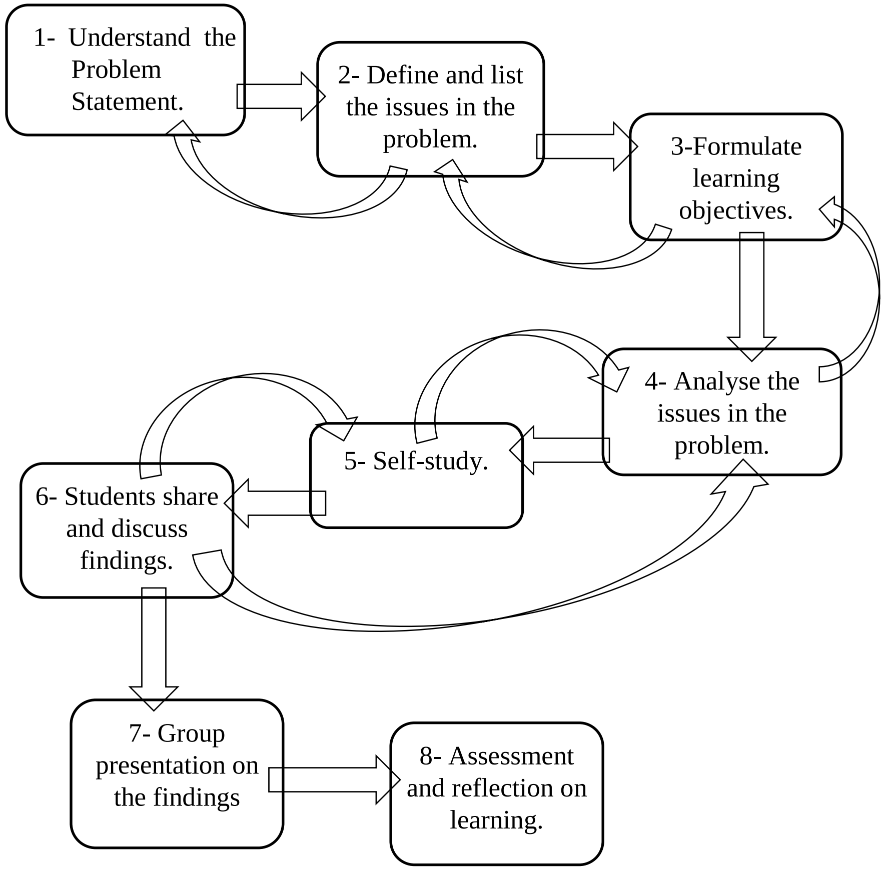


Figure 5-3: The PBL Flow Chart

A question and answer session are held at the end of the presentation. Throughout the PBL activities from step one to seven, the facilitator should observe the students such as the interactions, communications, and problem-solving skills and etc. so that the facilitator should be able to comments on each group performance during the reflection session. The observational tool (see Appendix G-1) with predetermined criteria is used by the facilitator to facilitate in the observation process. At the end of the PBL session, the students reflect on the issues that they face throughout the PBL activities such as:

- What you have experienced during the self-study and seeking for information?
- What have you experienced during the group discussion and presentation?
- What have you experienced during the group presentation?
- What about the group members? Teamwork? Cooperation? Individuals' contribution? Etc.

The facilitator then comments and reflects on the each group performance and what they should do's and don'ts during the PBL session. Some of the comments by the facilitator can be as below and the students are expected to improve the performance in next PBL session.

- Students' progress on tasks given.
- Students' time management.
- Students' discussion activities.
- Students' teamwork.
- Students' problem-solving skills.
- Students' critical thinking.
- Students' presentation.

The PBL flow chart in Figure 5-3 shows that there is always the possibility for the students to step back if they found some issues unclear or need revisions. Every PBL session is accompanied with a guideline for the facilitator. The guideline contains PBL activities and time allocated for every activity. With the guideline, the facilitator knows the total time for each PBL session and time for each activity. See Appendixes P-2, Q-2, R-3 and S-3 for the examples of PBL's guidelines. The facilitator is also provided with the PBL's timetable that shows the sessions of PBL in the whole duration of a course.

In order for the facilitator to have a clearer understanding of the PBL's steps, a description about each step needs to be provided. Table 5-2 shows the steps of PBL and its description so that the facilitator knows what need to do at every PBL step. The steps and descriptions of this PBL are not ultimate because it can be revised or fine-tuned accordingly to suit the institutional or course objectives. Example, it might not be necessary to have the assessments (self- or peer- assessment) at the end of every PBL session if the facilitator feels that not necessary and enough with the reflections or based on several PBL session earlier the results might the same.

Lastly, the researcher has the opinion that the students' progress and achievement cannot be seen only with one PBL session. The PBL needs to be in several session in order to look at the effect because the students need to adapt and they are expected to improve in the next PBL session until PBL becomes their learning culture.

Table 5-2: The description of the steps in conducting a PBL session.

Steps	Descriptions
1- Understand the Problem Statement.	Students are presented with the problem statement. The problem is ill-structured however scaffolding and sufficient information is provided to the students to facilitate them in solving the problem. Vygotsky's zone of proximal development (ZPD) can be applied as the concept of scaffolding in this PBL approach. The students need to read through and discuss the issue in the small group. With their prior knowledge and experiences that they have, they should make clear the facts of the problem. The facilitator should facilitate the students in understanding the problem statement through a series of probing questions.
2- Define and list the issues in the problem.	What do we know? What do we not know? Through group brainstorming, the students analyse and interpret the problem-based on their understanding of the problem and drawing on their prior knowledge and experiences. What do we need to now? Students identify the learning issues and information or knowledge that they need in order to solve the problem.
3- Formulate learning objectives.	The group have identified the learning issues and formulate learning objectives. The facilitator should facilitate the students in the identification of the issues and formulate the learning

	objectives through a series of probing questions if they are seemed confusing and deviating from the actual learning objectives.
4- Analyse the issues in the problem.	Analyse the issues in the problem through group brainstorming to make assumptions, make possible tentative solutions and generate as many as possible reasonable explanations for the phenomenon. The issues that need further clarification and information are divided among the members in the group for self-study. The facilitator should facilitate the students in analysing the issues in the problem through a series of probing questions.
5- Self-study.	Students seek information related to the issues that need further clarification and information individually. They need to give priority on issues the one that has been provided by the group in the search for the information.
6- Students share and discuss findings.	Students share and discuss findings of self-study with the group and list recommendations, solutions, or hypotheses. The facilitator checks and assesses the learning by probing questions related to the issues.
7- Group presentation on the findings	Each group of students need to present their findings in front of other groups so that they can arguing and questioning on the issues followed by Q & A session and comments by the facilitator. In this way, the students will able to gain knowledge and learn from each other. Facilitator comments on the presentation skill of the group such language, voice, body posture, etc. so that they can improve in the next presentation.
8- Assessment and reflection on learning.	Self-assessment and peer assessment are conducted to get the students' insight on the particular PBL session so that improvement could be done. The students in the group are to do the reflection on what they have gone through during the process of step 1 to 7.

	This reflection could help the students to improve in the next session. Example-1: if they have problems to understand the problem statement, the facilitator will consider revising problem statement. Example-2: if they have problems with the attitude of the member of the group, the facilitator could take the appropriate action.

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APPENDICES

Appendix A-1. Pre-Test CNC Milling and Programming

CNC 0612 CNC MILLING AND PROGRAMMING
DURATION 90 MINUTES

Student's Name : ______________________

Student's I/D No. : ______________________

Semester/Trade/Group : ______________________

Date : ______________________

Circle the correct answers

1. What is the acronym for CNC?
   A. Computer Numerical Constant
   B. Computer Numerous Control
   C. Common Number Computation
   D. Computer Numerical Control

2. In accordance with the control mode, CNC systems are subdivided into three basic categories that differ in their performance. Name three of control modes available in CNC system.
   A. Rapid, feed and slow traverse control
   B. Spindle, Turret and Table control
   C. RPM, Turret and Axes control
   D. Point to point, straight cut and contouring control

3. Name **three** controllable machine components of a CNC machine tool.
   A. Feed axes, feed drive & Measuring device
   B. Feed axes, drive screw & Measuring scale
   C. Feed screw, feed drive & Measuring device
   D. Feed axes, feed drive & rotary axes

4. Computer Numerical Control is applied to a wide range of manufacturing processes. State four applications of CNC in that manufacturing process.
   A. Metal cutting, flame cutting, sheet metal forming and woodworking
   B. Sheet metal punching, water jet cutting, welding and laser cutting
   C. Metal cutting, welding, water jet cutting and laser cutting
   D. All of the above

5. A sheet on which working process and cutting process are expressed by numeric value and alphabetic symbol according to a predetermined rule is called:
   A. Block number or subprogram
   B. Address or block number
   C. Part program or machine program
   D. Subprogram or machine program

6. "**G0**" is a move command of a straight line rapid traverse and is used for positioning at programmed coordinates in CNC technology. What is the unit used to measure the movement of the rapid traverse for "**G0**" in CNC milling?

A. Meter/minute

B. Millimeter/revolution

C. Millimeter/minute

D. Revolution per minute

7. Name the symbols mark X and Y in the schematic diagram below.

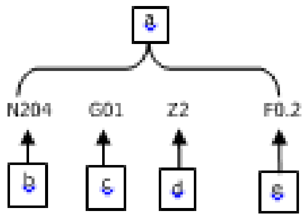
A. Y is machine home point, X is workpiece clamping point

B. Y is machine zero point, X is workpiece zero point

C. Y is machine reference point, X is workpiece zero point

D. Y is chuck reference point, X is workpiece zero point

8. Choose the correct punching word in the program line below.



A. a- command word, b-data, c-command word, d-address

B. a-address, b-end of block, c-command word, d-Block number

C. a-block, b-Block number, c-command word d-address, e-technology,

D. a-end of block, b-Block number, c-command word, d-address

9. What is the function of programming code G40 in a CNC milling program?

A. Moving tool to the tool change point

B. Tool radius compensation off

C. Tool radius compensation left

D. Tool radius compensation right

10. An end-mill with diameter 10mm is used to machine a workpiece with cutting speed of 30m/min. If the same cutting speed is used to machine a workpiece with end-mil diameter of 8mm, what will happen to the spindle speed?

A. Spindle speed will reduce

B. Spindle speed will not change

C. Spindle speed will increase

D. Spindle feed will increase

11. "**G1**" is a move command of a straight line feed traverse and is used for cutting the workpiece in CNC technology. What is the unit used to measure the movement of the feed traverse for "**G1**" in CNC milling?

A. Millimeter/minute

B. Meter/minute

C. Millimeter/revolution

D. Revolution per minute

12. What is the function of programming code **G41** in a CNC milling program?

A. Moving to the tool change point

B. Tool radius compensation lift

C. Tool radius compensation right

D. Tool radius compensation left

13. The information that can be derived from the technical drawing of the component are;

I. Shape of the workpiece.

II. Size of material and machining allowance.

III. Material of workpiece.

IV. Dimension and accuracy.

V. Tool to be used.

Which is true or false?

A. I, II, III true

B. III, IV, V false

C. All false

D. All true

14. What is the unit used for the movement of "**G2**" and the feed traverse for CNC milling?

A. Millimeter/revolution ..... clockwise

B. Millimeter/minute ...... clockwise

C. Meter/minute ..... counter-clockwise

D. Revolution per minute ..... counter-clockwise

15. What is the function of programming code G42 in a CNC milling program?

A. Tool radius compensation right

B. Tool radius compensation on

C. Moving tool to the tool change point

D. Tool radius compensation left

Fill in the blanks

DNC	tool offset	absolute programming
automatic tool changer	polar coordinate system	incremental programming

16. In ____________________________ all measurements are made from the part origin.

17. ____________________________ allows tool change without the intervention of the operator.

18. On ___________________________, a point is defined by the radius vector and angle.

19. In ______________________________ a central computer controls the operations of one or more machines.

20. ____________________________ is the function used to correct the values entered in the coordinate system preset block.

Subjective:

21. State 4 example of manufacturing process where the CNC is applied.

____

____

____

____

22. Name 3 types of interpolation which has been used in CNC.

____

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____

23. A workpiece is to be machined with 2 flutes end-mill and 10mm diameter, if feed per tooth is 0.06mm and cutting speed is 60m/min, calculate the **RPM** and **feed rate** for this machining work.

____

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____

24. State the function/s of **Electronic Hand wheel** which available in CNC machines:

____

____

____

____

25. What is/are the function/s of "**Test run Mode**"?

26. What is the function of these miscellaneous codes?
    - M3:
    - M4:
    - M5:
    - M8:
    - M9:

27. What is the function of these "**G**" codes?
    - G90:
    - G91:
    - G94:
    - G95:
    - G4:

28. State the different between "**Manual operation mode**" and "**Manual Data Input** (MDI) mode" which available in CNC machines:

    "Manual operation mode":

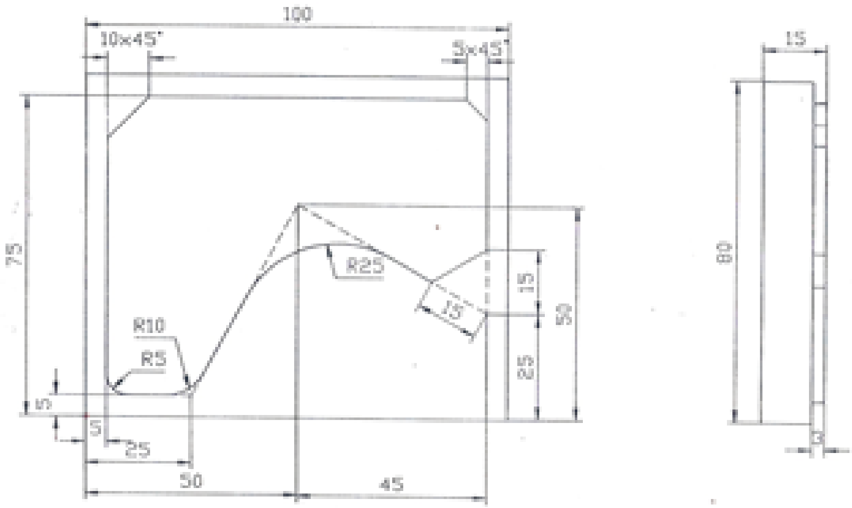
    "Manual Data Input (MDI) mode":

29. State the meaning of the following command functions from Heidenhain Conversational format:

Command function	Meaning?
CC+C	
CT	
RND	
L	
CR	

30. Explain the "Labels" for subprograms and program section repeats.

31. Write a complete contour program for the part below according to the Heidenhain ISO programming format. The tool and technological data given is as follows:
    - 4 flutes end-mill with diameter 16mm
    - Cutting speed 35m/min
    - Feed per tooth is 0.06mm



Appendix A-2. Pre-Test CNC Lathe and Programming

CNC 0632 CNC LATHE AND PROGRAMMING
DURATION 90 MINUTES

Student's Name : ______________________

Student's I/D No. : ______________________

Semester/Trade/Group : ______________________

Date : ______________________

Circle the correct answers

1. What is the acronym for CNC?
   A. Computer Numerical Constant
   B. Computer Numerous Control
   C. Common Number Computation
   D. Computer Numerical Control

2. In accordance with the control mode, CNC systems are subdivided into three basic categories that differ in their performance. Name three of control modes available in CNC system.
   A. Rapid, feed and slow traverse control
   B. Spindle, Turret and Table control
   C. RPM, Turret and Axes control
   D. Point to point, straight cut and contouring control

3. Name **three** controllable machine components of a CNC machine tool.
   A. Feed axes, feed drive & Measuring device
   B. Feed axes, drive screw & Measuring scale
   C. Feed screw, feed drive & Measuring device
   D. Feed axes, feed drive & rotary axes

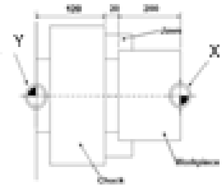
4. Computer Numerical Control is applied to a wide range of manufacturing processes. State four applications of CNC in that manufacturing process.
   A. Metal cutting, flame cutting, sheet metal forming and woodworking
   B. Sheet metal punching, water jet cutting, welding and laser cutting
   C. Metal cutting, welding, water jet cutting and laser cutting
   D. All of the above

5. A sheet on which working process and cutting process are expressed by numeric value and alphabetic symbol according to a predetermined rule is called:
   A. Block number or subprogram
   B. Address or block number
   C. Part program or machine program
   D. Subprogram or machine program

6. "**G0**" is a move command of a straight line rapid traverse and is used for positioning at programmed coordinates in CNC technology. What is the unit used to measure the movement of the rapid traverse for "**G0**" in CNC Lathe?

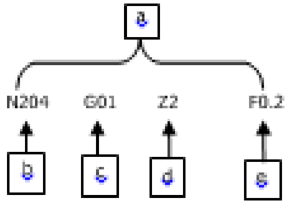
   A. Meter/minute
   B. Millimeter/revolution
   C. Millimeter/minute
   D. Revolution per minute

7. Name the symbols mark X and Y in the schematic diagram below.



   A. Y is machine home point, X is workpiece clamping point
   B. Y is machine zero point, X is workpiece zero point
   C. Y is machine reference point, X is workpiece zero point
   D. Y is chuck reference point, X is workpiece zero point

8. Choose the correct punching word in the program line below.



   A. a- command word, b-data, c-command word, d-address
   B. a-address, b-end of block, c-command word, d-Block number
   C. a-block, b-Block number, c-command word d-address, e-technology,
   D. a-end of block, b-Block number, c-command word, d-address

9. What is the function of programming code G40 in a CNC turning program?

   A. Moving tool to the tool change point
   B. Tool radius compensation off
   C. Tool radius compensation left
   D. Tool radius compensation right

10. A carbide insert with cutting speed of 200 m/min is used to machine a workpiece at 100mm in diameter. If the same cutting speed is used to machine a workpiece with at 80mm in diameter, what will happen to the spindle speed?

A. Spindle speed will reduce
B. Spindle speed will not change
C. Spindle speed will increase
D. Spindle feed will increase

11. "**G1**" is a move command of a straight line feed traverse and is used for cutting the workpiece in CNC technology. What is the unit used to measure the movement of the feed traverse for "**G1**" in CNC lathe?

A. Millimeter/minute
B. Meter/minute
C. Millimeter/revolution
D. Revolution per minute

12. What is the function of programming code **G41** in a CNC lathe program?

A. Moving to the tool change point
B. Tool radius compensation lift
C. Tool radius compensation right
D. Tool radius compensation left

13. The information that can be derived from the technical drawing of the component are;

I. Shape of the workpiece.
II. Size of material and machining allowance.
III. Material of workpiece.
IV. Dimension and accuracy.
V. Tool to be used.

Which is true or false?

A. I, II, III true
B. III, IV, V false
C. All false
D. All true

14. What is the unit used for the movement of "**G2**" and the feed traverse for CNC lathe?

A. Millimeter/revolution ..... clockwise
B. Millimeter/minute ...... clockwise
C. Meter/minute ..... counter-clockwise
D. Revolution per minute ..... counter-clockwise

15. What is the function of programming code G42 in a CNC turning program?

A. Tool radius compensation right
B. Tool radius compensation on
C. Moving tool to the tool change point
D. Tool radius compensation left

Fill in the blanks

DNC	tool offset	absolute programming
automatic tool changer	polar coordinate system	incremental programming

16. In ______________________ all measurements are made from the part origin.

17. ______________________ allows tool change without the intervention of the operator.

18. On ______________________, a point is defined by the radius vector and angle.

19. In ______________________ a central computer controls the operations of one or more machines.

20. ______________________ is the function used to correct the values entered in the coordinate system preset block.

Subjective:

21. State 4 example of manufacturing process where the CNC is applied.

____

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____

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22. Name 3 types of interpolation which has been used in CNC.

____

____

____

23. A workpiece with maximum diameter 120 mm is to be machined with a single tip carbide insert, if feed rate is 100 mm/min and cutting speed is 180 m/min, calculate the **RPM** and **feed rate in mm/rev** for this machining work.

____

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24. State the function/s of **Electronic Hand wheel** which available in CNC machines:

____

____

____

____

25. What is/are the function/s of "**Test run Mode**"?

26. What is the function of these miscellaneous codes?
    M3:
    M4:
    M5:
    M8:
    M9:

27. What is the function of these "**G**" codes?
    G90:
    G91:
    G94:
    G95:
    G4:

28. State the different between "**Manual operation mode**" and "**Manual Data Input** (MDI) mode" which available in CNC machines:

    "Manual operation mode":

    "Manual Data Input (MDI) mode":

29. State the meaning of the following command functions from CNC Traub programming format:

G2/G3 X/U Z/W R D/C

Command function	Meaning?
G2/G3	
X, Z	
U, W	
R	
D/C	

Appendix B-1. Post-Test CNC Milling and Programming

GMI German-Malaysian Institute

DIPLOMA PROGRAMME

FINAL EXAMINATION

Academic Period : July 2011

Subject	:	CNC MILLING AND PROGRAMMING
Code	:	CNC 0612
Duration	:	1.5 HOURS
Total Marks	:	100

GENERAL INSTRUCTIONS:

1. Write down clearly (with capital letters) your name, trade, group and the date of examination at the bottom of this page.
2. Do not open this question booklet until you are told to do so by the invigilator.
3. Read the specific instructions and questions carefully before answering.

This question paper consists of **9** printed pages including this page.

Student's Name	:	
Student's I/D No.	:	
Semester/Trade/Group	:	
Date	:	

CNC 0612 CNC MILLING AND PROGRAMMING

SECTION A: - 20 MARKS

Circle the correct answers for questions 1 to 20.

1. Name **three** controllable machine components of a CNC machine tool.

   A. Feed axes, drive screw & Measuring scale
   B. Feed axes, feed drive & rotary axes
   C. Feed axes, feed drive & Measuring device
   D. Feed screw, feed drive & Measuring device

2. What is the acronym for CNC?

   A. Computer Numerical Constant
   B. Common Number Computation
   C. Computer Numerous Control
   D. Computer Numerical Control

3. In accordance with the control mode, CNC systems are subdivided into three basic categories that differ in their performance. Name three of control modes available in CNC system.

   A. Point to point, straight cut and contouring control
   B. Spindle, Turret and Table control
   C. RPM, Turret and Axes control
   D. Rapid, feed and slow traverse control

4. A sheet on which working process and cutting process are expressed by numeric value and alphabetic symbol according to a predetermined rule is called:

   A. Subprogram or machine program
   B. Block number or subprogram
   C. Address or block number
   D. Part program or machine program

5. Computer Numerical Control is applied to a wide range of manufacturing processes. State four applications of CNC in that manufacturing process.

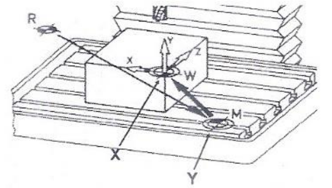
   A. Metal cutting, welding, water jet cutting and laser cutting
   B. Metal cutting, flame cutting, sheet metal forming and woodworking
   C. Sheet metal punching, water jet cutting, welding and laser cutting
   D. All of the above

CNC 0612 CNC MILLING AND PROGRAMMING

6. **"G0"** is a move command of a straight line rapid traverse and is used for positioning at programmed coordinates in CNC technology. What is the unit used to measure the movement of the rapid traverse for **"G0"** in CNC Milling?

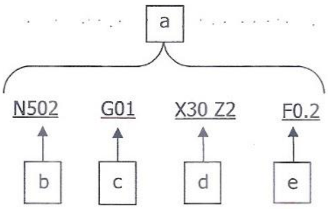
   A. Revolution per minute
   B. Meter/minute
   C. Millimeter/revolution
   D. Millimeter/minute

7. Name the symbols mark X and Y in the schematic diagram below.



   A. Y is machine home point, X is workpiece clamping point
   B. Y is machine zero point, X is workpiece zero point
   C. Y is machine reference point, X is workpiece zero point
   D. Y is chuck reference point, X is workpiece zero point

8. Choose the correct punching word in the program line below.



   A. a- command word, b-data, c-command word, d-address, e-technology
   B. a-address, b-end of block, c-command word, d-Block number, e-technology
   C. a-end of block, b-Block number, c-command word, d-address, e-technology
   D. a-block, b-Block number, c-command word d-address, e-technology

9. What is the function of programming code **G40** in a CNC Milling program?

   A. Tool radius compensation off
   B. Moving tool to the tool change point
   C. Tool radius compensation left
   D. Tool radius compensation right

10. "**G1**" is a move command of a straight line feed traverse and is used for cutting the workpiece in CNC technology. What is the unit used to measure the movement of the feed traverse for "**G1**" in CNC milling?

A. Meter/minute
Millimeter/minute
C. Revolution per minute
D. Millimeter/revolution

11. An end-mill with diameter **12mm** is used to machine workpiece with cutting speed of 30m/min. If the same value of cutting speed is used to machine the workpiece with end-mill diameter **8mm**, what will happen to the spindle speed?

A. Spindle speed will reduce
B. Spindle speed will increase
Spindle speed will not change
D. Spindle feed will increase

12. What is the function of programming code **G41** in a CNC program?

A. Moving to the tool change point
B. Tool radius compensation lift
C. Tool radius compensation left
D. Tool radius compensation right

13. The information that can be derived from the technical drawing of the component are;

I. Shape of the workpiece.
II. Size of material and machining allowance.
III. Material of workpiece.
IV. Dimension and accuracy.
V. Tool to be used.

Which is true or false?

A. I, II, III true
B. III, IV, V false
C. All false
D. All true

14. What is the unit used for the movement of "**G2**" and the feed traverse for CNC milling?

A. Millimeter/revolution ..... clockwise
B. Millimeter/minute ...... clockwise
C. Meter/minute ..... counter-clockwise
D. Revolution per minute ..... counter-clockwise

15. What is the function of programming code **G42** in a CNC milling program?

   A. Tool radius compensation right
   B. Tool radius compensation left
   C. Moving tool to the tool change point
   D. To activate the tool radius compensation on

16. What is the function of programming code **G17** in a CNC milling program?

   A. X and Z programming plane with tool axis Y
   B. X and Y programming plane with tool axis Z
   C. Y and Z programming plane with tool axis X
   D. Moving tool to the tool change point

17. What is the advantage, when the tool moves at constant cutting speed?

   A. To enable spindle rotate at constant revolution per minute
   B. To enable spindle rotates at high speed
   C. To enable tool perform cutting at high speed
   D. To provide better cutting performance for tool insert and tool life

18. After machining for a certain period of time the tool insert will wear. How these affect the **workpiece dimensions**?

   A. The tool diameter become smaller in size
   B. The workpiece will increase in size
   C. The total length of workpiece become shorter in size
   D. The workpiece will become rough

19. State three factors that affect metal cutting operations on CNC machines.

   A. Machine, tool & coolant
   B. Workpiece, material & CNC operator
   C. Spindle speed, cutting speed & NC program
   D. Feed rate, depth of cut & workpiece zero setting

20. Choose the correct statement of G30 and G31 code function in CNC milling ISO programming format for Heidenhain controller.

   A. G30 is a deep hole drilling cycle and G31is an automatic retraction.
   B. G30 and G31 is an external and internal threading cycle.
   C. G30 is a tapping cycle and G31 is tapping cycle call.
   D. G30 is the minimum and G31 is the maximum point for graphic definition.

CNC 0612 **CNC MILLING AND PROGRAMMING**

SECTION B – 80 MARKS

PART I – 10 MARKS

For questions 1 to 10, fill in the blanks with the correct answer given below:

miscellaneous codes	open-loop control system	cartesian coordinate system	absolute programming
cutting fluid	Tool magazine	closed-loop control system	direct numerical control (DNC),
spindle speed limit	tool length offsets	tool geometry offsets	subprogram
tool offset	polar coordinate system	incremental programming	main program

1. ________________________ is applied to reduce heat and increase tool life.

2. _____________________ allows tool change without the intervention of the operator.

3. On _____________________ a point is defined by the radius vector and angle.

4. _________________ _____ is the function used to correct the values entered in the coordinate system preset block.

5. _________________________ has two perpendicular axes in a two-dimensional surface, which is known as a plane.

6. ________________________ work like on/off switches for the function they control.

7. In ________________________ all measurements are made from the part origin.

8. The __________________________ are used to compensate for the tools that differ in length.

9. In ___________________ a central computer controls the operations of one or more machines..

10. A ________________________ is another program that can be called from the program being executed.

CNC 0612 CNC MILLING AND PROGRAMMING

PART II – 70 MARKS

1. Name 3 types of interpolation which has been used in CNC. 6 Marks

2. A 4 flutes end-mill cutter with diameter of 25mm is use to machine a workpiece on a CNC milling machine, if the feed per tooth is 0.08 mm and cutting speed is 80 m/min, calculate the **RPM** and **feed rate in mm/min** for this machining work. 6 Marks

3. State 4 examples of manufacturing process where the CNC is applied. 8 Marks

4. State the function of these miscellaneous codes below: 6 Marks

M3 :
M4 :
M5 :
M8 :
M9 :
M30 :

5. State the different between "**Manual operation mode**" and "**Manual Data Input** (MDI) mode" which available in CNC machines: 3 Marks

"Manual operation mode":

"Manual Data Input (MDI) mode":

CNC 0612 CNC MILLING AND PROGRAMMING

6. State the function/s of **Electronic Hand wheel** which available in CNC machines: 3 Marks

____

____

____

____

7. What is/are the function/s of **"Test run Mode"**? 3 Marks

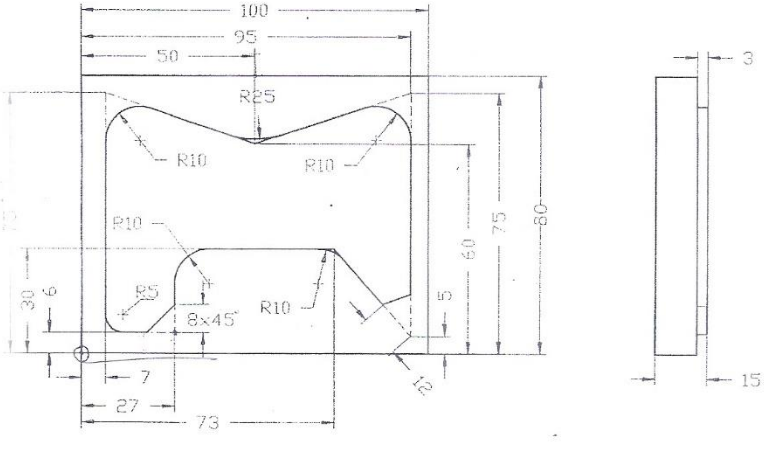
____

____

____

____

8. Write a complete contour program for the part below according to the Heidenhain ISO programming format. The tool and technological data given is as follows: 35 MARKS
   - 4 flutes end-mill with diameter 16mm
   - Cutting speed 35m/min
   - Feed per tooth is 0.06mm



Appendix B-2. Post-Test CNC Lathe and Programming

GMI German-Malaysian Institute

DIPLOMA PROGRAMME

FINAL EXAMINATION

Academic Period : January 2014

Subject	:	CNC TURNING & PROGRAMMING
Code	:	CNC 0622
Duration	:	1.5 HOURS
Total Marks	:	100

GENERAL INSTRUCTIONS:

1. Write down clearly (with capital letters) your name, trade, group and the date of examination at the bottom of this page.
2. Do not open this question booklet until you are told to do so by the invigilator.
3. Read the specific instructions and questions carefully before answering.

This question paper consists of **12** printed pages including this page.

Student's Name	:	______________
Student's I/D No.	:	______________
Semester/Trade/Group	:	______________
Date	:	______________

CNC 0622 CNC TURNING & PROGRAMMING

SECTION A – 15 MARKS

Answer all questions. Select the best answer for each item/question and shade your answer clearly on the OMR sheet provided. Use a 2B pencil only.

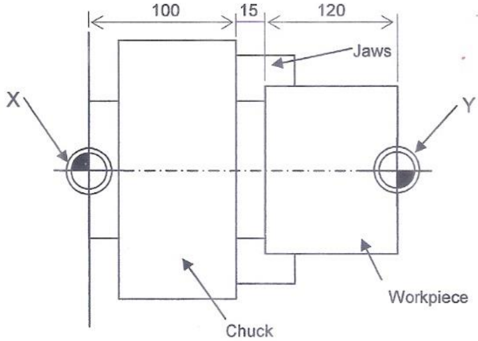
1. Which statement below is **not correct** about CNC machine and CNC machining?

   A. Nowadays CNC lathe machine are more sophisticated and user friendly.
   B. Nowadays CNC lathe machine necessarily needs proficiency in ISO programming.
   C. Nowadays CNC lathe machine incorporate specifically designed processors and CPUs built into the machine.
   D. Nowadays CNC lathe machine can still incorporate knowledge in conventional turning.

2. What do you think could be the first guideline to determine the best cutting speed and feed to machine a work piece using an insert?

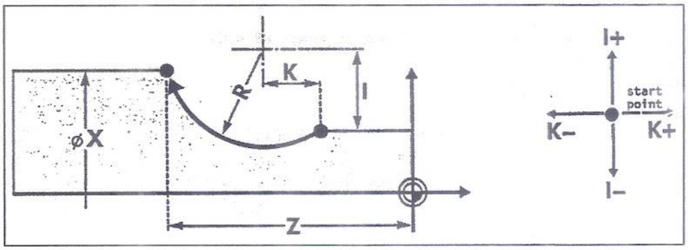
   A. By using calculation.
   B. By referring to manufacture's catalog.
   C. By experience and assumption.
   D. By trial and error method.

3. Name the symbols mark X and Y in the schematic diagram below.



   A. X is machine zero point, Y is workpiece zero point.
   B. X is machine reference point, Y is workpiece zero point.
   C. X is chuck reference point, Y is workpiece zero point.
   D. X is machine home point, Y is workpiece clamping point.

4. Logically, what do you think that we do not need to specify R when I and K are used to define the G2 movement below?



A. Distance from workpiece zero point to arc centre point already define the radius of the arc.
B. Distance from start point of the arc to the arc centre point already define the radius of the arc.
C. Distance from end point of the arc to the workpiece zero point already define the radius of the arc.
D. Distance from start point to the workpiece zero point already define the radius of the arc.

5. One of the statements below is **correct** about open loop or close loop system which is:

A. In open loop system, there is a feedback signals.
B. Close loop system is much more complex and expensive compared to open loop system.
C. Open loop system had a feedback signals that will correct any programmed position or velocity error due to unstable machining condition that are affected by load, temperature, humidity or lubrication.
D. The close loop system cannot verify whether the command did or not, commit an error.

6. During machining (CNC turning machine) the spindle rotates at various number of revolution per minute. Why this happen? Choose the correct statement for CNC turning machine.

A. The machine work with constant spindle speed.
B. The machine work with constant cutting speed.
C. The machine work with constant cutting feed.
D. None of the above.

7. After machining for a certain period of time the tool insert will wear. How this affect the workpiece dimensions?

A. The diameter of workpiece becomes smaller in size.
B. The total length of workpiece becomes shorter in size.
C. The workpiece will increase in diameter.
D. The work piece will become rough.

8. Which statement below is correct about types of control modes in CNC turning?

   A. Point to point controls permit positioning the tools at rapid traverse without engagement of cutting tool with the work piece.
   B. Point to point controls permit positioning the tools at rapid traverse with engagement of cutting tool with the work piece.
   C. In point to point control, each axis can be programmed individually to any desired feed rate.
   D. In point to point control, each axis can be programmed for contour movement.

9. Which is the best method of tool length setting in CNC lathe?

   A. By touching the tool at the rotating diameter of the workpiece.
   B. By touching the tool at the rotating end of the workpiece.
   C. By using tool presetting equipment or trial machining.
   D. By adjusting the machine parameter.

10. The most significant advantage of using canned cycle such as G71-Longitudinal Roughing cycle is to __________________.

    A. make the program run as single blocks, thus making the program longer
    B. provide for finished contour that could be stored as a subroutine
    C. simplify the program as the controller can execute these geometries calculations automatically
    D. be used for approach angle smaller than 90° and descending contour

11. **"G1"** is a move command of a straight line feed traverse and is used for cutting the workpiece in CNC technology. What is the unit used to measure the movement of the feed traverse for **"G1"** in CNC turning?

    A. Millimeter/revolution
    B. Meter/minute
    C. Millimeter/minute
    D. Revolution /minute

12. What does it mean by the sentence feed (F) is one of a modal code?

    A. This code stay in effect only for the blocks that they are programmed.
    B. This code work like on/off switches for the function they control.
    C. This code stay in effect until cancelled by another code in the same group.
    D. This code decide the movement and direction of the tool.

13. Why is CNC turning machines provide with spindle speed limitation function?

    A. To avoid the machine turret from moving too fast to avoid collision.
    B. To avoid the machine turret from moving too slow to avoid collision.
    C. To limit spindle from running at high rotational speed and to avoid damage the spindle bearings.
    D. To avoid spindle from running too long and damage the spindle shaft.

14. A steel raw material which is 80 mm in diameter had been turned on a CNC lathe with constant cutting speed of 340 m/min. What comparison could be expected if the same raw material with diameter of 56mm is going to be turned using constant cutting speed of 300 m/min.

    A. Spindle speed will reduce.
    B. Spindle speed will increase.
    C. Spindle speed will not change.
    D. Spindle will damage.

15. Select the correct method to key in the wear correction value for the insert at the machine after tool wear had been identified.

    A. Key in the different value for both X and Z length of the part produced compare to the actual desired dimension.
    B. No need to key in since the machine can compensate itself.
    C. Key in the different value for X length of the part produced compare to the actual desired dimension.
    D. Key in the different value for Z length of the part produced compare to the actual desired dimension.

SECTION B – 85 MARKS

This paper consists of two (2) parts: Part I and Part II.

PART I – 10 MARKS

For questions 1 to 10, fill in the blanks with the correct answer given below.

coordinate Cartesian system	interpolator software	preparatory codes	absolute programming
cutting fluid	slipping clutch	dwell	direct numerical control (DNC)
spindle speed limit	tool length offsets	miscellaneous codes	polar coordinate system

1. ____________________ that can be coupled with the feed drive ensure feed mechanisms suffer minimum damage in the event of unintentional collisions.

2. ____________________ CNC machine controller coordinates the movement of each axis by calculating target point along the intended path.

3. ____________________ decide the mode of the system and execute the programmed information.

4. The ____________________ are used to compensate for the tools that differ in length.

5. ____________________ is applied to reduce heat and increase tool life.

6. The ____________________ is programmed using the G04 code to stop the tool motion.

7. In ____________________ a central computer controls the operations of one or more machines.

8. On ____________________, a point is defined by the radius vector and angle.

9. The ____________________ is the maximum spindle RPM which will not be exceeded even if a higher speed is entered later in the program.

10. ____________________ has two perpendicular axes in a two-dimensional surface, which is known as a plane.

CNC 0622 CNC TURNING & PROGRAMMING

PART II - 75 MARKS

Write your answer in the blank space provided below the questions.

1. Describe the definition of machine and work part coordinate system. **4 Marks**

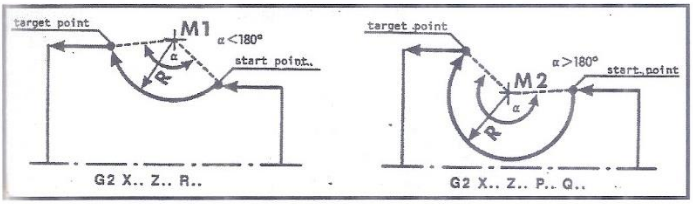
2. State 5 major factors that affect metal cutting operations on CNC machines. **5 Marks**

3. State the function of these CNC Turning codes below. **8 Marks**

M03 :
M04 :
M05 :
M08 :
G01 :
G96 :
G46 :
G92 :

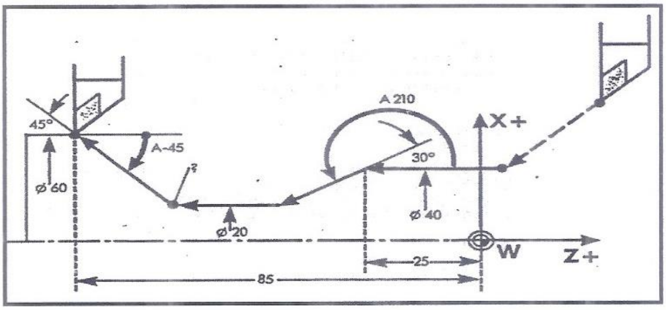
4. Name 4 types of interpolation which has been used in CNC. **4 Marks**

5. Describe the rules of Circular Arc G2 and G3. **6 Marks**



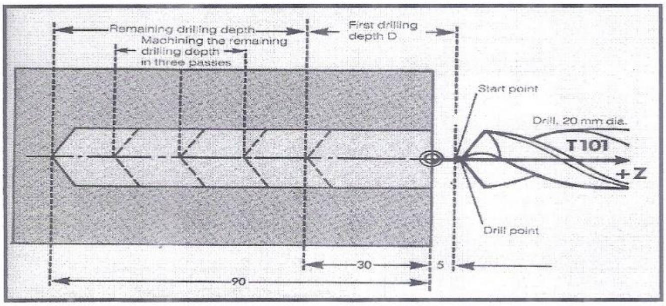
6. A work piece of diameter **0.062 m** is to be machined on a CNC lathe machine, if the feed 220 mm/min and cutting speed is **300 m/min**, calculate the RPM minimum and feed rate in mm/rev for this machining work. **6 Marks**

7. Program the contour by using angle (A) function. **8 Marks**



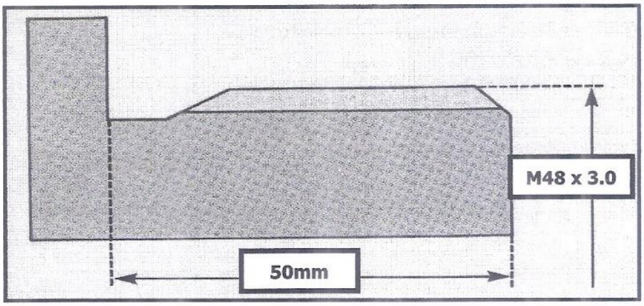
8. Program the drilling cycle by using G83.

5 Marks



9. Complete the program of G76 thread cycle below by fill in the blanks. The external thread of **M48** with thread pitch of **3.0mm**, length of thread is **50mm** as shown below:

8 Marks



10. State 3 fundamental design principles for mechanical built of machines.

3 Marks

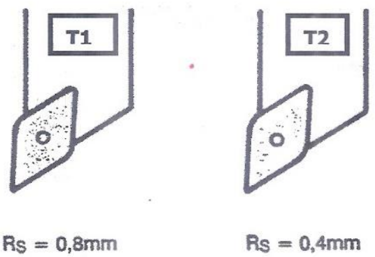
CNC 0622 CNC TURNING & PROGRAMMING

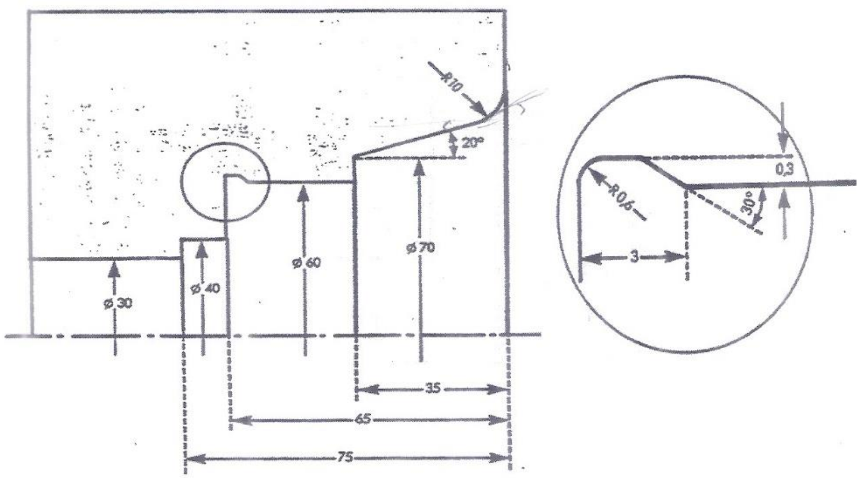
11. Prepare the **full program with header G54 by using ISO programming format**. Please state your own block number sequence and tool selection by facing, roughing, finishing for internal turning process.

18 Marks

Cutting parameter and ISO G & M codes can use:

T0101 (roughing/ facing) = G96 V200 T_____ M4 M8
T0202 (finishing) = G96 V250 T_______ M4 M8
Feed rate = 0.2 mm/rev
G92 S_____ Q_______
G71 P_ Q_ I_ K_ D_ F_ E_ (Using longitudinal roughing cycle)

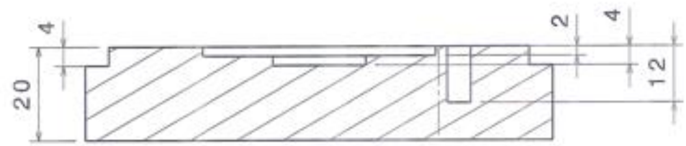




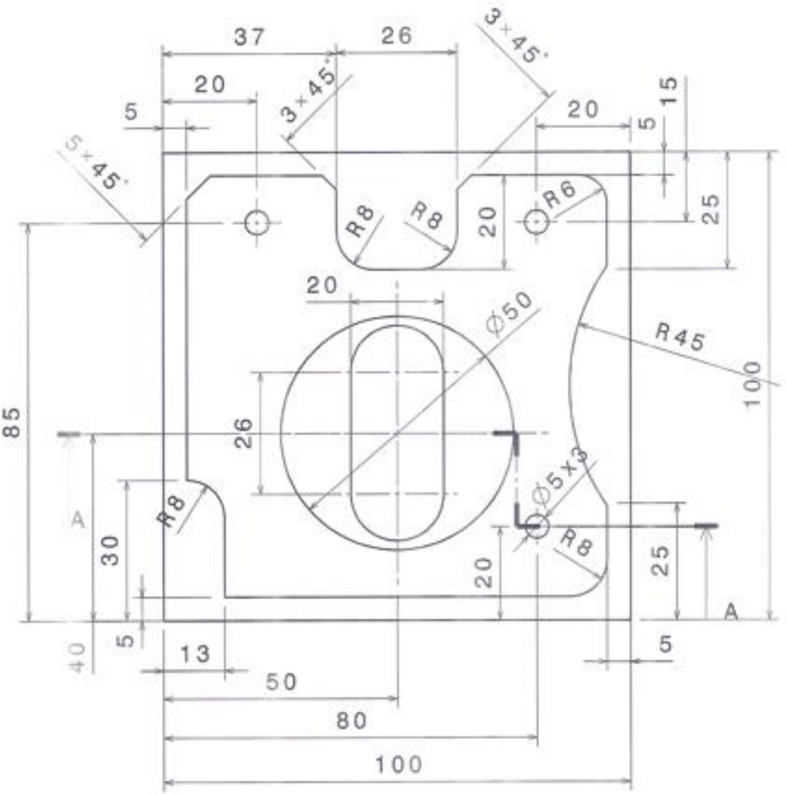
Appendix C-1. CNC Milling Programming Test One and Two

CNC Milling Programming Test One

1- Write a contour NC program for the workpiece below on a piece of paper. Determine the appropriate tool to machine the contour. Determine the cutting speed for the tool and calculate the spindle speed and feed rate needed for the contour programming. (1 hour).

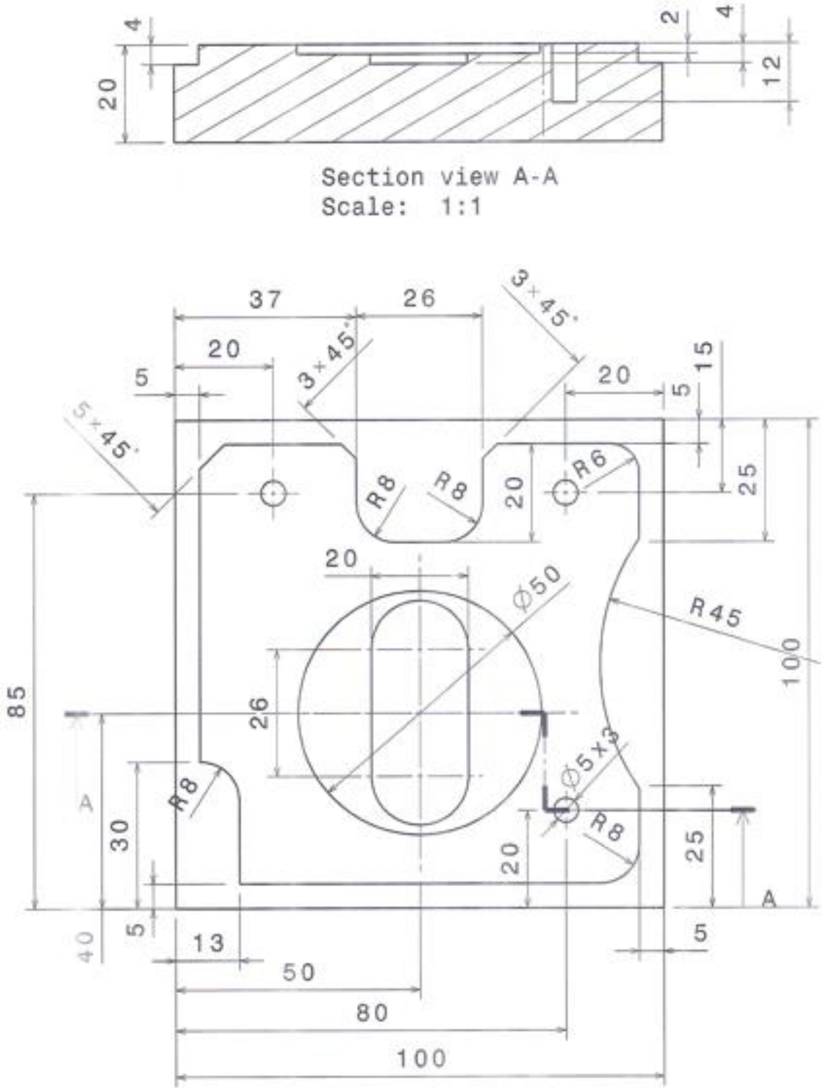


Section view A-A
Scale: 1:1



CNC Milling Programming Test Two

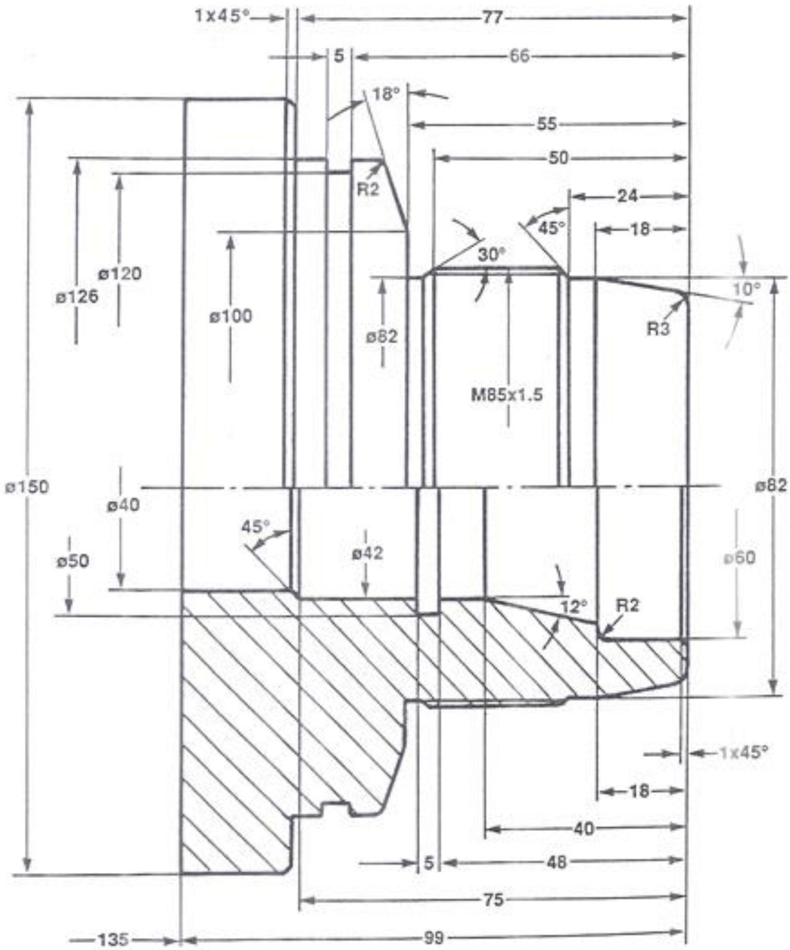
2- Produce a complete NC program for the workpiece below with contour, drilling and pocket milling. Determine the appropriate tools to machine the contour, slot, and circular pocket as well as the holes. Determine the cutting speed for all tools and calculate the spindle speed and feed rate needed in the programming. The CNC programming should be done in the CNC simulator. The program should be checked with the Wire-frame" and Test Run" simulation without errors. (2 hours).



Appendix C-2. CNC Lathe Programming Test One and Two

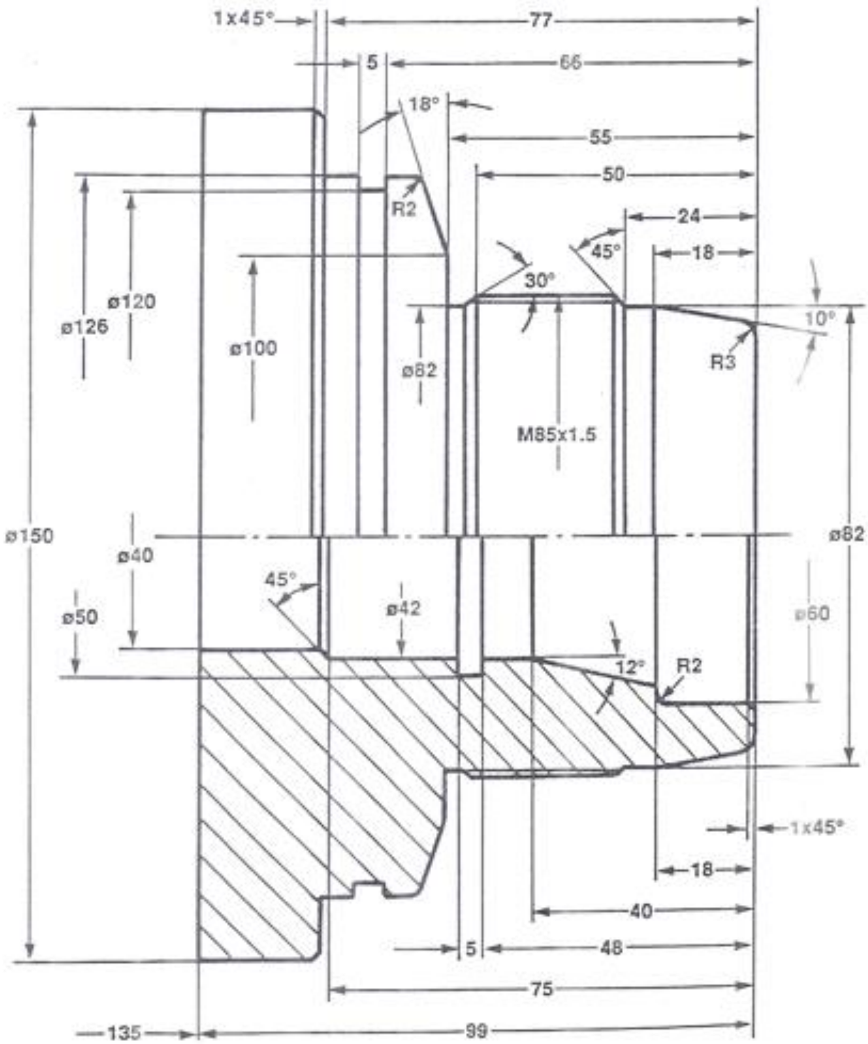
CNC Lathe Programming Test One

1- Write the external and internal contours NC program for the workpiece below on a piece of paper. Determine the appropriate tool to machine the external and internal contours. Determine the cutting speed for the tool and calculate the spindle speed and feed rate needed for the contour programming. (1 hour).



CNC Lathe Programming Test Two

2- Produce a complete NC program for the workpiece below with external and internal contours, drilling, grooving and threading. Determine the appropriate tools to machine the contours, grooves, and thread. Determine the cutting speed for all tools and calculate the spindle speed and feed rate needed in the programming. The CNC programming should be done in the CNC simulator. The program should be checked with the Wire-frame" and Test Run" simulation without errors. (2 hours).



Appendix D-1. Students' Questionnaire Form

QUESTIONNAIRE FORM

The objective of this questionnaire is to find out the students' perception, awareness and obstacles or challenges on Problem-Based Learning (PBL) approach implementation in Technical Vocational and Training - TVET (CNC programming courses in GMI).

Objektif soal selidik ini adalah untuk membuat tinjauan tentang persepsi, kesedaran dan halangan-halangan atau cabaran-cabaran pelajar-pelajar dalam melaksanakan pendekatan pembelajaran berasaskan masalah (PBL) dalam Pendidikan Teknikal Vokasional dan Latihan - TVET (CNC kursus pengaturcaraan di GMI).

Section A: Student's Background
Please circle the appropriate facts about yourself. All information and feedback are confidential.

Sila bulatkan fakta-fakta yang sesuai tentang diri anda. Semua maklumat dan maklum-balas anda adalah rahsia.

Semester:	3	4												
Trade/Group:	CPT	CPT1	CPT2	CPT3	TDT	TDT1	TDT2	TDT3	MOT					
Gender:	Male	Female												
Age (years):	17	18	19	20	21	22	23	24	25	26	27	28	29	Above 30

Education before GMI:						
SPM	IKM	IKBN	ILP	Community Collage	Polytechnic	
STPM	KKTM	IKTBN	ADTEC	Giat MARA	JMTI	Others

Sections B, C and D of this questionnaire have a number of questions about your perception, awareness and challenges/obstacles on PBL in TVET (CNC programming courses in GMI). Please choose the one that you think most appropriate response to each question. Please circle the appropriate response alongside the question.

Bahagian-bahagian B, C dan D pada soal selidik ini mempunyai beberapa soalan mengenai persepsi, kesedaran dan cabaran/halangan PBL dalam TVET (kursus pengaturcaraan CNC di GMI). Sila pilih salah satu gerak-balas yang anda fikir paling sesuai untuk setiap soalan. Sila bulatkan gerak-balas yang sesuai yang sebaris dengan soalan.

1- Strongly disagree 2- Disagree 3- Undecided 4- Agree 5- Strongly Agree						
1-Sangat tidak bersetuju 2-Tidak bersetuju 3-Tidak pasti 4-Bersetuju 5-Sangat bersetuju						
No.	**Description** *(Butiran)*	**1**	**2**	**3**	**4**	**5**
	Section B: Student's Perception on Problem-Based Learning. ***Persepsi pelajar terhadap pembelajaran berasaskan masalah.***					
1.	PBL enhanced application of my prior knowledge. *(PBL meningkatkan penggunaan pengetahuan lepas saya.)*	1	2	3	4	5
2.	PBL helped me to develop myself to be a self-directed learner. *(PBL membantu dalam membentuk diri saya untuk menjadi seorang pelajar kendiri.)*	1	2	3	4	5
3.	PBL helped me to develop myself to be an active learner. *(PBL membantu dalam membentuk diri saya untuk menjadi seorang pelajar yang aktif.)*	1	2	3	4	5
4.	PBL stimulated my thinking process. *(PBL merangsang proses pemikiran saya.)*	1	2	3	4	5
5.	PBL helped to develop my skills in technical reasoning and decision making. *(PBL membantu dalam membentuk kemahiran berfikir saya dalam teknikal dan membuat keputusan.)*	1	2	3	4	5
6.	PBL helped to develop my skills in problem solving and critical thinking. *(PBL membantu membentuk kemahiran saya dalam menyelesaikan masalah dan pemikiran kritikal.)*	1	2	3	4	5
7.	PBL developed and improved my communication skills. *(PBL membentuk dan meningkatkan kemahiran komunikasi saya.)*	1	2	3	4	5
8.	PBL developed and enhanced my level of confidence in public speaking. *(PBL membentuk dan meningkatkan tahap keyakinan dalam pengucapan awam saya.)*	1	2	3	4	5
9.	I learnt more when seeking for solutions for the issues of learning. *(Saya lebih banyak belajar ketika mencari penyelesaian bagi isu-isu pembelajaran.)*	1	2	3	4	5
10.	PBL improved my teamwork spirit. *(PBL meningkat semangat kerja berpasukan saya.)*	1	2	3	4	5
11.	I learnt better during group interactions in the PBL. *(Saya belajar lebih baik ketika interaksi kumpulan di dalam PBL.)*	1	2	3	4	5
12.	PBL taught me learn how to learn. *(PBL mengajar saya belajar bagaimana untuk belajar.)*	1	2	3	4	5
	Section C: Student's Awareness on Problem-Based Learning. ***Kesedaran pelajar terhadap pembelajaran berasaskan masalah.***					
13.	I am aware of the rationale for implementing PBL in the CNC programming courses. *(Saya sedar rasionalnya untuk melaksanakan PBL dalam kursus-kursus pengaturcaraan CNC.)*	1	2	3	4	5
14.	I am aware of the competencies that could be acquired from PBL approach. *(Saya sedar tentang kecekapan-kecekapan yang boleh diperolehi daripada pendekatan PBL.)*	1	2	3	4	5
15.	I am aware that students are self-directed learning in PBL approach. *(Saya sedar bahawa pelajar mengamalkan pembelajaran kendiri dari pendekatan PBL.)*	1	2	3	4	5
16.	I am aware about the importance of small group discussions in PBL approach. *(Saya sedar tentang kepentingan perbincangan dalam kumpulan kecil dengan pendekatan PBL.)*	1	2	3	4	5
17.	I am aware that PBL approach could stimulate students' learning. *(Saya sedar bahawa pendekatan PBL boleh merangsang pembelajaran pelajar.)*	1	2	3	4	5

1- Strongly disagree 2- Disagree 3- Undecided 4- Agree 5- Strongly Agree						
1-Sangat tidak bersetuju 2-Tidak bersetuju 3-Tidak pasti 4-Bersetuju 5-Sangat bersetuju						
No.	**Description *(Butiran)***	**1**	**2**	**3**	**4**	**5**
18.	I am aware that PBL approach could improve students' communication skills. *(Saya sedar bahawa pendekatan PBL dapat meningkatkan kemahiran komunikasi pelajar.)*	1	2	3	4	5
19.	I am aware that PBL approach could develop students to be an active learner. *(Saya sedar bahawa pendekatan PBL dapat membentuk pelajar menjadi pelajar yang aktif.)*	1	2	3	4	5
20.	I am aware that PBL approach could train students to think critically. *(Saya sedar bahawa pendekatan PBL boleh melatih pelajar untuk berfikir secara kritikal.)*	1	2	3	4	5
21.	I am aware that PBL approach could develop skills in problem solving. *(Saya sedar bahawa pendekatan PBL dapat membentuk kemahiran dalam menyelesaikan permasalahan.)*	1	2	3	4	5
22.	I am aware that PBL approach could enhance intrinsic motivation of students. *(Saya sedar bahawa pendekatan PBL dapat meningkatkan motivasi intrinsic/dalaman pelajar.)*	1	2	3	4	5
	Section D: Challenges/obstacles in Problem-Based Learning implementation. *Cabaran/halangan dalam perlaksanaan pembelajaran berasaskan permasalahan.*					
23.	I am complaisant with traditional learning methods as compared to PBL. *(Saya lebih selesa dengan kaedah pembelajaran tradisional berbanding PBL.)*	1	2	3	4	5
24.	I have the mind-set that *"PBL is actually putting the burden of educating to the students"*. *(Saya mempunyai set-minda bahawa "PBL adalah sebenar meletakkan beban mendidik kepada pelajar".)*	1	2	3	4	5
25.	I have difficulties to determine the learning objectives. *(Saya menghadapi kesukaran untuk menentukan objektif pembelajaran.)*	1	2	3	4	5
26.	Literature resources (TVET) related to the problem is limited. *(Sumber literasi (TVET) yang berkaitan dengan masalah adalah terhad.)*	1	2	3	4	5
27.	Time constraint to figure out on the problem and seek the learning issues in more depth. *(Kekangan dengan masa untuk memikirkan tentang masalah dan mencari isu-isu pembelajaran secara lebih mendalam.)*	1	2	3	4	5

Appendix E-1. Student's Interview Guideline

Guideline for Group Interview (Students)

PBL

1. Experience
    a. When was PBL first introduced to you?
    b. What are the courses/subjects that you have experience with PBL approach?

2. Awareness
    a. Do you know what actually PBL is?

3. Perception
    a. Generally, what do you feel/think about PBL?
    b. Knowledge gained
        i. Do you feel PBL approach help you in acquiring new knowledge? If yes, how? If not, why?
    c. Skills gained
        i. Do you feel PBL approach help you in acquiring technical skills? If yes, how? If not, why?
        ii. Do you feel PBL approach help you in acquiring generic skills (communication, problem solving, teamwork)? If yes, how? If not, why?
        iii. Do you feel PBL approach stimulated your problem-solving skill? If yes, how? If not, why?
        iv. Do you think PBL approach develops better problem-solving skills?
    d. Teamwork
        i. Do you feel PBL approach stimulated your teamwork? If yes, how? If not, why?

4. Challenges/obstacles
    a. What do you feel the challenges/obstacles for you as a student to adapt PBL approach in your learning?

5. Motivation
    a. What are your motivations for learning through PBL approach?

CNC simulator

a. Do CNC simulator benefits you in the CNC programming course adopting PBL approach? If yes, how? If not, why?

Others

a. Do you feel the problem statement was adequate and understood?
b. Do you feel the scaffolding to the problem was adequate and helpful?
c. Do you want to add anything to this interview?

Appendix F-1. Letter of consent

AALBORG UNIVERSITET

Department of Development and Planning
Vestre Havnepromenade 5
9000 Aalborg

Letter of Consent

Dear GMI Student:

You are being selected to participate in a research study that being conducted by Hashim bin Mohamad, a PhD student at the University of Aalborg, Denmark. The research aims to investigate the impact on students' competencies and whether PBL approach has contributed to the development of students' generic skills especially in communication, problem solving and teamwork. The three elements of generic skills (top three industries' requirement) are important to ensure the Technical Vocational Education and training (TVET) providers stay relevant in producing workforces with competencies as required by the industry.

As part of this study, the researcher will be observing with voice and video recording the PBL's activities from time to time. You are expected to be involved in several assessments' activities namely self-assessment and peer-assessment as well as group interview and a questionnaire that require your opinion about problem-based learning. The focus group interview and questionnaires are confidential and they will take approximately 10 minutes to complete the questionnaire and 30 to 60 minutes for interview.

Your participation in this study will contribute to the literature and knowledge enriches related to problem-based learning. The findings of this research study will help the educators in TVET to develop and improve the training approach that will best contribute to the development of students' generic skills and learning needs.

I, ____ understand and agree to the following that:

1. My participation is on voluntary basis and I may withdraw at any time without obligation.
2. The personal information and data derived my participation in the study will be confidentially maintained at all times and will be only used for the research purposes, as part of the researcher's doctoral thesis and in journal or article publications.
3. My assessments and responses to the questionnaires as well as interview are for the purpose of data analysis.
4. The researcher will be observing and video recording some of the PBL's activities from time to time.
5. The focus group interview session will be voice recorded and transcribed.
6. Should I have any questions, I can contact Hashim bin Mohamad (Hashim@plan.aau.dk) at The Department of Development and Planning, Aalborg university, Denmark (+4550655613 or +60195112900).

______________________ Signature	______________________ Date

Appendix G-1. Observational Tool for Facilitator Participant Observer

Observational Tool

Semester:	3		4						
Trade/Group:	CPT	CPT1	CPT2	CPT3	TDT	TDT1	TDT2	TDT3	MOT
Sub-group	1	2	3	4	5				

Please evaluate the criteria by using the scale below:

1- Poor 2- Fair 3- Good 4- Very Good 5- Excellent

Criteria	PBL1	PBL2	PBL3	PBL4	PBL5	Remarks
Application of knowledge						
Demonstrating the application of prior knowledge						
Demonstrating the ability to adapt and apply relevant concepts						
Self-Directed Learning						
Demonstrating the ability to set and achieve the learning objectives						
Demonstrating the ability to search relevant information from various learning resources independently.						
Demonstrating the ability to be more self-directed with the help of CNC simulator.						
Technical reasoning & Decision making Skills						
Demonstrating the ability to make appropriate decision to the problem.						
Demonstrating the ability to give technical reasoning to the decision made.						
Problem Solving & Critical Thinking Skills						
Demonstrating the ability to solve problems in an appropriate manner.						
Demonstrating the ability to think critically to the issues in the problem.						
Team work						
Demonstrating the ability to conduct an effective group meeting/discussion.						
Demonstrating a good and active interaction among the group members.						
Demonstrating the ability to contribute and exchange of ideas in the group discussion.						
Demonstrating the ability to work towards the attainment of the team's learning objectives.						
Communication Skills						
Demonstrating the ability to speak clearly, proficient with language in group discussion and presentation.						
Demonstrating the ability to explain and present confidently in the group meeting and oral presentation.						
Demonstrating the ability to deliver the content very well and understood by audience.						
Demonstrating the ability to place the appropriate words to the thoughts that want to explain.						
Demonstrating the ability to listen and answer to the questions very well.						
CNC Simulator						
Demonstrating the ability to help student in decision making & problem solving.						
Comments:						

Appendix G-2. Observational Tool Rubric for Facilitator Participant Observer

Observational Tool Rubric

	4- Very Good	3- Good	2- Fair	1-Poor
Application of knowledge	-Demonstrating outstanding application of prior knowledge. -Demonstrating outstanding ability to adapt and apply relevant concepts.	-Demonstrating the application of prior knowledge that meet the expectation. -Demonstrating the ability to adapt and apply relevant concepts that meet the expectation.	-Demonstrating satisfactory application of prior knowledge. -Demonstrating satisfactory ability to adapt and apply relevant concepts	-Fail to apply prior knowledge. - Fail to adapt and apply relevant concepts.
Self-Directed Learning	-Demonstrating outstanding ability to set and achieve the learning objectives. -Demonstrating outstanding ability to search relevant information from various learning resources independently. -Demonstrating outstanding ability to be more self-directed with the help of CNC simulator.	-Demonstrating the ability to set and achieve the learning objectives that meet the expectation. -Demonstrating the ability to search relevant information from various learning resources independently that meet the expectation. -Demonstrating the ability to be more self-directed with the help of CNC simulator that meet the expectation.	-Demonstrating satisfactory ability to set and achieve the learning objectives. -Demonstrating satisfactory ability to search relevant information from various learning resources independently. -Demonstrating satisfactory ability to be more self-directed with the help of CNC simulator.	-Fail to set and achieve the learning objectives. -Fail to search relevant information from various learning resources independently. -Fail to be self-directed with the help of CNC simulator.
Technical reasoning & Decision making Skills	-Demonstrating outstanding ability to make appropriate decision to the problem. -Demonstrating outstanding ability to give technical reasoning to the decision made.	-Demonstrating the ability to make appropriate decision to the problem that meet the expectation. -Demonstrating the ability to give technical reasoning to the decision made that meet the expectation.	-Demonstrating satisfactory ability to make appropriate decision to the problem. -Demonstrating satisfactory ability to give technical reasoning to the decision made.	-Fail to make appropriate decision to the problem. - Fail to give technical reasoning to the decision made.
Problem Solving & Critical Thinking Skills	-Demonstrating outstanding ability to solve problems in an appropriate manner. -Demonstrating outstanding ability to think critically to the issues in the problem.	-Demonstrating the ability to solve problems in an appropriate manner that meet the expectation. -Demonstrating the ability to think critically to the issues in the problem that meet the expectation.	-Demonstrating satisfactory ability to solve problems in an appropriate manner. -Demonstrating satisfactory ability to think critically to the issues in the problem.	- Fail to solve problems in an appropriate manner. - Fail to think critically to the issues in the problem.
Team work	-Demonstrating outstanding ability to conduct an effective group meeting/discussion. -Demonstrating a very good and active interaction among the group members. -Demonstrating outstanding ability to contribute and exchange of ideas in the group discussion. -Demonstrating outstanding ability to work towards the attainment of the team's learning objectives.	-Demonstrating the ability to conduct an effective group meeting/discussion that meet the expectation. -Demonstrating a good and active interaction among the group members that meet the expectation. -Demonstrating the ability to contribute and exchange of ideas in the group discussion that meet the expectation. -Demonstrating the ability to work towards the attainment of the team's learning objectives that meet the expectation.	-Demonstrating satisfactory ability to conduct an effective group meeting/discussion. -Demonstrating a satisfactory active interaction among the group members. -Demonstrating satisfactory ability to contribute and exchange of ideas in the group discussion. -Demonstrating satisfactory ability to work towards the attainment of the team's learning objectives.	- Fail to conduct an effective group meeting/discussion. - Fail to have active interaction among the group members. - Fail to contribute and exchange of ideas in the group discussion. - Fail to work towards the attainment of the team's learning objectives.
Communication Skills	-Demonstrating outstanding ability to speak clearly, proficient with language in group discussion and presentation. -Demonstrating outstanding ability to explain and present confidently in the group meeting and oral presentation. -Demonstrating outstanding ability to deliver the content very well and understood by audience. -Demonstrating outstanding ability to place the appropriate words to the thoughts that want to explain. -Demonstrating outstanding ability to listen and answer to the questions very well.	-Demonstrating the ability to speak clearly, proficient with language in group discussion and presentation that meet the expectation. -Demonstrating the ability to explain and present confidently in the group meeting and oral presentation that meet the expectation. -Demonstrating the ability to deliver the content well and understood by audience that meet the expectation. -Demonstrating the ability to place the appropriate words to the thoughts that want to explain that meet the expectation. -Demonstrating the ability to listen and answer to the questions well that meet the expectation.	-Demonstrating satisfactory ability to speak clearly, proficient with language in group discussion and presentation. -Demonstrating satisfactory ability to explain and present confidently in the group meeting and oral presentation. -Demonstrating satisfactory ability to deliver the content very well and understood by audience. -Demonstrating satisfactory ability to place the appropriate words to the thoughts that want to explain. -Demonstrating satisfactory ability to listen and answer to the questions very well.	- Fail to speak clearly, proficient with language in group discussion and presentation. - Fail to explain and present confidently in the group meeting and oral presentation. - Fail to deliver the content very well and understood by audience. - Fail to place the appropriate words to the thoughts that want to explain. - Fail to listen and answer to the questions very well.

Appendix H-1. Example of the PBL Timetable

Table 3-6: Example of the PBL Timetable.

PRO3BL TIMETABLE

SUBJECT:	CNC MILLING AND PROGRAMMING - CNC 0612				
TOTAL UNITS:	75	Lecture/PBL 40%:	30 Hrs	Actual Lecture/PBL:	41%
GROUP:	S3CPT	Practical 60%:	45 Hrs		

1 UNIT = 1 HOUR

TRAINING WEEK (TW)	1	1	2	2	2&3	3	4	4 & 5	5	6	6	7	7	8			TOTAL UNITS	%
TEACHING UNITS (TU)	5.00	5.00	4.25	3.00	7.75	5.00	5.00	10.25	5.00	5.00	5.00	5.00	5.00	4.75		0.00	75	100%
LECTURE	0.50	1.50	0.50		2.00												4.50	6.00%
PRO3BL STATEMENT NO	PBL1	PBL2	PBL3	PBL3	PBL3			PBL4										
PRO3BL UNITS	4.50	3.50	3.75	3.00	5.25	0.00	0.00	5.25	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.25	35.00%
1- Discuss in Group: Explore Problem	0.25	0.25	0.50	0.25	0.25			0.25									1.75	6.67%
2- Discuss in Group: List 3 Ks	0.25	0.25	0.25	0.25	0.25			0.25									1.50	5.71%
3- Discuss in Group: List Actions to be taken according to timeline	0.25	0.25	0.25	0.25	0.25			0.25									1.50	5.71%
4-Perform Self Study	0.25	0.25	0.25	0.25	0.50			0.50									2.00	7.62%
5-Group work: Exchange Knowledge & List out Possible Solutions	2.00	1.00	0.75	0.50	2.00			2.00									8.25	31.43%
6-Present Findings & QA	0.50	0.50	1.00	1.00	1.00			1.00									5.00	19.05%
7-Reflections	1.00	1.00	0.75	0.50	1.00			1.00									5.25	20.00%
ASSESSMENT /REFLECTION									1.00								1.00	3.81%
PROJECT-BL/PRACTICAL WORK					0.50	5.00	5.00	5.00	4.00	5.00	5.00	5.00	5.00	4.75			44.25	59.00%
TOTAL 75.00	5.00	5.00	4.25	3.00	7.75	5.00	5.00	10.25	5.00	5.00	5.00	5.00	5.00	4.75	0.00	0.00	75.00	100.00%

Appendix I-1. Example of PBL Activities in the CNC Programming Courses

Figure A: Environment in at a computer lab with students working with the CNC milling simulator.

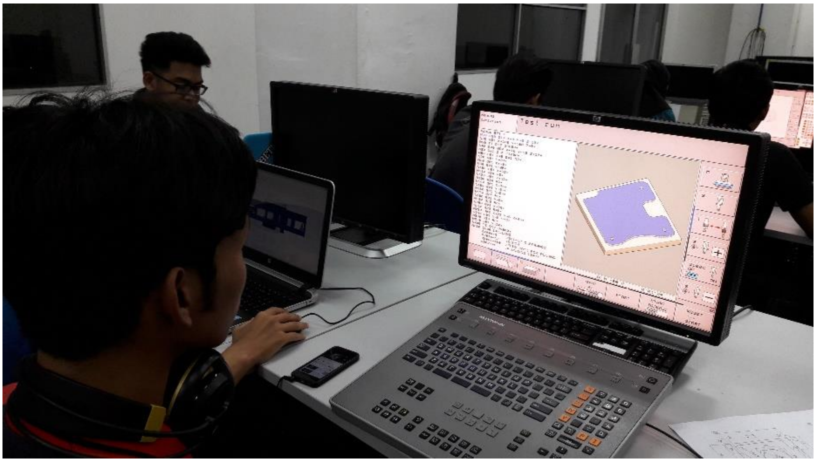


Figure B: Students in a computer lab working with the CNC milling simulator.

Figure C: Environment in at a computer lab with students working with the CNC lathe simulator.

Figure D: Students in a computer lab working with the CNC lathe simulator.

Figure E: Example one of a NC program produced by the students.

Figure F: Example two of a NC program produced by the students.

Figure G: Environment in a PBL room with students in a discussion during the PBL session.

Figure H: Students in a discussion during the PBL session.

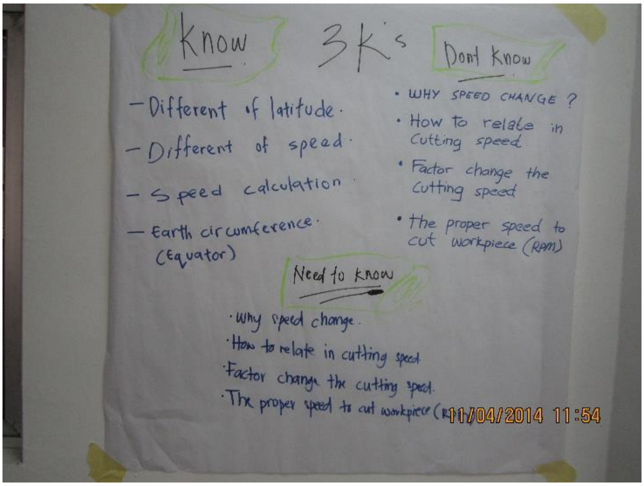


Figure I: Example one of the output of students' discussion on 3-Ks during the PBL session.

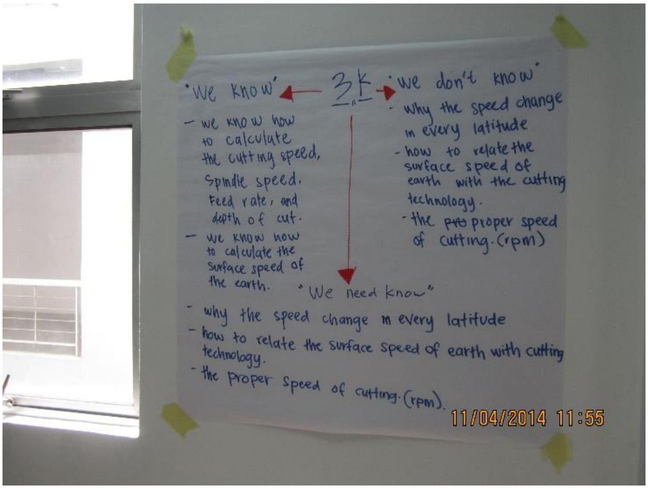


Figure J: Example two of the output of students' discussion on 3-Ks during the PBL session.

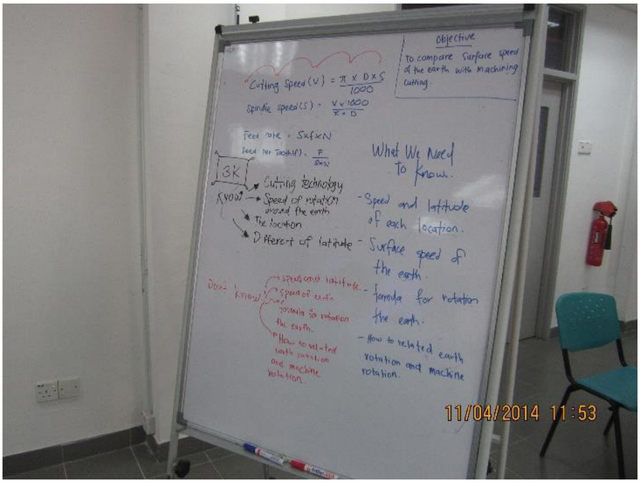


Figure K: Example three of the output of students' discussion on 3-Ks during the PBL session.

Figure L: Environment in the students' presentation during their PBL session.

Appendix J-1. Student's Self-Assessment of Likert-Scale

Self-assessment

Student's Name : ______________________

Student's I/D No. : ______________________

Semester/Trade/Group : ______________________

Date : ______________________

1- Strongly disagree 2- Disagree 3- Undecided 4- Agree 5- Strongly Agree						
No.	**Description**	**1**	**2**	**3**	**4**	**5**
	Application of knowledge (Aplikasi Pengetahuan)					
1.	I am able to apply my prior knowledge to solve new problem (i.e. conventional machine to CNC machine). *Saya berupaya menggunakan pengetahuan terdahulu saya untuk menyelesaikan masalah baru (Mesin konvensional kepada Mesin CNC).*	1	2	3	4	5
2.	I am able to adapt and apply relevant concepts to new problem's situation (i.e. ISO programming concept to conversational programming). *Saya berupaya menyesuaikan dan mengaplikasi konsep-konsep yang berkaitan dengan keadaan masalah baru (iaitu konsep pengaturcaraan ISO kepada pengaturcaraan perbualan).*	1	2	3	4	5
	Self-Directed Learning (Pembelajaran Kendiri)					
3.	I am able to set learning objectives and achieve it. *Saya berupaya menetapkan objektif-objektif pembelajaran dan mencapainya.*	1	2	3	4	5
4.	I am able to search relevant information from various learning resources independently to solve new problem. *Saya boleh mencari maklumat yang relevan daripada pelbagai sumber pembelajaran secara berdikari untuk menyelesaikan masalah baru.*	1	2	3	4	5
5.	I am able to push myself to the limit of my knowledge and abilities. *Saya berupaya menolak diri saya kepada had pengetahuan dan kebolehan saya.*	1	2	3	4	5
6.	I am able to identify my areas of opportunity for improvement in learning. *Saya berupaya mengenal pasti ruang-ruang peluang untuk meningkatan dalam pembelajaran.*	1	2	3	4	5
	Technical reasoning & Decision Making Skills (i.e. contour programming). ***Pertimbangan Teknikal & Kemahiran membuat keputusan*** *(iaitu pengaturcaraan kontur).*					
7.	I am able to identify useful information in the product/project. *Saya berupaya mengenal pasti maklumat yang berguna dalam produk/projek.*	1	2	3	4	5
8.	I am able to list the processes required in the product/project. *Saya berupaya menyenaraikan proses-proses yang diperlukan di dalam produk/projek.*	1	2	3	4	5
9.	I am able to prioritize the processes of product/project. *Saya berupaya menyenaraikan proses-proses dalam produk/projek mengikut keutamaan.*	1	2	3	4	5
10.	I am able to list the tools needed to process the component with CNC machine. *Saya berupaya menyenaraikan alat-alat yang diperlukan untuk memproses komponen dengan mesin CNC.*	1	2	3	4	5
11.	I am able to determine the component's datum point to process the component with CNC machine. *Saya berupaya menentukan titik datum komponen untuk memproses komponen tersebut dengan mesin CNC.*	1	2	3	4	5
12.	I am able to make decision related to which machining/manufacturing strategy to use in the product/project. *Saya berupaya membuat keputusan berkaitan dengan strategi permesinan/pembuatan yang patut digunakan untuk produk/projek.*	1	2	3	4	5
	Problem Solving & Critical Thinking Skills (i.e. contour programming techniques). ***Penyelesaian Masalah & Kemahiran Berfikir Secara Kritikal (iaitu kontur teknik pengaturcaraan).***					
13.	I am able to reason and synthesize information. *Aku berupaya untuk memberi sebab dan menghubungkan maklumat.*	1	2	3	4	5
14.	I am able to identify multiple approaches to solve the problem. *Saya berupaya mengenalpasti beberapa pendekatan untuk menyelesaikan masalah.*	1	2	3	4	5

15.	I am able to propose one or more solutions to solve the problem. *Saya berupaya mencadangkan satu atau lebih kaedah penyelesaian untuk menyelesaikan masalah.*	1	2	3	4	5
16.	I am able to identify the important issues in the problem. *Saya berupaya mengenal pasti isu-isu penting dalam masalah.*	1	2	3	4	5
17.	I am able to evaluate the outcomes of the solution and determine appropriate action if needed. *Saya berupaya menilai hasil penyelesaian dan menentukan tindakan yang sewajarnya jika perlu.*	1	2	3	4	5
18.	I always have different way of doing things or solving problem. *Saya sentiasa mempunyai cara yang berbeza untuk melakukan perkara-perkara atau menyelesaikan masalah.*	1	2	3	4	5
19.	I always think of better ways of doing things or solving problem. *Saya sentiasa memikirkan cara-cara yang lebih baik untuk melakukan perkara-perkara atau menyelesaikan masalah.*	1	2	3	4	5
20.	I will always analyse the problem or objective before I start any action. *Saya akan sentiasa menganalisis masalah atau matlamat sebelum saya memulakan apa-apa tindakan.*	1	2	3	4	5
21.	I will always evaluate possible solutions, answers or plans for the problem. *Saya sentiasa akan menilai penyelesaian, jawapan atau pelan yang mungkin bagi masalah.*	1	2	3	4	5
	Team work *Kerja berpasukan*					
22.	I hand work/assignment in on time. *Saya serahkan kerja/tugasan tepat pada masanya.*	1	2	3	4	5
23.	I attend every group meeting and arrive on time. *Saya menghadiri setiap mesyuarat kumpulan dan tiba pada masanya.*	1	2	3	4	5
24.	I always work hard towards the attainment of the team's learning objectives. *Saya sentiasa berusaha keras ke arah mencapai objektif pembelajaran pasukan.*	1	2	3	4	5
25.	I am keen to be actively involved in a group discussion. *Saya berminat untuk terlibat secara aktif dalam perbincangan kumpulan.*	1	2	3	4	5
26.	I respect group members' opinions, ideas and contribution. *Saya menghormati pendapat, idea dan sumbangan ahli-ahli kumpulan.*	1	2	3	4	5
27.	I acknowledge others' opinions, ideas and contribution. *Saya menghargai pendapat, idea dan sumbangan orang lain.*	1	2	3	4	5
28.	I like to help members who lagged behind in the group. *Saya suka membantu ahli-ahli yang ketinggalan jauh di belakang dalam Kumpulan.*	1	2	3	4	5
29.	I like to share bibliographic sources with my group members. *Saya suka berkongsi sumber-sumber bibliografik dengan ahli kumpulan saya.*	1	2	3	4	5
30.	I offer feedback to my team mates in constructive and friendly way. *Saya menawarkan maklum-balas kepada rakan sepasukan saya dengan cara membina dan mesra.*	1	2	3	4	5
31.	I support group decisions although I am not totally in agreement. *Saya menyokong keputusan Kumpulan walaupun saya tidak benar-benar dalam persetujuan.*	1	2	3	4	5
	Communication Skills (with enough practise) ***Kemahiran Berkomunikasi (dengan latihan yang cukup)***					
32.	I believe I don't need to read script and be confident with my oral presentation. *Saya percaya saya tidak perlu baca skrip dan yakin dengan pembentangan lisan saya.*	1	2	3	4	5
33.	I always eager to answer questions during Q & A session. *Saya sentiasa bersemangat untuk menjawab soalan semasa sesi Q & A.*	1	2	3	4	5
34.	I always prepare to listen and be a good listener during the oral presentation. *Saya sentiasa bersedia untuk mendengar dan menjadi pendengar yang baik semasa pembentangan lisan.*	1	2	3	4	5
35.	I am able to deliver the content well and understood by audience. *Saya berupaya menyampaikan kandungan dengan baik dan difahami oleh penonton.*	1	2	3	4	5
36.	I am able to place the appropriate words to the thoughts I want to explain. *Saya berupaya meletakkan kata-kata yang sesuai untuk perkara yang difikiran yang saya ingin terangkan.*	1	2	3	4	5
37.	I am able to answer questions that related to the presented topic well. *Saya berupaya menjawab soalan-soalan yang berkaitan dengan topik yang dibentangkan dengan baik.*	1	2	3	4	5

Appendix J-2. Student's Peer-Assessment of Likert-Scale

Peer-assessment

	My Name	My Course mate
Student's Name :		
Student's I/D No. :		
Semester/Trade/Group :		
Date :		

1-Strongly disagree 2- Disagree 3- Undecided 4- Agree 5- Strongly Agree

No.	Description	1	2	3	4	5
	Attitudes	1	2	3	4	5
1.	He/she was able to discuss on a topic and stand up for his/her point of view.	1	2	3	4	5
2.	He/she attended every class and arrived on time.	1	2	3	4	5
3.	He/she studied and prepared for every class.	1	2	3	4	5
4.	He/she did his/her best effort in each class and assignment.	1	2	3	4	5
5.	He/she was always eager to participate in discussion.	1	2	3	4	5
6.	He/she was open to criticism and accepted feedback openly.	1	2	3	4	5
7.	He/she used feedback to improve his/her attitudes.	1	2	3	4	5
8.	He/she participated actively in the group discussion.	1	2	3	4	5
9.	He/she shared important and valuable information with the group members.	1	2	3	4	5
10.	He/she showed responsibility and commitment in all the group activities.	1	2	3	4	5
	Team work	1	2	3	4	5
11.	He/she handed work/assignment in on time.	1	2	3	4	5
12.	He/she attended every group meeting and arrived on time.	1	2	3	4	5
13.	He/she worked hard towards the attainment of the team's learning objectives.	1	2	3	4	5
14.	He/she keened to be actively involved in a group discussion.	1	2	3	4	5
15.	He/she respected group member's opinions, ideas and contribution.	1	2	3	4	5
16.	He/she acknowledged others' opinions, ideas and contribution.	1	2	3	4	5
17.	He/she helped group members who lagged behind in the group.	1	2	3	4	5
18.	He/she shared information and bibliographic sources with others in the group.	1	2	3	4	5
19.	He/she offered feedback to his/her team mates in constructive and friendly way.	1	2	3	4	5
20.	He/she supported group decisions although he/she was not totally in agreement.	1	2	3	4	5

Appendix K-1. Students' Feedback on Group Interviews

Feedback of the Group Students' Interviews

Do you know what actually PBL is?

Sem3 MoT
Problem-based learning is a learning method that based on problem.
Problem-based learning is a learning that working in team to solve problem.
Every solution to the problem will be presented at the end of the discussion.
Problem-based learning is a learning system to solve problem in team.

Sem3 TDT
Problem-based learning is a learning system that based on problem, exchange opinions and ideas, good teamwork, make clear about the study.
Enhance communication skills in the group.
To improve communication in teams.
Problem-based learning is a way of learning through problem solving in team.
Every solution to the problem will be presented at the end of the discussion.

Sem3 CPT
Problem-based learning is problem-based learning. Group will be given a problem to discuss and do research about it
Problem-based learning is a process of learning that encourage students to work in team.
Problem-based learning involved group discussion on the problems and the decision was based on majority.
Problem-based learning is a new way of teaching and new way to work in group.

Sem4 MoT
Problem-based learning is learning in group to solve problem with right approach.
Present the solution with Q &A session.
Build up self-confidence in our presentation.
Information search and Share information and knowledge with members in the group.
Improve our communication.
We were committed to our assignment.
Problem-based learning is a learning method that start with a problem and the students work in groups to solve the problem.
Problem-based learning is a self-reliance learning method that start with a problem and the students work in groups to solve the problem.

Problem-based learning is a self-reliance learning method that start with a problem and the students work in groups to solve the problem.

Sem4 TDT1
Problem-based learning is a new way of learning drives with a problem.
Problem-based learning is learning develop through problem and to resolve through group working.

Sem4 TDT2
Problem-based learning is a new way of acquiring knowledge with a problem.
Problem-based learning is learning develop through problem and to resolve through group working.
Problem-based learning is one of the way used to help us learn to solve problem in the group independently and we have to present our work to the lecturer and the lecturer will guide us.

Sem4 TDT3
Problem-based learning is a way of acquiring knowledge through problem and be brave enough to talk and cooperate in a team. Problem-based learning need us to think outside the box to solve problem.
Problem-based learning is learning in group to solve problem.
Problem-based learning is a team learning to solve problem.

Sem4 CPT1
Problem-based learning is a new approach of learning that work in group to solve problem.
Problem-based learning is a new learning method. It teaches us to work and collaborate in team.
It increases our team spirit.

Sem4 CPT2
Problem-based learning is learning in group to solve problem with students are free to contribute their ideas to solve problems.
Problem-based learning is a learning method that start with a problem and the students work in groups to solve the problem.

Sem4 CPT3
Problem-based learning is learning in group to solve problem with right approach.
Problem-based learning is a learning method that start with a problem and the students work in groups to solve the problem.
Problem-based learning is a self-reliance learning method that start with a problem and the students work in groups to solve the problem.
Problem-based learning is a self-reliance learning method that start with a problem and the students work in groups to solve the problem.

When PBL was first introduced to you?

Sem3 MoT
German-Malaysian Institute, IKM, community college.

Sem3 TDT
German-Malaysian Institute, IKM,

Sem3 CPT
German-Malaysian Institute, IKM, MRSM

Sem4 MoT
German-Malaysian Institute, IKM, community college.

Sem4 TDT1
German-Malaysian Institute, IKM, community college.

Sem4 TDT2
German-Malaysian Institute, IKM, community college.

Sem4 TDT3
German-Malaysian Institute, IKM, community college.

Sem4 CPT1
German-Malaysian Institute, IKM, community college.

Sem4 CPT2
German-Malaysian Institute, IKM, community college.

Sem4 CPT3
German-Malaysian Institute, IKM, community college.

What are the courses/subjects that you have experience with PBL approach?

Sem3 MoT
In semester one. Subjects: math 1, English, physic.
Semester two: German, Math 2, English, Malaysian studies, Electric & Electronic Technology.
Semester three: Math 3, English, German, material science, CNC lathe
Semester four: GDT- Geometry Dimensional & Tolerances, Industrial management.

Sem3 TDT
In semester one. Subjects: math 1, English, physic.

Semester two: German, Math 2, English, Malaysian studies, Electric & Electronic Technology.
Semester three: Math 3, English, German, material science, CNC lathe
Semester four: GDT- Geometry Dimensional & Tolerances, Industrial management.

Sem3 CPT
In semester one. Subjects: math 1, English, physic.
Semester two: German, Math 2, English, Malaysian studies, Electric & Electronic Technology.
Semester three: Math 3, English, German, material science, CNC lathe
Semester four: GDT- Geometry Dimensional & Tolerances, Industrial management.

Sem4 MoT
In semester one. Subjects: math 1, English, physic.
Semester two: German, Math 2, English, Malaysian studies, Electric & Electronic Technology.
Semester three: Math 3, English, German, material science, CNC lathe
Semester four: GDT- Geometry Dimensional & Tolerances, Industrial management.

Sem4 TDT1
In semester one. Subjects: math 1, English, physic.
Semester two: German, Math 2, English, Malaysian studies, Electric & Electronic Technology.
Semester three: Math 3, English, German, material science, CNC lathe
Semester four: GDT- Geometry Dimensional & Tolerances, Industrial management.

Sem4 TDT2
In semester one. Subjects: math 1, English, physic.
Semester two: German, Math 2, English, Malaysian studies, Electric & Electronic Technology.
Semester three: Math 3, English, German, material science, CNC lathe
Semester four: GDT- Geometry Dimensional & Tolerances, Industrial management.

Sem4 TDT3
In semester one. Subjects: math 1, English, physic.
Semester two: German, Math 2, English, Malaysian studies, Electric & Electronic Technology.
Semester three: Math 3, English, German, material science, CNC lathe
Semester four: GDT- Geometry Dimensional & Tolerances, Industrial management.

Sem4 CPT1
In semester one. Subjects: math 1, English, physic.
Semester two: German, Math 2, English, Malaysian studies, Electric & Electronic Technology.
Semester three: Math 3, English, German, material science, CNC lathe
Semester four: GDT- Geometry Dimensional & Tolerances, Industrial management.

Sem4 CPT2
In semester one. Subjects: math 1, English, physic.
Semester two: German, Math 2, English, Malaysian studies, Electric & Electronic Technology.
Semester three: Math 3, English, German, material science, CNC lathe
Semester four: GDT- Geometry Dimensional & Tolerances, Industrial management.

Sem4 CPT3
In semester one. Subjects: math 1, English, physic.
Semester two: German, Math 2, English, Malaysian studies, Electric & Electronic Technology.
Semester three: Math 3, English, German, material science, CNC lathe
Semester four: GDT- Geometry Dimensional & Tolerances, Industrial management.

Generally, what do you feel/think about PBL?

Sem3 MoT
In our opinion pbl is burden because it did not taught from the beginning of subject.
A new learning system to solve faced.
Yes, PBL is very helpful in thinking critically to solve problems and to help work in groups

Sem3 TDT
This helps improve communication.
A new learning system to solve faced Yes, PBL is very helpful in thinking critically to solve problems and to help work in groups.

Sem3 CPT
We feel that Problem-based learning is good to work in team because we can give ideas to solve problems.
Problem-based learning helped us to think critically and working in teams and it also a bit burden.
Stimulating individuals mind for not to depend on the notes given but to search more information on the subject.
We think it can help students to solve critical problem, but it consumes time and a bit burden.

Sem4 MoT
Yes, is a good learning process that easy accepted and practice by most students.
Sometimes we feel hard to find appropriate resources to the problem.
PBL consume a lot of time and we can't get any skills with it.
Great type of learning, improve self-knowledge and self-confidence.
Sometimes it helps sometimes not.

PBL is good because it open students' mind that students need to think good in order to solve problems.
PBL burden students because we have many PBL assignment given by other TTO at the same time.
Good group discussion but less in practical.
We still need the TTO to teach us as time constraint and PBL is not suitable when we have very limited time and we are overloaded with other assignment.
Helpful because it can create teamwork spirit and encourage the students to think out the box.

Sem4 TDT1
Problem-based learning is an exciting way of learning approach and useful.
Problem-based learning is learning in group and solve problems given.

Sem4 TDT2
Problem-based learning is a good way of learning by discussion and interaction in the group.
Problem-based learning is learning in group and solve problems given.
Problem-based learning is a fun way of learning and it help us to think and work on the problem ourselves. Some of the information that we can't get in the class.

Sem4 TDT3
Problem-based learning has made us to understand better on the subject because we experience the gain of knowledge.
Very good especially for those who really work to solve the problem.
Problem-based learning is good for students who really participate in learning.

Sem4 CPT1
Yes good, the good thing about Problem-based learning, it makes us work in team, seek for information and doing presentation on the solution to the problem but we have many assignment and time constraint.
Very good because we share ideas, learn new knowledge from each other members in the group.

Sem4 CPT2
Yes good and enjoyable, discussion in group can generate good ideas to solve the problem and improve our communication skills.
Very good because we learn how to solve problem, share ideas, learn new knowledge from each other members in the group.

Sem4 CPT3
Yes, is a good learning process that easy accepted and practice by most students.
Sometimes we feel hard to find appropriate resources to the problem
PBL consume a lot of time and we can't get any skills with it.
Great type of learning, improve self-knowledge and self-confidence.

Sometimes it helps sometimes not.
PBL is good because it open students' mind that students need to think good in order to solve problems.
PBL burden students because we have many PBL assignment given by other TTO at the same time.
Good group discussion but less in practical.
We still need the TTO to teach us as time constraint and PBL is not suitable when we have very limited time and we are overloaded with other assignment.
Helpful because it can create teamwork spirit and encourage the students to think out the box.

Do you feel PBL approach help you in acquiring new knowledge? If yes, how? If not, why?

Sem3 MoT
Yes, because when we find information on the internet we do not meet with information that only for the problems but a lot of information related.
Yes, with pbl system, we need to make or review on each problem encountered. With this process we can foster the spirit of cooperation within the group.
Yes, PBL can give me more knowledge in information retrieval and have confidence in giving presentations.

Sem3 TDT
Yes, because when we find information with various ways the internet book journal etc. exchange opinions and knowledge.
Yes, with the pbl system, we need to make or review on each problem encountered. With this process we can foster the spirit of cooperation within the group.
Yes, PBL can give me more knowledge in information retrieval and have confidence in giving presentations.

Sem3 CPT
Yes, because Problem-based learning can help students to thinking critically and make them to seek for information alone and through discussion in team.
Yes, Problem-based learning needed the students to search for information by all means such as internet, books, and journals individually and in team.
Yes, because we search for information ourselves and we shared the information among members in the group.
Yes, it helps us because we have to solve critical problem in a group. Thus, we need to find all the sources we need and any additional knowledge.

Sem4 MoT
Yes, by discussion, sharing idea and prior knowledge of the members in the group.
Yes, information search, discussion and sharing idea in the group.

Yes, we can acquire new knowledge by during seeking information to solve the problems. Also through discussion and exchange ideas.
Yes, we can acquire new knowledge by during seeking information to solve the problems. Also through discussion and exchange ideas.

Sem4 TDT1
Yes, everybody in the group presented their ideas and findings and also through discussion in the group.
Yes, we work for the knowledge through information search and group discussion and presentation by other groups.

Sem4 TDT2
Yes, because the question is far off the subject and we have to search in the internet and books information that to relate to the question.
Yes, we work for the knowledge through journals, technical books and group discussion and presentation by other groups.
When problem given, we started to search and compare and gain as much information as possible and some information we can't learn in the class.

Sem4 TDT3
Yes, by in information search and discussion in the group.
Yes, it does help us to gain knowledge from variety sources in order to solve the related problems Yes, because in our opinion if we learn something new on our own it will remain longer in our mind.

Sem4 CPT1
Yes, by identify problem, a lot of information related to the problem searched and discussion in the group.
Yes, search information through internet, books, programming manuals etc. this activities contributed to new knowledge.

Sem4 CPT2
Yes, by discussion and sharing idea in the group.
Yes, information search, discussion and sharing idea in the group.

Sem4 CPT3
Yes, by discussion, sharing idea and prior knowledge of the members in the group.
Yes, information search, discussion and sharing idea in the group.
Yes, we can acquire new knowledge by during seeking information to solve the problems. Also through discussion and exchange ideas.
Yes, we can acquire new knowledge by during seeking information to solve the problems. Also through discussion and exchange ideas.

Do you feel PBL approach help you in acquiring technical skills? If yes, how? If not, why?

Sem3 MoT
Not helpful, as technical skills was practical-based and skill-based to operate a machine or even a product.
No, because the technical areas we need higher skills than theory.
No, this PBL is not suitable in the technical subject because it unable to improve our technical skills.

Sem3 TDT
Less, because PBL only apply in a class not in a workshop.
No, because the technical areas we need higher skills than theory.
No, this PBL is not suitable in the technical subject because it unable to improve our technical skills.

Sem3 CPT
Yes because Problem-based learning it makes the team members to be independent and giving ideas in solving the machining problem.
Yes, with Problem-based learning we were able to know more about the subject during information search.
Yes, because each of every member in the group has their distinctive technical skills that we can learn.
Yes, theoretical matter possible, but we need to practice hands on to acquired technical skills.

Sem4 MoT
No, we believe PBL can be apply to theory only but technical skills need practice to master the skills.
No, because technical skills need to be demonstrate by skills person, practice and hands-on.
No, technical skills focus more on practical aspect while PBL focus on theoretical aspect.
No, technical skills can only be acquired by doing with a lot of hands-on.
No, technical skills focus more on practical aspect while PBL focus on theoretical aspect.
No, technical skills good to be learnt by demonstration from an expert and we need to practice to master the skills.
No, technical skills can be acquired only with a lot of practice.

Sem4 TDT1
Yes, by discussion in the group we learned the skills through our teammate who have experience in CNC lathe machining.
No, Problem-based learning helps us in acquiring communication skills.

Sem4 TDT2
Yes, by discussion in the group we learned the skills through our teammate who have experience in CNC lathe machining.
No, Problem-based learning helps us in acquiring communication skills.
In some way yes because some of the PBL given were related to technical.

Sem4 TDT3
No, technical skills need to be trained by an experience trainer.
Yes, after we have searched the information on technical aspect of CNC, then we need to present it.
Yes, when we try to solve problem ourselves, it will increase our knowledge and skills in technical.
Sem4 CPT1
Yes, on the technique but not on technical skills.
No, technical skills need practice and hands-on.

Sem4 CPT2
No, we believe PBL can be apply to theory only but technical skills need practice to master the skills.
No, because technical skills need to be demonstrate by skills person, practice and hands-on.

Sem4 CPT3
No, we believe PBL can be apply to theory only but technical skills need practice to master the skills.
No, because technical skills need to be demonstrate by skills person, practice and hands-on.
No, technical skills focus more on practical aspect while PBL focus on theoretical aspect.
No, technical skills can only be acquired by doing with a lot of hands-on.
No, technical skills focus more on practical aspect while PBL focus on theoretical aspect.
No, technical skills good to be learnt by demonstration from an expert and we need to practice to master the skills.
No, technical skills can be acquired only with a lot of practice.

Do you feel PBL approach help you in acquiring generic skills (communication, problem solving, team work)? If yes, how? If not, why?

Sem3 MoT
Yes, PBL related to teamwork, to increase collaboration and get new ideas and results from the group.
Yes, being able to increase self-confidence by doing presentations in public.
Yes, being able to increase the level of confidence during the communication in front of the public.

Sem3 TDT
Yes, communication, problem solving, team work through Presentation, group meeting and be self-confident.
Yes, being able to increase self-confidence by doing presentations in public.
Yes, being able to increase the level of confidence during the presentation in front of the crowd of people.
Yes, being able to increase the level of confidence during the presentation in front of the public.

Sem3 CPT
Yes, Problem-based learning help the team to enhance skills in skills communication, speaking, mingles, in learning session.
Yes, Problem-based learning helped us to be more confident in our presentation in the classroom.
Yes, every members in the team need to speak in the discussion and explain and present the ideas.
Yes, because we have to communicate in group and present our solution to the problem. Thus, it helps us become more confident and increases our generic skills.

Sem4 MoT
Yes, because PBL emphasis on teamwork and teamwork need some skill in communication and convincing skill.
Yes, through group interaction, presentation, public speaking, seeking information to solve problem.
Yes, through group interaction, presentation, public speaking, seeking information to solve problem.
Yes, because PBL is actually a platform for us to practice our speaking, in group interaction, communication, team working, public speaking and presentation.
PBL develop our self-confidence.
Yes, we build up our confidence in our speaking, in group interaction, communication, team working, public speaking and presentation.
Yes, we enhance our confidence in our speaking, in group interaction, communication, team working, public speaking and presentation.
Yes, PBL help us to improve our communication skills and increase our confident level.

Sem4 TDT1
Yes, because we can practice and improve our communication and presentation skills during PBL sessions.
Problem-based learning needs us to present our ideas and solution to the problems. This will help our develop self-confidence.

Sem4 TDT2
Yes, it helps us to be open-minded, improve our communication and presentation skills during PBL sessions.

Yes, Problem-based learning our communication through interaction in the group and presentation.
Yes, it helps us in gaining some soft skills such as presentation, speaking, selling ideas.

Sem4 TDT3
Yes, Problem-based learning open chances for us to speak and voice out our opinion on related issues to the problem in front of the group members and also to other groups.
Yes, after we have searched the information, then we need to present it, from there we have chances to practice our communication, public speaking etc.
Yes, through presentation, public speaking.

Sem4 CPT1
Yes, through many presentation, Q &A session, group interactions, group discussion can generate new ideas. Working with new problem.
Yes, through presentation, public speaking, seeking information to solve problem.

Sem4 CPT2
Yes, with active learning like PBL we have the chance to enhance our generic skills and self-confidence.
Yes, through group interaction, presentation, public speaking, seeking information to solve problem.

Sem4 CPT3
Yes, because PBL emphasis on teamwork and teamwork need some skill in communication and convincing skill.
Yes, through group interaction, presentation, public speaking, seeking information to solve problem.
Yes, through group interaction, presentation, public speaking, seeking information to solve problem.
Yes, because PBL is actually a platform for us to practice our speaking, in group interaction, communication, team working, public speaking and presentation.
PBL develop our self-confidence.
Yes, we build up our confidence in our speaking, in group interaction, communication, team working, public speaking and presentation.
Yes, we enhance our confidence in our speaking, in group interaction, communication, team working, public speaking and presentation.
Yes, PBL help us to improve our communication skills and increase our confident level.

Do you feel PBL approach stimulated your teamwork? If yes, how? If not, why?

Sem3 MoT

Yes because PBL encourages teamwork and discussion to find solution of the problem.
Yes this enable us to increase self-confidence while performing a presentation in public.
Yes, it is easier to solve the problem with discussion in the group and be able to reduce time in solving the problem faced by the group members.

Sem3 TDT
Yes because PBL encourages teamwork with distribute work, share ideas and enduring relationships.
Yes this enable us increase self-confidence while performing a presentation in public.
Yes, to solve the problem easier while within the Group and be able to take a shorter time in solving the problem faced by the group members.

Sem3 CPT
Yes, Problem-based learning needs team working to solve problem.
Yes, it was easier to solve problem in group discussion.
Yes, because there were a lot of ideas in the group that helped in solving problems and it helped us learn to work in team.
Yes, because we become more open-minded to accept people's opinion and decision making in group.

Sem4 MoT
Yes, because PBL promotes team working to solve problem, thus, will build up the team spirit among students.
Yes, one of PBL criteria is for students to work in team that makes the learning to be easier to work on the solution.
Yes, PBL approach stimulated teamwork, every member in the group were given task and need to present in the group meeting. It was discussed in the group, thus, enhance the team spirit of the group.
Yes, because in PBL we need to work together as a team to solve problem.

Sem4 TDT1
Yes, because we were always have to work in group in every PBL activities like information search and presentation of solution.
Yes, because we worked in group in every problem solving activities, information search and presentation of solution.

Sem4 TDT2
Yes some may have teamwork value, but some did not want to work hoping others to work.
Yes, Problem-based learning activities generates interest toward learning especially during discussion in group.
Yes, we helps because we often communicate during Problem-based learning session.

Sem4 TDT3
Yes, by many group working and members try to give their best idea to solve the solution.
Yes, Problem-based learning gives us room to get to know our friends, practice to communicate better, speak out, share and debate the opinion.
Yes, we have chances to work and discuss to solve problem in team.

Sem4 CPT1
Yes, PBL: by many group working and members exchange ideas and cooperation with the group.
Yes, PBL activities encourage student to in team, collaborate and discussion to solve problem.
Sem4 CPT2
Yes, PBL: by many group working and members exchange ideas we can generate a good solution to the problem.
Yes, PBL activities encourage student to be self-reliance and healthy working group that makes the learning to be easier to work on the solution.

Sem4 CPT3
Yes, because PBL promotes team working to solve problem, thus, will build up the team spirit among students.
Yes, one of PBL criteria is for students to work in team that makes the learning to be easier to work on the solution.
Yes, PBL approach stimulated teamwork, every member in the group were given task and need to present in the group meeting. It was discussed in the group, thus, enhance the team spirit of the group.
Yes, because in PBL we need to work together as a team to solve problem.

Do you feel PBL approach stimulated your problem solving skill? If yes, how? If not, why?

Sem3 MoT
Yes, with a group discussion is stimulating to solve problem.
Yes, with PBL we need to do more research and in details to settle every problem encountered.
Yes, because working in groups we generate a lot of ideas to fix the problems.

Sem3 TDT
Yes, when searching for information from group discussions extremely stimulating to solve.
Yes, with PBL we need to do more research and in details to settle every problem encountered.

Yes, because working in groups we generate a lot of ideas to fix the problems.

Sem3 CPT
Yes, because each members in the group need to give ideas and study in depth to solve problem.
Yes, Problem-based learning made us think critically and trigger us to generate ideas in the discussion.
Yes, because Problem-based learning activities inspired students to generate good ideas in solving problems.
Yes, because we have to solve problems ourselves with TTO's facilitation.

Sem4 MoT
Yes, PBL that promotes working in group has made problem activities much easier.
Yes, the problem had pushed us to think harder and search the information related to the problem solving.
Yes, the problem itself drives the students to solve the problem in team.
Yes, every problem given, we need to find the way to solve the problem.
Yes, PBL encourage to think out the box In solving the problem.
Yes, PBL make students to think how to solve the problem with the help of scaffold provided.

Sem4 TDT1
Yes, because we have to solve problems on our own with minimum guide from TTO.
Yes, everybody have their own opinion and information and need to debate to select the right solution to the problem. We learnt to compromise and agree to disagree.

Sem4 TDT2
Yes, because we have to solve problems independently, from related information search, discuss until present the solution.
Yes, because we worked in group to generate creative ideas to solve problem.
Yes, we learnt to solve problems independently rather than just depend on the lecturer.

Sem4 TDT3
Yes, activities to search information, discussion and solving together in the group stimulate the problem solving skills.
Yes, through seeking information and exchange information in the group.
Yes, from the problem we search for information, discuss in team to solve problem.

Sem4 CPT1
Yes, when we identify the 3 Ks, what we know, what we don't know, what we need to know to start with information search to solve the problem.
Yes, when team working new and a lot of idea generated and we discuss to select the best solution to the problem.

Sem4 CPT2
Yes, PBL that promotes working in group has made problem activities much easier.
Yes, team working in PBL encourage generation of ideas to solve problems.

Sem4 CPT3
Yes, PBL that promotes working in group has made problem activities much easier.
Yes, the problem had pushed us to think harder and search the information related to the problem solving.
Yes, the problem itself drives the students to solve the problem in team.
Yes, every problem given, we need to find the way to solve the problem.
Yes, PBL encourage to think out the box In solving the problem.
Yes, PBL make students to think how to solve the problem with the help of scaffold provided.

Do you think PBL approach develops better problem solving skills?

Sem3 MoT
Yes because students need to be more independent and find information to solve the real problem encountered.
Yes, students are able to work in group and solve the problem.

Sem3 TDT
Yes, many problem, many chances of solving problem.
Yes, students are able to work in group and solve the problem.

Sem3 CPT
Yes, working in team to solve problem is the intention of Problem-based learning
Yes, because the decisions achieved were based on the discussion and group's consensus.
Yes of course
Yes

Sem4 MoT
PBL make us an active learner.
Fun, we like to work in team that make us active in learning not passive.
Fun working in team make learning motivated us much.
Teamwork with active in learning motivated us much.

Sem4 TDT1
Yes, through group discussion we get many ideas and solutions from the team members.
Yes, because we need to do a lot of thinking and think creative in order to solve problem, discuss and come out with a good solution.

Sem4 TDT2

Yes, maybe
Yes, because we experiencing the activities of problem solving through books, internet, etc.
Yes, because the problem drive us to find the solution.

Sem4 TDT3
Yes, with many group discussion
Yes, the process of problem solving in PBL trained us to better problem solver.
Yes, because we had a lot of discussion and exchange ideas in solving problem increase our skills.

Sem4 CPT1
Yes, because we need to work in team with many group discussion to refine and get the best solution.
Yes, during information search it stimulate our mind to further the search to find better solution.

Sem4 CPT2
Yes, because PBL train our mind to think better and effective to solve problem.
Yes, through many discussion, debate will generate better solution to the problem.

Sem4 CPT3
Yes, because PBL makes us work for the solution, thus train our mind to think better to solve problem.
Yes, through PBL activities, students were train to be a better problem solvers.
Yes, with PBL activities we were stimulated to solve problems.
Yes, in PBL, we solve a lot of problem that enhance our skills in problem solving.

Do CNC simulator benefits you in the CNC programming course adopting PBL approach? If yes, how? If not, why?

Sem3 MoT
Yes because learning will become more efficient, effective and more knowledge from reading books.
Yes is very important as the beginners in CNC programming for each student to start working with CNC machine.
Yes, because CNC simulator is one of the programming tool that could help students understand the functions of CNC machine.

Sem3 TDT
Yes, hand-on experience on programming at the controller
Simulation on how to key in the program
Simulation on geometry

Yes, it is very important in CNC programming as a beginner for each student to familiar with CNC controller.
Yes, because CNC simulator is one of the programming tool that could help students get use with CNC machine.

Sem3 CPT
Yes, CNC simulator enable students to plan in term of making the program and we can observe the errors and make remedies.
Yes, because the simulator is like the exactly CNC controller at the CNC machine.
Yes, because it helped the students to practice and experience like an actual CNC controller.
Yes, because it helps us imagine the real machining process on the machine thus avoid any error.

Sem4 MoT
Yes, we can observe the part simulation and can identify problem in the program and can do correction to the program before the actual machining is performed.
Yes, we can work out the program on ourselves without involvement of the TTO, we can observe the part simulation and can detect mistake in the program and can do correction to the program before the actual machining is performed.
Yes, with simulator we can do analysis on our program strategies and optimize the cutting strategy and technology.
Yes, it can improve our programming skill before we go the real machine.

Sem4 TDT1
Yes, because simulation will detect error in programming.
Yes, because the simulator can show the graphic of the machining process that shows what happen.

Sem4 TDT2
Yes, because simulation will show what happen to our program and we can do 'trial an error' until we get the right program that we want.
Yes, because the simulator can show the graphic of the machining process that shows what happen.
Yes, we experience programming like doing at the actual CNC machine controller and avoid any collision if wrongly programmed.

Sem4 TDT3
Yes, it is easier for us to do the program compared to just write it on paper without knowing right or wrong.
Yes, because the simulator can show in graphic whether the program is right or wrong.
Yes, we can see at the screen what happen to the program we input into the simulator.

Sem4 CPT1
Yes, we can observe the part simulation and can troubleshoot if any error in the program. We can practice on the function of buttons of the simulator so that we can use the machine controller without much problem.
Yes, because we can explore the simulator ourselves without worries on damaging the simulator. We can easily apply the knowledge and skills to the actual CNC machine controller.

Sem4 CPT2
Yes, we can observe the part simulation and can identify problem in the program and can do correction to the program before the actual machining is performed.
Yes, we can observe the part simulation and can detect mistake in the program and can do correction to the program before the actual machining is performed.

Sem4 CPT3
Yes, we can observe the part simulation and can identify problem in the program and can do correction to the program before the actual machining is performed.
Yes, we can work out the program on ourselves without involvement of the TTO, we can observe the part simulation and can detect mistake in the program and can do correction to the program before the actual machining is performed.
Yes, with simulator we can do analysis on our program strategies and optimize the cutting strategy and technology.
Yes, it can improve our programming skill before we go the real machine.

What are your motivations of learning through PBL approach?

Sem3 MoT
Enable to resolve the problem and teach us the meaning of teamwork and to foster ties with friends.
This way can foster the spirit of cooperation among the group members and also exchange the ideas.

Sem3 TDT
Yes, no answer right and wrong answer, freely think, Team working.
Enable to resolve the problem and teach us the meaning of teamwork and to foster ties with friends.
This way can foster the spirit of cooperation among the group members and also exchange the ideas.

Sem3 CPT
Yes, PBL make the team to discuss and think critically in solving problem
To get high marks and A grade.
Enhance self-confidence.
To increase our generic skills, technical skills and knowledge.

Sem4 MoT
PBL make us an active learner.
Fun, we like to work in team that make us active in learning not passive.
Fun working in team make learning motivated us much.
Teamwork with active in learning motivated us much.

Sem4 TDT1
More discussion more knowledge
Drilling through discussion for the best solution to the problem given.

Sem4 TDT2
To pass subject. When we have successfully presented the solution.
Fun working together in a group and every problem and we assume the problem as a challenges for us to solve it.
We have fun in learning with Problem-based learning.

Sem4 TDT3
We have chances to learn in group better than learn alone and challenge to solve problems.
Faced the fear to talk in front of people and learn to communicate better.
Convincing people of our solution to the problem.

Sem4 CPT1
Get good marks, teamwork with active in learning motivated us much.
Self-directed learning and the spirit of working in team to solve problem together.

Sem4 CPT2
PBL educate individual to be more Self-directed in learning, tolerant in team to solve problem.
Teamwork with active in learning motivated us much.

Sem4 CPT3
PBL make us an active learner.
Fun, we like to work in team that make us active in learning not passive.
Fun working in team make learning motivated us much.
Teamwork with active in learning motivated us much.

What you feel the challenges/obstacles for you as a student to adapt PBL approach in your learning?

Sem3 MoT
Time, because too many subject in a semester.
Compete with other groups to get a perfect score.

The challenge is the time when doing the presentation to get the audience understand.
To solve problem given in the problem statement in no time.

Sem3 TDT
When our ideas was not accepted by group members.
When group members were not cooperate.
Language during presentation
Cost for project for presentation
The challenge is the time when doing the presentation to get the audience understand.
To solve problem given in the problem statement in no time.

Sem3 CPT
Time to gather information by the group members and to solve problem.
Don't have enough time, due date too short and team members that did not participate and cooperate in the discussion.
Time was not sufficient.
Lack of time, different opinion, lark of teamwork, lark of sources.

Sem4 MoT
The problems challenging.
Time constraint and we have also other PBL assignment in the same week given by other TTO.
Internet is not consistent.
To solve problem in a limited time with other PBL assignment at the same time.
Time constraint.
Some of the problem statements were hard to understand.
Time constraint.
Finding the right information to the problem with limited of time.

Sem4 TDT1
Wifi limited access after 10pm.
Some of group members did not cooperate, not contribute and materials found was not appropriate and difficult to understand. Can't find the information.

Sem4 TDT2
The group activities. Some members in the group were not doing their job.
Time constrain to solve the problem because we have many assignment to do given by other lecturers.
Negative attitude of members in the group.

Sem4 TDT3
Time constrain to solve problem and presentation in English.
Limited time and character of members in group.
To solve the problem in time and present it in English.

Sem4 CPT1
Time constraint and we have also other PBL assignment in the same week given by other TTO.
Teammate busy with other PBL assignment,
Time limited

Sem4 CPT2
Time constraint and we have also other PBL assignment in the same week given by other TTO. Internet is not consistent.
Time limited, to solve problem in a limited time with other PBL assignment at the same time.

Sem4 CPT3
The problems challenging.
Time constraint and we have also other PBL assignment in the same week given by other TTO.
Internet is not consistent.
To solve problem in a limited time with other PBL assignment at the same time.
Time constraint.
Some of the problem statements were hard to understand.
Time constraint.
Finding the right information to the problem with limited of time.

Do you feel the problem statement was adequate and understood?

Sem3 MoT
Understand but how to resolve it is taking time.
With only problem, it is not sufficient because students have to deal with real problems. Understood and cleared with problems given.

Sem3 TDT
Yes
With only problem, it is not sufficient because students have to deal with real problems. Understood and cleared with problems given.

Sem3 CPT
Yes, because all the problems of PBL given were understandable and we managed to solve it.
Yes, understood
Yes,
Yes,

Sem4 MOT
Yes, with good clue
Yes
Yes,
Yes,

Sem4 TDT1
Yes, please bold the key words in the problem statement.
Yes, the problem statement was clear and we were able to identify our objectives.

Sem4 TDT2
Yes, the problem statement was clear and we were able to identify our objectives.
Yes,

Sem4 TDT3
Yes, some easy to understand but some were not easy to understand.
Sometimes yes, sometimes no
Yes,

Sem4 CPT1
Yes,
Yes for some PBL problem statement but some not.

Sem4 CPT2
Yes, but we more specific explanation to the problem.
Yes for some PBL problem statement but some not.

Sem4 CPT3
Yes, with good clue
Yes
Yes
Yes

Do you feel the scaffolding to the problem was adequate and helpful?

Sem3 MoT
Sufficient and help in terms of information related to the problem.
Yes, because the scaffolding is an arrangement that can help students in problem solving.
Sufficient and help in finding additional information.

Sem3 TDT
No, not sufficient
Yes,

Yes,

Sem3 CPT
Yes, the notes given really helps that contain the definitions and ways of working out with the problems.
Yes, sufficient
Yes, the scaffolding was helpful and the information very much related to the problem that we want to solve.
Yes,

Sem4 MoT
Yes sufficient,
Yes,
Yes, the content sufficient to solve the problem
Yes, very helpful

Sem4 TDT1
No, because we still have to find out more information in the internet etc.
Yes, it helps us in searching and giving the information in details to the solution.

Sem4 TDT2
Yes, it guide us in problem solving
Yes, it facilitate us in problem solving.
Yes, sufficient

Sem4 TDT3
Yes sufficient, we don't need to search some else
Yes, it facilitates us in problem solving.
Yes, sufficient because it can be the framework or steps to solve the problem.

Sem4 CPT1
Yes,
Yes sufficient,

Sem4 CPT2
Yes,
Yes sufficient,

Sem4 CPT3
Yes sufficient,
Yes,
Yes, the content sufficient to solve the problem
Yes, very helpful

Appendix L-1. Awareness on PBL: Percentages and Frequencies of Students' Responses of Likert-Scale Questionnaire.

Table 4-7: Percentage and frequency of semester three students' awareness on PBL (N = 47).

Student's Awareness on Problem-Based Learning.	1-Strongly disagree	2-Disagree	3-Undecided	4-Agree	5-Strongly Agree	Mean
12-I am aware of the rationale for implementing PBL in the CNC programming courses.		1 (2.1%)	17 (36.2%)	24 (51.1%)	5 (10.6%)	3.70
13-I am aware that students are self-directed learning in PBL approach.			14 (29.8%)	30 (63.8%)	3 (6.4%)	3.77
14-I am aware about the importance of small group discussions in PBL approach.			4 (8.5%)	31 (66%)	12 (25.5%)	3.17
15-I am aware that PBL approach could stimulate students' learning.	1 (2.1%)		7 (14.9%)	30 (63.8%)	9 (19.1%)	3.98
16-I am aware that PBL approach could improve students' communication skills.			3 (6.4%)	21 (44.7%)	23 (48.9%)	4.43
17-I am aware that PBL approach could develop students to be an active learner.	1 (2.1%)		5 (10.6%)	29 (61.7%)	12 (25.5%)	4.09
18-I am aware that PBL approach could train students to think critically.			5 (10.6%)	30 (63.8%)	12 (25.5%)	4.15
19-I am aware that PBL approach could develop skills in problem solving.			9 (19.1%)	30 (63.8%)	8 (17%)	3.98
20-I am aware that PBL approach could enhance intrinsic motivation of students.	1 (2.1%)	1 (2.1%)	9 (19.1%)	26 (55.3%)	10 (21.3%)	3.91
Total	**3 (0.7%)**	**2 (0.5%)**	**73 (17.3%)**	**251 (59.3%)**	**94 (22.2%)**	**3.91**

Table 4-8: Percentage and frequency of semester four students' awareness on PBL (N = 85).

Student's Awareness on Problem-Based Learning.	1-Strongly disagree	2-Disagree	3-Undecided	4-Agree	5-Strongly Agree	Mean
12-I am aware of the rationale for implementing PBL in the CNC programming courses.		4 (4.7%)	21 (24.7%)	47 (55.3%)	13 (15.3%)	3.81
13-I am aware that students are self-directed learning in PBL approach.		3 (3.5%)	19 (22.4%)	51 (60%)	12 (14.1%)	3.85
14-I am aware about the importance of small group discussions in PBL approach.			14 (16.5%)	50 (58.8%)	21 (24.7%)	4.08
15-I am aware that PBL approach could stimulate students' learning.	1 (1.2%)	3 (3.5%)	9 (10.6%)	44 (51.8%)	28 (32.9%)	4.12
16-I am aware that PBL approach could improve students' communication skills.		2 (2.4%)	4 (4.7%)	46 (54.1%)	33 (38.8%)	4.29
17-I am aware that PBL approach could develop students to be an active learner.		1 (1.2%)	12 (14.1%)	46 (54.1%)	26 (30.6%)	4.14
18-I am aware that PBL approach could train students to think critically.		1 (1.2%)	10 (11.8%)	42 (49.4%)	32 (37.6 %)	4.24
19-I am aware that PBL approach could develop skills in problem solving.		2 (2.4%)	12 (14.1%)	43 (50.6%)	28 (32.9%)	4.14
20-I am aware that PBL approach could enhance intrinsic motivation of students.	4 (4.7%)	4 (4.7%)	12 (14.1%)	40 (47.1%)	25 (29.4%)	3.92
Total	**5 (0.7%)**	**20 (2.6%)**	**113 (14.8%)**	**409 (53.5%)**	**218 (28.5%)**	**4.07**

Appendix L-2. Perception on PBL: Percentages and Frequencies of Students' Responses of Likert-Scale Questionnaire.

Table 4-11: Percentage and frequency of semester three students' perception on PBL (N = 47).

Student's Perception on Problem-Based Learning.	1-Strongly disagree	2-Disagree	3-Undecided	4-Agree	5-Strongly Agree	Mean
1-PBL enhanced application of my prior knowledge.	-	1 (2.1%)	4 (8.5%)	27 (57.4%)	15 (31.9%)	4.19
2-PBL helped me to develop myself to be a self-directed learner.	-	-	8 (17%)	25 (53.2%)	14 (29.8%)	4.13
3-PBL stimulated my thinking process.	-	-	4 (8.5%)	24 (51.1%)	19 (40.4 %)	4.32
4-PBL helped to develop my skills in technical reasoning and decision making.	-	-	7 (14.9%)	25 (53.2%)	15 (31.9%)	4.17
5-PBL helped to develop my skills in problem solving and critical thinking.	-	-	7 (14.9%)	24 (51.1%)	16 (34%)	4.19
6-PBL developed and improved my communication skills.	-	-	3 (6.4%)	22 (46.8%)	22 (46.8%)	4.40
7-PBL developed and enhanced my level of confidence in public speaking.	1 (2.1%)	-	7 (14.9%)	16 (34%)	23 (48.9%)	4.28
8-I learnt more when seeking for solutions for the issues of learning.	-	-	4 (8.5%)	28 (59.6%)	15 (31.9%)	4.23
9-PBL improved my teamwork spirit.	1 (2.1%)	1 (2.1%)	2 (4.3%)	26 (55.3%)	17 (36.2%)	4.21
10-I learnt better during group interactions in the PBL.	2 (4.3%)	-	12 (25.5%)	22 (46.8%)	11 (23.4%)	3.85
11-PBL taught me learn how to learn.	-	-	13 (27.7%)	19 (40.4%)	15 (31.9%)	4.04
Total	**4 (0.8%)**	**2 (0.4%)**	**71 (13.7%)**	**258 (49.9%)**	**182 (35.2%)**	**4.18**

Table 4-12: Percentage and frequency of semester four students' perception on PBL (N = 85).

Student's Perception on Problem-Based Learning.	1-Strongly disagree	2-Disagree	3-Undecided	4-Agree	5-Strongly Agree	Mean
1-PBL enhanced application of my prior knowledge.	-	4 (4.7%)	12 (14.1%)	39 (45.9%)	30 (35.3%)	4.12
2-PBL helped me to develop myself to be a self-directed learner.		2 (2.4%)	13 (15.3%)	42 (49.4%)	28 (32.9%)	4.13
3-PBL stimulated my thinking process.	1 (1.2%)	1 (1.2%)	8 (9.4%)	43 (50.6%)	32 (37.6 %)	4.22
4-PBL helped to develop my skills in technical reasoning and decision making.	1 (1.2%)	1 (1.2%)	8 (9.4%)	42 (49.4%)	33 (38.8%)	4.24
5-PBL helped to develop my skills in problem solving and critical thinking.		3 (3.5%)	12 (14.1%)	47 (55.3%)	23 (27.1%)	4.06
6-PBL developed and improved my communication skills.		1 (1.2%)	7 (8.2%)	48 (56.5%)	29 (34.1%)	4.24
7-PBL developed and enhanced my level of confidence in public speaking.		2 (2.4%)	9 (10.6%)	50 (58.8%)	24 (28.2%)	4.13
8-I learnt more when seeking for solutions for the issues of learning.	1 (1.2%)	5 (5.9%)	16 (18.8%)	40 (47.1%)	23 (27.1%)	3.93
9-PBL improved my teamwork spirit.	1 (1.2%)	1 (1.2%)	10 (11.8%)	51 (60%)	22 (25.9%)	4.08
10-I learnt better during group interactions in the PBL.		4 (4.7%)	18 (21.2%)	47 (55.3%)	16 (18.8%)	3.88
11-PBL taught me learn how to learn.	1 (1.2%)	2 (2.4%)	16 (18.8%)	44 (51.8%)	22 (25.9%)	3.99
Total	**5 (0.5%)**	**26 (2.8%)**	**129 (13.8%)**	**493 (52.7%)**	**282 (30.2%)**	**4.09**

Appendix L-3. Challenges/obstacles on PBL: Percentages and Frequencies of Students' Responses of Likert-Scale Questionnaire.

Table 4-15: Percentage and frequency of semester three students' challenges/obstacles on PBL (N = 47).

Challenges/obstacles in Problem-Based Learning implementation.	1-Strongly Agree	2-Agree	3-Undecided	4-disagree	5-Strongly disagree	Mean
21-I am complacent with traditional learning methods as compared to PBL.	1 (2.1%)	14 (29.8%)	24 (51.1%)	6 (12.8%)	2 (4.3%)	2.87
22-I have the mind-set that *"PBL is actually putting the burden of educating to the students"*.	3 (6.4%)	11 (23.4%)	17 (36.2%)	13 (27.7%)	3 (6.4%)	3.04
23-I have difficulties to determine the learning objectives.	2 (4.3%)	14 (29.8%)	21 (44.7%)	8 (17%)	2 (4.3%)	2.87
24-Literature resources (TVET) related to the problem is limited.	2 (4.3%)	12 (25.5%)	26 (55.3%)	7 (14.9%)	-	2.80
25-Time constraint to figure out on the problem and seek the learning issues in more depth.	8 (17%)	12 (25.5%)	19 (40.4%)	8 (17%)	-	2.57
Total	**16 (6.8%)**	**63 (26.8%)**	**107 (45.5%)**	**42 (17.9%)**	**7 (3%)**	**2.83**

Table 4-16: Percentage and frequency of semester four students' challenges/obstacles on PBL (N = 85).

Challenges/obstacles in Problem-Based Learning implementation.	1-Strongly Agree	2-Agree	3-Undecided	4-disagree	5-Strongly disagree	Mean
21-I am complacent with traditional learning methods as compared to PBL.	17 (20%)	23 (27.1%)	23 (27.1%)	15 (17.6%)	7 (8.2%)	2.67
22-I have the mind-set that *"PBL is actually putting the burden of educating to the students"*.	21 (24.7%)	18 (21.2%)	21 (24.7%)	16 (18.8%)	9 (10.6%)	2.69
23-I have difficulties to determine the learning objectives.	14 (16.5%)	24 (28.2%)	29 (34.1%)	15 (17.6%)	3 (3.5%)	2.64
24-Literature resources (TVET) related to the problem is limited.	14 (16.5%)	26 (30.6%)	28 (32.9%)	15 (17.6%)	2 (2.4%)	2.59
25-Time constraint to figure out on the problem and seek the learning issues in more depth.	23 (27.1%)	32 (37.6 %)	18 (21.2%)	9 (10.6%)	3 (3.5%)	2.26
Total	**89 (20.9%)**	**123 (28.9%)**	**119 (28.0%)**	**70 (16.5%)**	**24 (5.6%)**	**2.57**

Appendix M-1. Example of a Students Learning Outcomes.

CNC MILLING PBL 3					
Learning outcome: • To write a complete workable NC program (ISO) using proper tools and cutting technology with the aid of CNC simulator.			Problem statement : Problem 3: You are an engineer in a manufacturing company. Your task is to prepare a part program (NC program) for a component that going to be machined using CNC machine.		
Big question/concept	Course content	Learning objectives	Know	Don't know	What need to find out
How to write a complete workable NC program?	**Introduction to CNC Milling** • DIFFERENCE BETWEEN CONVENTIONAL MILLING AND CNC MILLING MACHINES • COORDINATE SYSTEM • CNC MILLING AXES DIRECTIONS X, Y AND Z • ZERO POINT AND REFERENCE POINT OF CNC MILLING MACHINE • WORKPIECE COORDINATE SYSTEM WITH G17 AND G18 PLANE • STORED ZERO OFFSET • ABSOLUTE DIMENSIONS G90 • INCREMENTAL DIMENSIONS G91 • G0, G1, G2, AND G3 COMMAND o TRAVEL STRAIGHT LINE IN RAPID TRAVERSE (G0) o TRAVEL STRAIGHT LINE IN FEED TRAVERSE (G1) o TRAVEL CIRCULAR ARC IN FEED TRAVERSE (G2 & G3)				

CNC MILLING PBL 3					
Learning outcome: • To write a complete workable NC program (ISO) using proper tools and cutting technology with the aid of CNC simulator.			Problem statement : Problem 3: You are an engineer in a manufacturing company. Your task is to prepare a part program (NC program) for a component that going to be machined using CNC machine.		
Big question/concept	Course content	Learning objectives	Know	Don't know	What need to find out
How to write a complete workable NC program?	• MISCELLANEOUS FUNCTIONS M (M3, M4, M5, M8, M9, M30) • TOOL RADIUS COMPENSATION G40, G41, G42 COMMAND • TOOL CHANGE COMMAND (T) • RPM - CONSTANT SPINDLE SPEED (S) **CNC MILLING PROGRAMMING (HEIDENHAIN iTNC530 CTRL)** CONTOURS PROGRAMMING TECHNIQUES • CONTOUR APPROCH AND DEPARTURE • TANGENTIAL APPROCH AND DEPARTURE • CONTOUR PROGRAMMING WITH CARTESIAN COORDINATES • CONTOUR PROGRAMMING WITH POLAR COORDINATES HEIDENHAIN iTNC530 PROGRAM STRUCTURE				

<table>
<tr><td colspan="6">CNC MILLING PBL 3</td></tr>
<tr><td colspan="3">Learning outcome:
• To write a complete workable NC program (ISO) using proper tools and cutting technology with the aid of CNC simulator.</td><td colspan="3">Problem statement :

Problem 3: You are an engineer in a manufacturing company. Your task is to prepare a part program (NC program) for a component that going to be machined using CNC machine.</td></tr>
<tr><td>Big question/concept</td><td>Course content</td><td>Learning objectives</td><td>Know</td><td>Don't know</td><td>What need to find out</td></tr>
<tr><td>How to write a complete workable NC program?</td><td>CYCLES AND MACHINING POINT PATTERNS

CYCLES
• DRILLING CYCLE G240 (CENTERING)
• DEEP HOLE DRILLING CYCLE G203
• DEEP HOLE DRILLING CYCLE G205
• REAMING CYCLE G201
• BORING CYCLE G202
• TAPPING CYCLE G206 WITH FLOATING TAP HOLDER
• TAPPING CYCLE G207 WITH RIGID TAPPING
• RECTANGULAR POCKET CYCLE G251
• CIRCULAR POCKET CYCLE G252
• SLOT MILLING CYCLE G253
• CIRCULAR SLOT CYCLE G254

CYCLES FOR MACHINING POINT PATTERNS
• CIRCULAR PATTERN G220
• LINEAR PATTERN G221</td><td></td><td></td><td></td><td></td></tr>
</table>

<table>
<tr><td colspan="6">CNC MILLING PBL 3</td></tr>
<tr><td colspan="3">Learning outcome:
• To write a complete workable NC program (ISO) using proper tools and cutting technology with the aid of CNC simulator.</td><td colspan="3">Problem statement :

Problem 3: You are an engineer in a manufacturing company. Your task is to prepare a part program (NC program) for a component that going to be machined using CNC machine.</td></tr>
<tr><td>Big question/concept</td><td>Course content</td><td>Learning objectives</td><td>Know</td><td>Don't know</td><td>What need to find out</td></tr>
<tr><td>How to write a complete workable NC program?</td><td>WORKING WITH CNC MILLING SIMULATOR (ISO)
START THE CNC MILLING SIMULATOR SOFTWARE

EXPLORING THE SIMULATOR'S BUTTON AND SOFTKEYS FUNCTIONS
PROGRAM MANAGEMENT
• CREATE FOLDER, NEW PROGRAM, COPY, DELETE, ETC.
PROGRAM EDITING
GRAPHIC MANAGEMENT
TOOL MANAGEMENT
RUN A WORKPIECE SIMULATION</td><td></td><td></td><td></td><td></td></tr>
</table>

Appendix N-1. Percentages and Frequencies of Students Semester Three's Responses of Likert-Scale Self-Assessment.

Table 4-28: Self-assessment of semester three students on application of knowledge.

Application of knowledge	1-Strongly disagree	2-Disagree	3-Undecided	4-Agree	5-Strongly Agree	Mean
1- I am able to apply my prior knowledge to solve new problem (i.e. conventional machine to CNC machine).		2 (4.3%)	17 (36.2%)	25 (53.2%)	3 (6.4%)	3.62
2- I am able to adapt and apply relevant concepts to new problem's situation (i.e. ISO programming concept to conversational programming).	1 (2.1%)	1 (2.1%)	17 (36.2%)	25 (53.2%)	3 (6.4%)	3.60
Total	**1 (1.1%)**	**3 (3.2%)**	**34 (36.1%)**	**50 (53.2%)**	**6 (6.4%)**	**3.61**

Table 4-29: Self-assessment of semester three students on self-directed learning.

Self-Directed Learning	1-Strongly disagree	2-Disagree	3-Undecided	4-Agree	5-Strongly Agree	Mean
3- I am able to set learning objectives and achieve it.		1 (2.1%)	9 (19.1%)	29 (61.7%)	8 (17%)	3.94
4- I am able to search relevant information from various learning resources independently to solve new problem.	-	2 (4.3%)	6 (12.8%)	32 (68.1%)	7 (14.9%)	3.94
5- I am able to push myself to the limits of my knowledge and abilities.	1 (2.1%)		7 (14.9%)	29 (61.7%)	10 (21.3%)	4.00
6- I am able to identify my areas of opportunity for improvement in learning.		1 (2.1%)	5 (10.6%)	34 (72.3%)	7 (14.9%)	4.00
Total	**1 (0.5%)**	**4 (2.1%)**	**27 (14.4%)**	**124 (66%)**	**32 (17%)**	**3.97**

Table 4-30: Self-assessment of semester three students on technical reasoning & decision making skills.

Technical reasoning & Decision Making Skills (i.e. contour programming).	1-Strongly disagree	2-Disagree	3-Undecided	4-Agree	5-Strongly Agree	Mean
7- I am able to identify useful information in the product/project		1 (2.1%)	11 (23.4%)	30 (63.8%)	5 (10.6%)	3.83
8- I am able to list the processes required in the product/project.	1 (2.1%)		11 (23.4%)	30 (63.8%)	5 (10.6%)	3.81
9- I am able to prioritize the processes of product/project.			9 (19.1%)	32 (68.1%)	6 (12.8%)	3.94
10- I am able to list the tools needed to process the component with CNC machine.		1 (2.1%)	5 (10.6%)	33 (70.2%)	8 (17%)	4.02
11- I am able to determine the component's datum point to process the component with CNC machine.	1 (2.1%)	2 (4.3%)	2 (4.3%)	27 (57.4%)	15 (31.9%)	4.13
12- I am able to make decision related to which machining/manufacturing strategy to use in the product/project.		2 (4.3%)	12 (25.5%)	29 (61.7%)	4 (8.5%)	3.74
Total	**2 (0.7%)**	**6 (2.1%)**	**50 (17.7%)**	**181 (64.2%)**	**43 (15.2%)**	**3.91**

Table 4-31: Self-assessment of semester three students on problem solving & critical thinking skills.

Problem Solving & Critical Thinking Skills (i.e. contour programming techniques).	1-Strongly disagree	2-Disagree	3-Undecided	4-Agree	5-Strongly Agree	Mean
13- I am able to reason and synthesize information.		3 (6.4%)	15 (31.9%)	27 (57.4%)	2 (4.3%)	3.60
14- I am able to identify multiple approaches to solve the problem.			8 (17%)	33 (70.2%)	6 (12.8%)	3.96
15- I am able to propose one or more solutions to solve the problem.		1 (2.1%)	21 (44.7%)	23 (48.9%)	2 (4.3%)	3.55
16- I am able to identify the important issues in the problem.		2 (4.3%)	9 (19.1%)	35 (74.5%)	1 (2.1%)	3.74
17- I am able to evaluate the outcomes of the solution and determine appropriate action if needed.		2 (4.3%)	14 (29.8%)	27 (57.4%)	4 (8.5%)	3.70
18- I always have different way of doing things or solving problem.		1 (2.1%)	16 (34%)	25 (53.2%)	5 (10.6%)	3.72
19- I always think of better way of doing things or solving problem.			7 (14.9%)	32 (68.1%)	8 (17%)	4.02
20- I will always analyse the problem or objective before I start any action.			10 (21.3%)	30 (63.8%)	7 (14.9%)	3.94
21- I will always evaluate possible solutions, answers or plans for the problem.		1 (2.1%)	16 (34%)	22 (46.8%)	8 (17%)	3.79
Total		**10 (2.4%)**	**116 (27.4%)**	**254 (60%)**	**43 (10.2%)**	**3.78**

Table 4-32: Self-assessment of semester three students on teamwork.

Team work	1-Strongly disagree	2-Disagree	3-Undecided	4-Agree	5-Strongly Agree	Mean
22- I handed work/assignment in on time.	1 (2.1%)	1 (2.1%)	6 (12.8%)	22 (46.8%)	17 (36.2%)	4.13
23- I attended every group meeting and arrived on time.	1 (2.1%)	1 (2.1%)	4 (8.5%)	24 (51.1%)	17 (36.2%)	4.17
24- I always worked hard towards the attainment of the team's learning objectives.			3 (6.4%)	30 (63.8%)	14 (29.8%)	4.23
25- I am keen to be actively involved in a group discussion.	1 (2.1%)		5 (10.6%)	29 (61.7%)	12 (25.5%)	4.09
26- I respected group member's opinions, ideas and contribution.	1 (2.1%)			20 (42.6%)	26 (55.3%)	4.49
27- I acknowledged others' opinions, ideas and contribution.	1 (2.1%)		1 (2.1%)	20 (42.6%)	25 (53.2%)	4.45
28- I like to help members who lagged behind in the group.	1 (2.1%)		2 (4.3%)	26 (55.3%)	18 (38.3%)	4.28
29- I like to share bibliographic sources with my group members.			5 (10.6%)	30 (63.8%)	12 (25.5%)	4.15
30- I offered feedback to my team mates in constructive and friendly way.		1 (2.1%)	7 (14.9%)	29 (61.7%)	10 (21.3%)	4.02
31- I supported group decisions although I was not totally in agreement.	1 (2.1%)	6 (12.8%)	13 (27.7%)	22 (46.8%)	5 (10.6%)	3.51
Total	**7 (1.5%)**	**9 (1.9%)**	**46 (9.8%)**	**252 (53.6%)**	**156 (33.2%)**	**4.15**

Table 4-33: Self-assessment of semester three students on communication skills.

Communication Skills	1-Strongly disagree	2-Disagree	3-Undecided	4-Agree	5-Strongly Agree	Mean
32- I believe I don't need to read script and be very confident with my oral presentation.	1 (2.1%)	7 (14.9%)	21 (44.7%)	16 (34%)	2 (4.3%)	3.23
33- I always eager to answer questions during Q & A session.	2 (4.3%)	2 (4.3%)	16 (34%)	20 (42.6%)	7 (14.9%)	3.60
34- I always be prepared and be a good listener during the oral presentation.	1 (2.1%)	1 (2.1%)	2 (4.3%)	33 (70.2%)	10 (21.3%)	4.06
35- I am able to deliver the content very well and understood by audience.	1 (2.1%)	1 (2.1%)	18 (38.3%)	22 (46.8%)	5 (10.6%)	3.62
36- I am able to place the appropriate words to the thoughts I want to explain.		2 (4.3%)	14 (29.8%)	23 (48.9%)	8 (17%)	3.79
37- I am able to answer questions very well related to the presented topic.			16 (34%)	25 (53.2%)	6 (12.8%)	3.79
Total	**5 (1.8%)**	**13 (4.6%)**	**87 (30.8%)**	**139 (49.3%)**	**38 (13.5%)**	**3.68**

Appendix N-2. Percentages and Frequencies of Students Semester Four's Responses of Likert-Scale Self-Assessment.

Table 4-34: Self-assessment of semester four students on application of knowledge.

Application of knowledge	1-Strongly disagree	2-Disagree	3-Undecided	4-Agree	5-Strongly Agree	Mean
1- I am able to apply my prior knowledge to solve new problem (i.e. conventional machine to CNC machine).		2 (2.4%)	14 (16.5%)	52 (61.2%)	17 (20%)	3.99
2- I am able to adapt and apply relevant concepts to new problem's situation (i.e. ISO programming concept to conversational programming).		1 (1.2%)	22 (25.9%)	57 (67.1%)	5 (5.9%)	3.78
Total	**0 (0%)**	**3 (1.8%)**	**36 (21.2%)**	**109 (64.1%)**	**22 (12.9%)**	**3.89**

Table 4-35: Self-assessment of semester four students on self-directed learning.

Self-Directed Learning	1-Strongly disagree	2-Disagree	3-Undecided	4-Agree	5-Strongly Agree	Mean
3- I am able to set learning objectives and achieve it.		1 (1.2%)	17 (20%)	39 (45.9%)	28 (32.9%)	4.11
4- I am able to search relevant information from various learning resources independently to solve new problem.		1 (1.2%)	12 (14.1%)	55 (64.7%)	17 (20%)	4.04
5- I am able to push myself to the limits of my knowledge and abilities.		2 (2.4%)	18 (21.2%)	50 (58.8%)	15 (17.6%)	3.92
6- I am able to identify my areas of opportunity for improvement in learning.		1 (1.2%)	14 (16.5%)	45 (52.9%)	25 (29.4%)	4.11
Total	**0 (0%)**	**5 (1.5%)**	**61 (17.9%)**	**189 (55.6%)**	**85 (25%)**	**4.05**

Table 4-36: Self-assessment of semester four students on technical reasoning & decision making skills.

Technical reasoning & Decision Making Skills (i.e. contour programming).	1-Strongly disagree	2-Disagree	3-Undecided	4-Agree	5-Strongly Agree	Mean
7- I am able to identify useful information in the product/project			20 (23.5%)	39 (45.9%)	26 (30.6%)	4.07
8- I am able to list the processes required in the product/project.		1 (1.2%)	16 (18.8%)	46 (54.1%)	22 (25.9%)	4.05
9- I am able to prioritize the processes of product/project.		1 (1.2%)	21 (24.7%)	46 (54.1%)	17 (20%)	3.93
10- I am able to list the tools needed to process the component with CNC machine.		3 (3.5%)	10 (11.8%)	46 (54.1%)	26 (30.6%)	4.12
11- I am able to determine the component's datum point to process the component with CNC machine.		2 (2.4%)	12 (14.1%)	54 (63.5%)	17 (20%)	4.01
12- I am able to make decision related to which machining/manufacturing strategy to use in the product/project.		3 (3.5%)	15 (17.6%)	50 (58.8%)	17 (20%)	3.95
Total	**0 (0%)**	**10 (2%)**	**94 (18.4%)**	**281 (55.1%)**	**125 (24.5%)**	**4.02**

Table 4-37: Self-assessment of semester four students on problem solving & critical thinking skills.

Problem Solving & Critical Thinking Skills (i.e. contour programming techniques).	1-Strongly disagree	2-Disagree	3-Undecided	4-Agree	5-Strongly Agree	Mean
13- I am able to reason and synthesize information.		6 (7.1%)	23 (27.1%)	46 (54.1%)	10 (11.8%)	3.71
14- I am able to identify multiple approaches to solve the problem.		2 (2.4%)	16 (18.8%)	59 (69.4%)	8 (9.4%)	3.86
15- I am able to propose one or more solutions to solve the problem.		2 (2.4%)	39 (45.9%)	32 (37.6 %)	12 (14.1%)	3.64
16- I am able to identify the important issues in the problem.		3 (3.5%)	27 (31.8%)	44 (51.8%)	11 (12.9%)	3.74
17- I am able to evaluate the outcomes of the solution and determine appropriate action if needed.			24 (28.2%)	50 (58.8%)	11 (12.9%)	3.85
18- I always have different way of doing things or solving problem.		2 (2.4%)	21 (24.7%)	48 (56.5%)	14 (16.5%)	3.87
19- I always think of better way of doing things or solving problem.		1 (1.2%)	12 (14.1%)	55 (64.7%)	17 (20%)	4.04
20- I will always analyze the problem or objective before I start any action.		4 (4.7%)	22 (25.9%)	42 (49.4%)	17 (20%)	3.85
21- I will always evaluate possible solutions, answers or plans for the problem.		4 (4.7%)	21 (24.7%)	48 (56.5%)	12 (14.1%)	3.80
Total	**0 (0%)**	**24 (3.1%)**	**205 (26.8%)**	**424 (55.4%)**	**112 (14.6%)**	**3.82**

Table 4-38: Self-assessment of semester four students on teamwork.

Team work	1-Strongly disagree	2-Disagree	3-Undecided	4-Agree	5-Strongly Agree	Mean
22- I handed work/assignment in on time.	1 (1.2%)	1 (1.2%)	18 (21.2%)	44 (51.8%)	21 (24.7%)	3.98
23- I attended every group meeting and arrived on time.	1 (1.2%)	1 (1.2%)	16 (18.8%)	39 (45.9%)	28 (32.9%)	4.08
24- I always worked hard towards the attainment of the team's learning objectives.		1 (1.2%)	7 (8.2%)	40 (47.1%)	37 (43.5%)	4.33
25- I am keen to be actively involved in a group discussion.		2 (2.4%)	7 (8.2%)	39 (45.9%)	37 (43.5%)	4.31
26- I respected group member's opinions, ideas and contribution.			1 (1.2%)	35 (41.2%)	49 (57.6%)	4.56
27- I acknowledged others' opinions, ideas and contribution.				32 (37.6%)	53 (62.4%)	4.62
28- I like to help members who lagged behind in the group.			8 (9.4%)	41 (48.2%)	36 (42.4%)	4.33
29- I like to share bibliographic sources with my group members.	2 (2.4%)		16 (18.8%)	51 (60%)	16 (18.8%)	3.93
30- I offered feedback to my team mates in constructive and friendly way.		1 (1.2%)	9 (10.6%)	45 (52.9%)	30 (35.3%)	4.22
31- I supported group decisions although I was not totally in agreement.	2 (2.4%)	4 (4.7%)	14 (16.5%)	38 (44.7%)	27 (31.8%)	3.99
Total	**6 (0.7%)**	**10 (1.2%)**	**96 (11.3%)**	**404 (47.5%)**	**334 (39.3%)**	**4.24**

Table 4-39: Self-assessment of semester four students on communication skills.

Communication Skills	1-Strongly disagree	2-Disagree	3-Undecided	4-Agree	5-Strongly Agree	Mean
32- I believe I don't need to read script and be very confident with my oral presentation.	4 (4.7%)	5 (5.9%)	46 (54.1%)	22 (25.9%)	8 (9.4%)	3.29
33- I always eager to answer questions during Q & A session.	2 (2.4%)	3 (3.5%)	31 (36.5%)	36 (42.4%)	13 (15.3%)	3.65
34- I always be prepared and be a good listener during the oral presentation.	1 (1.2%)		12 (14.1%)	54 (63.5%)	18 (21.2%)	4.04
35- I am able to deliver the content very well and understood by audience.		3 (3.5%)	28 (32.9%)	42 (49.4%)	12 (14.1%)	3.74
36- I am able to place the appropriate words to the thoughts I want to explain.		2 (2.4%)	22 (25.9%)	47 (55.3%)	14 (16.5%)	3.86
37- I am able to answer questions very well related to the presented topic.	1 (1.2%)		26 (30.6%)	49 (57.6%)	9 (10.6%)	3.76
Total	**8 (1.6%)**	**13 (2.5%)**	**165 (32.4%)**	**250 (49.0%)**	**74 (14.5%)**	**3.72**

Appendix O-1. Students Semester Three's Responses of Likert-Scale Peer-Assessment.

		PA1_1	PA1_2	PA1_3	PA1_4	PA1_5	PA1_6	PA1_7	PA1_8	PA1_9	PA1_10	Attitude	PA1_11	PA1_12	PA1_13	PA1_14	PA1_15	PA1_16	PA1_17	PA1_18	PA1_19	PA1_20	Teamwork
S3MOT1	Student1	5	5	4	5	5	5	5	5	5	5		5	5	5	5	4	4	5	5	5	5	
	Student2	5	4	4	5	4	4	5	5	5	5		5	4	5	5	5	4	5	5	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.67	4.33	4.00	4.67	4.33	4.33	4.67	4.67	4.67	4.67	4.50	4.67	4.00	5.00	5.00	4.33	4.33	4.67	5.00	5.00	4.67	4.67
S3MOT2	Student1	3	4	3	4	3	4	3	4	3	4		3	4	3	4	3	4	3	4	3	4	
	Student2	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	5	
	Student3	4	4	4	4	4	3	4	5	3	5		4	3	5	4	5	3	5	4	4	3	
		4.00	4.33	4.00	4.33	4.00	4.00	4.00	4.67	3.67	4.67	4.17	4.00	4.00	4.33	4.33	4.33	4.00	4.33	4.33	4.00	4.00	4.17
S3MOT3	Student1	4	4	5	5	4	4	5	4	4	5		4	4	5	5	5	4	4	5	4	5	
	Student2	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	5	
	Student3	5	5	5	5	5	5	5	5	5	5		4	4	4	4	4	4	4	5	5	5	
		4.67	4.67	5.00	5.00	4.67	4.67	5.00	4.67	4.67	5.00	4.80	4.33	4.33	4.67	4.67	4.67	4.33	4.33	5.00	4.67	5.00	4.60
S3MOT4	Student1	5	4	4	4	4	5	4	4	4	4		4	4	4	4	5	5	4	4	3	5	
	Student2	4	2	3	2	3	4	4	4	4	4		3	3	3	4	4	4	4	4	4	5	
	Student3	4	3	3	3	3	4	4	3	4	4		4	3	3	4	4	3	4	3	4	4	
		4.33	3.00	3.33	3.00	3.33	4.33	4.00	3.67	4.00	4.00	3.70	3.67	3.33	3.33	4.00	4.33	4.00	4.00	3.67	3.67	4.67	3.87
S3MOT5	Student1	5	5	5	4	5	5	5	5	4	5		5	5	5	5	5	5	4	5	5	5	
	Student2	5	5	5	5	5	5	5	5	5	5		4	4	4	5	5	5	5	4	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	4	4	3	4	4	3	4	4	4	
		4.67	4.67	4.67	4.33	4.67	4.67	4.67	4.67	4.33	4.67	4.60	4.33	4.33	4.33	4.33	4.67	4.67	4.00	4.33	4.67	4.33	4.40
S3MOT6	Student1	4	4	5	5	5	4	5	5	5	5		5	5	5	5	5	5	5	5	4	4	
	Student2	4	5	5	4	4	4	5	4	5	5		4	5	5	4	4	4	4	5	5	5	
	Student3	4	4	4	4	4	4	4	4	4	4		5	4	5	4	5	5	4	4	5	5	
		4.00	4.33	4.67	4.33	4.33	4.00	4.67	4.33	4.67	4.67	4.40	4.67	4.67	5.00	4.33	4.67	4.67	4.33	4.67	4.67	4.67	4.63
S3MOT7	Student1	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	5	
	Student2	5	5	5	5	5	4	4	5	5	5		5	5	5	5	5	4	5	5	5	5	
	Student3	5	5	5	4	5	5	5	5	4	5		5	5	5	5	5	5	4	5	5	5	
		5.00	5.00	5.00	4.67	5.00	4.67	4.67	5.00	4.67	5.00	4.87	5.00	5.00	5.00	5.00	5.00	4.67	4.67	5.00	5.00	5.00	4.93
S3MOT8	Student1	4	4	5	5	5	4	4	4	5	5		5	5	5	5	5	4	5	5	4	4	
	Student2	4	4	4	4	4	4	5	5	5	5		5	5	5	5	5	5	5	5	5	4	
	Student3	4	4	4	4	4	4	4	4	4	5		4	3	5	4	5	5	4	4	5	5	
		4.00	4.00	4.33	4.33	4.33	4.00	4.33	4.33	4.67	5.00	4.33	4.67	4.33	5.00	4.67	5.00	4.67	4.67	4.67	4.67	4.33	4.67
S3MOT9	Student1	5	4	4	4	4	4	4	4	4	4		5	5	5	5	5	5	5	5	5	5	
	Student2	5	5	5	5	5	4	5	5	5	5		5	5	5	5	5	5	4	5	5	5	
	Student3	5	5	5	4	5	5	5	5	4	5		5	5	5	5	5	5	4	5	5	5	
		5.00	4.67	4.67	4.33	4.67	4.33	4.67	4.67	4.33	4.67	4.60	5.00	5.00	5.00	5.00	5.00	5.00	4.33	5.00	5.00	5.00	4.93
S3MOT10	Student1	5	4	5	4	5	4	4	5	4	5		4	5	5	4	5	5	4	4	5	5	
	Student2	5	4	5	4	4	5	4	4	4	5		4	4	5	4	4	4	5	4	4	5	
	Student3	4	4	4	3	4	4	4	4	4	4		3	4	4	5	4	4	4	5	5	5	
		4.67	4.00	4.67	3.67	4.33	4.33	4.00	4.33	4.00	4.67	4.27	3.67	4.33	4.67	4.33	4.33	4.33	4.33	4.33	4.67	5.00	4.40
S3MOT11	Student1	4	4	4	5	4	4	5	5	4	4		4	5	4	5	4	5	4	4	4	5	
	Student2	5	5	5	5	5	5	4	5	5	5		5	5	5	5	5	5	5	5	5	5	
	Student3	4	5	5	4	4	4	5	4	4	5		4	4	5	5	4	5	5	5	5	5	
		4.33	4.67	4.67	4.67	4.33	4.33	4.67	4.67	4.33	4.67	4.53	4.33	4.67	4.67	5.00	4.33	5.00	4.67	4.67	4.67	5.00	4.70
S3MOT12	Student1	5	5	4	4	4	5	5	5	5	5		5	4	5	5	5	5	4	4	5	4	
	Student2	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	4	5	5	5	
	Student3	5	5	5	4	5	5	5	5	4	5		5	5	5	5	5	5	5	5	5	5	
		5.00	5.00	4.67	4.33	4.67	5.00	5.00	5.00	4.67	5.00	4.83	5.00	4.67	5.00	5.00	5.00	5.00	4.33	4.67	5.00	4.67	4.83
S3MOT13	Student1	4	5	5	5	5	5	5	5	5	5		5	4	5	5	5	5	5	5	4	4	
	Student2	4	5	5	5	5	4	4	5	4	5		4	4	5	5	4	4	5	5	5	5	
	Student3	4	5	5	4	5	4	4	5	5	5		4	5	4	5	5	4	5	4	5	5	
		4.00	5.00	5.00	4.67	5.00	4.33	4.33	5.00	4.67	5.00	4.70	4.33	4.33	4.67	5.00	4.67	4.33	5.00	4.67	4.67	4.67	4.63
S3TDT14	Student1	4	4	4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4	4	4	
	Student2	4	4	4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4	4	4	
	Student3	4	4	3	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4	4	4	
		4.00	4.00	3.67	4.00	4.00	4.00	4.00	4.00	4.00	4.00	3.97	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
S3TDT15	Student1	5	4	5	4	5	4	5	4	4	4		5	4	4	4	5	4	5	4	5	5	
	Student2	4	4	4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4	4	4	
	Student3	5	5	5	5	5	5	4	5	5	5		5	5	5	5	5	5	5	3	5	5	
		4.67	4.33	4.67	4.33	4.67	4.33	4.33	4.33	4.33	4.33	4.43	4.67	4.33	4.33	4.33	4.67	4.33	4.67	3.67	4.67	4.67	4.43
	Student1	4	4	4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4	4	4	
S3TDT16	Student2	4	4	4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4	4	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4	4	4	
		4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
S3TDT17	Student1	5	5	5	5	5	4	5	5	5	5		5	5	5	5	5	5	5	4	5	5	
	Student2	5	5	5	5	5	5	5	5	5	4		5	5	4	5	5	5	5	5	5	5	
	Student3	4	5	5	4	4	4	4	4	4	4		4	4	4	4	5	5	5	4	5	5	
		4.67	5.00	5.00	4.67	4.67	4.33	4.67	4.67	4.67	4.33	4.67	4.67	4.67	4.33	4.67	5.00	5.00	5.00	4.33	5.00	5.00	4.77
S3TDT18	Student1	5	5	5	5	5	4	5	5	5	5		5	5	5	5	5	5	5	4	5	5	
	Student2	5	5	5	5	5	5	5	5	5	4		5	5	4	5	5	5	5	5	5	5	
	Student3	4	5	5	4	4	4	4	4	4	4		4	4	4	4	5	5	5	4	5	5	
		4.67	5.00	5.00	4.67	4.67	4.33	4.67	4.67	4.67	4.33	4.67	4.67	4.67	4.33	4.67	5.00	5.00	5.00	4.33	5.00	5.00	4.77
S3TDT19	Student1	4	4	4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4	4	4	
	Student2	5	4	4	3	5	4	4	3	4	4		4	4	5	4	3	4	5	3	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		5	4	4	4	4	4	4	4	4	4	
		4.33	4.00	4.00	3.67	4.33	4.00	4.00	3.67	4.00	4.00	4.00	4.33	4.00	4.33	4.00	3.67	4.00	4.33	3.67	4.33	4.00	4.07
S3TDT20	Student1	5	3	5	4	5	4	4	5	4	3		5	5	5	5	5	4	4	5	5	5	
	Student2	5	3	3	3	4	4	3	3	4	4		3	3	3	3	4	4	4	4	4	4	
	Student3	3	4	4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4	4	4	
		4.33	3.33	4.00	3.67	4.33	4.00	3.67	4.00	4.00	3.67	3.90	4.00	4.00	4.00	4.00	4.33	4.00	4.00	4.33	4.33	4.33	4.13
S3TDT21	Student1	5	5	4	5	5	5	5	5	5	5		5	5	5	5	4	4	5	5	5	5	
	Student2	5	4	4	5	4	4	5	5	5	5		5	4	5	5	5	4	5	5	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.67	4.33	4.00	4.67	4.33	4.33	4.67	4.67	4.67	4.67	4.50	4.67	4.00	5.00	5.00	4.33	4.33	4.67	5.00	5.00	4.67	4.67
S3TDT22	Student1	4	4	4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4	4	4	
	Student2	4	4	4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4	4	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4	4	4	
		4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
S3TDT23	Student1	4	4	4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4	4	4	
	Student2	5	5	4	5	5	5	4	5	5	5		5	4	5	5	5	5	5	5	5	5	
	Student3	4	4	4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4	4	4	
		4.33	4.33	4.00	4.33	4.33	4.33	4.00	4.33	4.33	4.33	4.27	4.33	4.00	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.30

S3TDT24	Student1	5	5	5	5	5	4	5	5	5	5		5	5	5	5	5	5	5	4	5	5	
	Student2	5	5	5	5	5	4	5	5	5	5		5	4	5	5	5	5	5	5	5	5	
	Student3	4	4	4	4	4	5	5	4	4	4		4	5	5	5	4	4	4	4	4	4	
		4.67	4.67	4.67	4.67	4.67	4.33	5.00	4.67	4.67	4.67	4.67	4.67	4.67	5.00	5.00	4.67	4.67	4.67	4.33	4.67	4.67	4.70
S3TDT25	Student1	5	5	5	4	5	5	5	5	5	5		5	5	5	4	5	5	5	5	5	5	
	Student2	5	5	5	5	4	5	5	5	5	5		5	4	5	5	5	5	5	5	5	5	
	Student3	5	5	5	5	5	4	5	5	5	5		5	5	5	5	5	5	5	4	5	5	
		5.00	5.00	5.00	4.67	4.67	4.67	5.00	5.00	5.00	5.00	4.90	5.00	4.67	5.00	4.67	5.00	5.00	5.00	4.67	5.00	5.00	4.90
S3TDT26	Student1	4	4	4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4	4	4	
	Student2	5	5	5	5	4	4	3	5	4	5		5	5	5	4	5	5	5	5	5	3	
	Student3	4	4	4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	3	4	4	
		4.33	4.33	4.33	4.33	4.00	4.00	3.67	4.33	4.00	4.33	4.17	4.33	4.33	4.33	4.00	4.33	4.33	4.33	4.00	4.33	3.67	4.20
S3TDT27	Student1	5	3	4	5	4	4	3	4	5	4		5	5	4	4	5	5	4	4	3	4	
	Student2	5	4	5	5	5	5	5	4	5	5		4	4	5	5	5	5	5	5	5	5	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.67	3.67	4.33	4.67	4.33	4.33	4.00	4.00	4.67	4.33	4.30	4.33	4.00	4.67	4.67	4.67	5.00	4.33	4.67	4.33	4.67	4.53
S3TDT28	Student1	4	5	5	5	5	5	5	4	5	5		4	4	5	5	5	5	5	5	4	4	
	Student2	4	4	3	4	3	3	4	4	4	4		4	4	4	4	4	4	4	4	3	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.00	4.33	4.00	4.33	4.00	4.00	4.33	4.00	4.33	4.33	4.17	4.00	3.67	4.67	4.67	4.33	4.67	4.33	4.67	4.00	4.33	4.33
S3TDT29	Student1	5	4	4	4	4	5	4	5	5	5		5	5	3	4	4	4	4	4	3	3	
	Student2	4	4	4	4	4	3	3	4	4	3		4	4	4	4	4	4	4	4	4	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.33	4.00	4.00	4.00	4.00	4.00	3.67	4.33	4.33	4.00	4.07	4.33	4.00	4.00	4.33	4.00	4.33	4.00	4.33	4.00	4.00	4.13
S3CPT30	Student1	4	5	5	5	4	4	5	5	5	4		4	5	5	5	4	4	4	5	5	5	
	Student2	5	5	5	4	4	4	4	5	5	4		4	4	5	4	4	4	4	4	4	4	
	Student3	5	4	4	4	4	3	3	4	4	4		5	5	2	4	4	4	4	4	4	4	
		4.67	4.67	4.67	4.33	4.00	3.67	4.00	4.67	4.67	4.00	4.33	4.33	4.67	4.00	4.33	4.00	4.00	4.00	4.33	4.33	4.33	4.23
S3CPT31	Student1	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	5	
	Student2	5	5	5	5	5	4	4	4	4	4		5	5	5	5	5	4	5	4	5	5	
	Student3	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	5	
		5.00	5.00	5.00	5.00	5.00	4.67	4.67	4.67	4.67	4.67	4.83	5.00	5.00	5.00	5.00	5.00	4.67	5.00	4.67	5.00	5.00	4.93
S3CPT32	Student1	1	5	4	3	4	5	5	4	5	5		4	5	4	5	5	5	4	5	5	4	
	Student2	4	4	5	5	5	5	5	5	4	4		5	5	5	5	5	5	5	5	5	5	
	Student3	5	3	4	4	4	5	4	5	4	5		5	5	4	5	4	4	3	3	4	4	
		3.33	4.00	4.33	4.00	4.33	5.00	4.67	4.67	4.33	4.67	4.33	4.67	5.00	4.33	5.00	4.67	4.67	4.00	4.33	4.67	4.33	4.57
S3CPT33	Student1	5	5	5	4	4	4	4	5	5	5		5	5	4	4	4	5	4	5	4	3	
	Student2	4	4	4	4	4	4	4	4	4	4		4	4	4	5	5	5	5	5	4	5	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.33	4.33	4.33	4.00	4.00	4.00	4.00	4.33	4.33	4.33	4.20	4.33	4.00	4.33	4.67	4.33	5.00	4.33	5.00	4.33	4.33	4.47
S3CPT34	Student1	3	3	4	4	4	4	3	4	4	4		4	4	3	5	5	5	4	4	5	4	
	Student2	4	4	3	5	3	5	4	3	5	4		4	4	5	4	5	5	5	5	5	5	
	Student3	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	4	5	5	4	
		4.00	4.00	4.00	4.67	4.00	4.67	4.00	4.00	4.67	4.33	4.23	4.33	4.33	4.33	4.67	5.00	5.00	4.33	4.67	5.00	4.33	4.60
S3CPT35	Student1	4	4	5	5	4	3	4	4	5	5		5	4	4	4	5	4	5	5	5	5	
	Student2	5	5	5	4	5	5	5	3	5	5		5	5	4	5	5	5	5	5	4	5	
	Student3	5	4	4	4	5	5	4	5	4	5		3	4	4	5	4	5	5	5	4	5	
		4.67	4.33	4.67	4.33	4.67	4.33	4.33	4.00	4.67	5.00	4.50	4.33	4.33	4.00	4.67	4.67	4.67	5.00	5.00	4.33	5.00	4.60
S3CPT36	Student1	5	5	4	5	5	5	5	4	4	4		5	5	5	5	5	5	4	5	5	5	
	Student2	3	5	3	5	5	5	4	5	5	5		4	3	4	4	5	4	5	5	5	4	
	Student3	4	5	5	4	5	4	5	5	5	5		4	5	5	5	5	5	5	5	5	5	
		4.00	5.00	4.00	4.67	5.00	4.67	4.67	4.67	4.67	4.67	4.60	4.33	4.33	4.67	4.67	5.00	4.67	4.67	5.00	5.00	4.67	4.70
S3CPT37	Student1	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	4	
	Student2	5	5	4	5	4	5	5	5	5	5		5	5	5	5	4	4	5	5	3	4	
	Student3	3	3	3	3	3	3	3	3	3	3		3	3	3	3	3	3	3	3	3	4	
		4.33	4.33	4.00	4.33	4.00	4.33	4.33	4.33	4.33	4.33	4.27	4.33	4.33	4.33	4.33	4.00	4.00	4.33	4.33	3.67	4.00	4.17
S3CPT38	Student1	4	4	4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4	4	3	
	Student2	5	4	4	5	5	4	5	4	4	5		5	4	4	4	4	5	4	4	4	5	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.33	4.00	4.00	4.33	4.33	4.00	4.33	4.00	4.00	4.33	4.17	4.33	3.67	4.33	4.33	4.00	4.67	4.00	4.33	4.33	4.33	4.23
S3CPT39	Student1	3	3	3	3	3	3	3	3	3	3		4	5	4	4	5	4	3	4	3	5	
	Student2	5	5	4	5	5	5	4	5	5	5		3	3	5	5	5	5	5	5	5	5	
	Student3	5	4	5	5	3	4	3	5	4	5		4	4	3	5	5	5	4	5	4	5	
		4.33	4.00	4.00	4.33	3.67	4.00	3.33	4.33	4.00	4.33	4.03	3.67	4.00	4.00	4.67	5.00	4.67	4.00	4.67	4.00	5.00	4.37
S3CPT40	Student1	4	4	4	4	5	5	5	4	4	5		4	4	4	4	4	5	5	4	4	4	
	Student2	4	4	4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4	4	4	
	Student3	4	2	3	3	4	4	4	4	4	3		4	4	4	4	4	4	4	4	4	4	
		4.00	3.33	3.67	3.67	4.33	4.33	4.33	4.00	4.00	4.00	3.97	4.00	4.00	4.00	4.00	4.00	4.33	4.33	4.00	4.00	4.00	4.07
S3CPT41	Student1	5	5	4	5	5	5	4	5	5	4		4	5	4	5	5	5	5	5	4	3	
	Student2	5	4	4	5	4	4	5	5	5	5		5	4	5	5	5	4	5	5	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.67	4.33	4.00	4.67	4.33	4.33	4.33	4.67	4.67	4.33	4.43	4.33	4.00	4.67	5.00	4.67	4.67	4.67	5.00	4.67	4.00	4.57
S3CPT42	Student1	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	4	5	5	
	Student2	3	5	3	4	4	5	3	5	4	3		3	5	4	5	4	4	4	5	3	3	
	Student3	5	5	5	5	5	5	5	5	5	5		4	5	5	4	5	5	5	5	5	5	
		4.33	5.00	4.33	4.67	4.67	5.00	4.33	5.00	4.67	4.33	4.63	4.00	5.00	4.67	4.67	4.67	4.67	4.67	4.67	4.33	4.33	4.57
S3CPT43	Student1	3	3	4	3	2	2	3	2	2	3		4	3	3	3	4	4	3	3	4	3	
	Student2	2	2	4	4	3	4	4	3	4	4		4	4	4	4	4	4	3	3	4	4	
	Student3	3	3	4	3	2	2	3	4	4	3		4	2	2	3	3	3	3	3	2	5	
		2.67	2.67	4.00	3.33	2.33	2.67	3.33	3.00	3.33	3.33	3.07	4.00	3.00	3.00	3.33	3.67	3.67	3.00	3.00	3.33	4.00	3.40
S3CPT44	Student1	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	5	
	Student2	5	4	4	5	4	4	5	5	5	5		5	4	5	5	5	4	5	5	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.67	4.33	4.33	4.67	4.33	4.33	4.67	4.67	4.67	4.67	4.53	4.67	4.00	5.00	5.00	4.67	4.67	4.67	5.00	5.00	4.67	4.73
S3CPT45	Student1	5	4	5	5	4	5	5	5	5	5		5	4	5	4	5	5	5	3	4	4	
	Student2	4	3	4	4	3	4	3	5	5	3		3	4	5	5	5	4	5	5	4	3	
	Student3	5	5	4	5	5	5	5	4	5	5		4	5	4	5	5	5	4	5	4	5	
		4.67	4.00	4.33	4.67	4.00	4.67	4.33	4.67	5.00	4.33	4.47	4.00	4.33	4.67	4.67	5.00	4.67	4.67	4.33	4.00	4.00	4.43
S3CPT46	Student1	4	4	4	4	4	4	4	4	5	5		4	4	4	4	4	4	5	5	5	4	
	Student2	4	2	3	1	2	2	2	4	4	4		4	4	4	4	4	4	4	3	3	3	
	Student3	4	4	4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4	4	4	
		4.00	3.33	3.67	3.00	3.33	3.33	3.33	4.00	4.33	4.33	3.67	4.00	4.00	4.00	4.00	4.00	4.00	4.33	4.00	4.00	3.67	4.00
S3CPT47	Student1	4	4	4	4	4	4	4	4	4	5		5	5	4	5	4	5	4	5	4	4	
	Student2	5	4	5	4	4	4	4	4	4	5		5	5	5	4	5	4	4	4	5	5	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.33	4.00	4.33	4.00	4.00	4.00	4.00	4.00	4.00	4.67	4.13	4.67	4.33	4.67	4.67	4.33	4.67	4.00	4.67	4.67	4.67	4.53

Appendix O-2. Students Semester Four's Responses of Likert-Scale Peer-Assessment.

		PA1_1	PA1_2	PA1_3	PA1_4	PA1_5	PA1_6	PA1_7	PA1_8	PA1_9	PA1_10	Attitude	PA1_11	PA1_12	PA1_13	PA1_14	PA1_15	PA1_16	PA1_17	PA1_18	PA1_19	PA1_20	Teamwork
S4TDT148	Student1	5	5	5	4	5	5	5	4	5	4		5	5	4	5	5	5	5	4	5	3	
	Student2	4	4	4	4	4	5	4	4	4	4		4	4	4	4	5	4	4	4	4	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.33	4.33	4.33	4.00	4.33	4.67	4.33	4.00	4.33	4.00	4.27	4.33	4.00	4.33	4.67	4.67	4.67	4.33	4.33	4.67	4.00	4.40
S4TDT149	Student1	5	5	5	5	5	5	4	4	4	4		4	3	4	4	5	5	5	5	5	4	
	Student2	5	4	4	5	4	4	5	5	5	5		5	4	5	5	5	4	5	5	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.67	4.33	4.33	4.67	4.33	4.33	4.33	4.33	4.33	4.33	4.40	4.33	3.33	4.67	4.67	4.67	4.67	4.67	5.00	5.00	4.33	4.53
S4TDT150	Student1	4	5	4	5	4	4	3	3	4	3		4	4	4	4	4	4	3	4	3	4	
	Student2	4	4	4	5	5	4	4	4	4	4		4	5	4	4	4	4	4	4	4	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.00	4.33	4.00	4.67	4.33	4.00	3.67	3.67	4.00	3.67	4.03	4.00	4.00	4.33	4.33	4.00	4.33	3.67	4.33	4.00	4.33	4.13
S4TDT151	Student1	5	4	5	4	5	4	5	5	5	5		5	5	4	4	4	4	4	4	5	5	
	Student2	5	4	4	5	4	4	5	5	5	5		5	4	5	5	5	4	5	5	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.67	4.00	4.33	4.33	4.33	4.00	4.67	4.67	4.67	4.67	4.43	4.67	4.00	4.67	4.67	4.33	4.33	4.33	4.67	5.00	4.67	4.53
S4TDT152	Student1	4	5	5	4	4	5	4	5	5	5		4	4	5	5	5	4	4	4	4	5	
	Student2	5	4	4	5	4	4	5	5	5	5		5	4	5	5	5	4	5	5	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.33	4.33	4.33	4.33	4.00	4.33	4.33	4.67	4.67	4.67	4.40	4.33	3.67	5.00	5.00	4.67	4.33	4.33	4.67	4.67	4.67	4.53
S4TDT153	Student1	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	5	
	Student2	4	4	4	5	5	5	5	4	4	4		4	5	4	4	4	5	4	5	5	5	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.33	4.33	4.33	4.67	4.67	4.67	4.67	4.33	4.33	4.33	4.47	4.33	4.33	4.67	4.67	4.33	5.00	4.33	5.00	5.00	5.00	4.67
S4TDT154	Student1	5	5	5	5	5	5	5	5	5	5		5	5	4	5	5	5	5	4	5	3	
	Student2	4	5	4	5	4	4	3	3	4	3		4	4	4	4	4	4	3	4	3	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.33	4.67	4.33	4.67	4.33	4.33	4.00	4.00	4.33	4.00	4.30	4.33	4.00	4.33	4.67	4.33	4.67	4.00	4.33	4.33	4.00	4.30
S4TDT155	Student1	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	5	
	Student2	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	4	5	5	5	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.67	4.67	4.67	4.67	4.67	4.67	4.67	4.67	4.67	4.67	4.67	4.67	4.33	5.00	5.00	4.67	5.00	4.33	5.00	5.00	5.00	4.80
S4TDT156	Student1	4	4	5	4	4	4	4	4	4	4		4	4	4	4	4	4	4	5	4	5	
	Student2	5	4	4	5	4	4	5	5	5	5		5	4	5	5	5	4	5	5	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.33	4.00	4.33	4.33	4.00	4.00	4.33	4.33	4.33	4.33	4.23	4.33	3.67	4.67	4.67	4.33	4.33	4.33	5.00	4.67	4.67	4.47
S4TDT157	Student1	5	5	5	5	4	5	5	5	4	4		5	5	5	4	4	4	5	5	5	5	
	Student2	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	5	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.67	4.67	4.67	4.67	4.33	4.67	4.67	4.67	4.33	4.33	4.57	4.67	4.33	5.00	4.67	4.33	4.67	4.67	5.00	5.00	5.00	4.73
S4TDT258	Student1	4	4	4	4	4	4	4	4	4	4		4	4	4	5	4	4	4	4	4	4	
	Student2	5	4	4	5	4	4	5	5	5	5		5	4	5	5	5	4	5	5	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.33	4.00	4.00	4.33	4.00	4.00	4.33	4.33	4.33	4.33	4.20	4.33	3.67	4.67	5.00	4.33	4.33	4.33	4.67	4.67	4.33	4.43
S4TDT259	Student1	4	4	4	4	4	4	4	4	4	4		4	4	3	4	4	4	4	4	4	4	
	Student2	5	4	4	5	4	4	5	5	5	5		5	4	5	5	5	4	5	5	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.33	4.00	4.00	4.33	4.00	4.00	4.33	4.33	4.33	4.33	4.20	4.33	3.67	4.33	4.67	4.33	4.33	4.33	4.67	4.67	4.33	4.37
S4TDT260	Student1	4	5	3	4	4	4	3	4	4	3		4	4	4	4	4	5	3	4	5	5	
	Student2	5	4	4	5	4	4	5	5	5	5		5	4	5	5	5	4	5	5	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.33	4.33	3.67	4.33	4.00	4.00	4.00	4.33	4.33	4.00	4.13	4.33	3.67	4.67	4.67	4.33	4.67	4.00	4.67	5.00	4.67	4.47
S4TDT261	Student1	3	3	3	3	4	3	4	3	4	3		3	3	3	3	4	4	3	4	4	4	
	Student2	5	4	4	5	4	4	5	5	5	5		5	4	5	5	5	4	5	5	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.00	3.67	3.67	4.00	4.00	3.67	4.33	4.00	4.33	4.00	3.97	4.00	3.33	4.33	4.33	4.33	4.33	4.00	4.67	4.67	4.33	4.23
S4TDT262	Student1	4	4	4	5	5	4	4	4	5	5		5	5	5	5	4	4	5	5	4	4	
	Student2	5	4	4	5	4	4	5	5	5	5		5	4	5	5	5	4	5	5	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.33	4.00	4.00	4.67	4.33	4.00	4.33	4.33	4.67	4.67	4.33	4.67	4.00	5.00	5.00	4.33	4.33	4.67	5.00	4.67	4.33	4.60
S4TDT263	Student1	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	5	
	Student2	5	4	4	5	4	4	5	5	5	5		5	4	5	5	5	4	5	5	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.67	4.33	4.33	4.67	4.33	4.33	4.67	4.67	4.67	4.67	4.53	4.67	4.00	5.00	5.00	4.67	4.67	4.67	5.00	5.00	4.67	4.73
S4TDT264	Student1	4	4	3	4	3	4	3	4	3	4		3	4	3	4	3	4	3	4	3	4	
	Student2	5	4	4	5	4	4	5	5	5	5		5	4	5	5	5	4	5	5	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.33	4.00	3.67	4.33	3.67	4.00	4.00	4.33	4.00	4.33	4.07	4.00	3.67	4.33	4.67	4.00	4.33	4.00	4.67	4.33	4.33	4.23
S4TDT365	Student1	5	4	4	4	4	4	4	4	5	4		4	4	4	4	4	4	4	4	4	3	
	Student2	5	4	4	5	4	4	5	5	5	5		5	4	5	5	5	4	5	5	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.67	4.00	4.00	4.33	4.00	4.00	4.33	4.33	4.67	4.33	4.27	4.33	3.67	4.67	4.67	4.33	4.33	4.33	4.67	4.67	4.00	4.37
S4TDT366	Student1	4	4	5	4	5	4	4	5	5	5		5	4	5	4	5	5	4	4	4	4	
	Student2	2	3	2	3	2	4	2	4	4	4		4	2	4	4	3	3	4	2	3	3	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		3.33	3.67	3.67	3.67	3.67	4.00	3.33	4.33	4.33	4.33	3.83	4.33	3.00	4.67	4.33	4.00	4.33	4.00	3.67	4.00	4.00	4.03
S4TDT367	Student1	4	4	3	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4	4	3	
	Student2	5	5	4	4	4	4	4	4	4	4		5	4	3	3	4	4	4	4	4	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.33	4.33	3.67	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.03	4.33	3.67	4.00	4.00	4.00	4.33	4.00	4.33	4.33	4.00	4.10
S4TDT368	Student1	2	4	3	4	4	4	4	4	4	4		4	2	3	3	4	4	4	4	4	3	
	Student2	5	4	4	5	4	4	5	5	5	5		5	4	5	5	5	4	5	5	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		3.67	4.00	3.67	4.33	4.00	4.00	4.33	4.33	4.33	4.33	4.10	4.33	3.00	4.33	4.33	4.33	4.33	4.33	4.67	4.67	4.00	4.23

S4TDT369	Student1	5	4	4	4	4	4	4	4	5	4		4	4	4	4	4	4	4	4	4	3	
	Student2	5	4	4	5	4	4	5	5	5	5		5	4	5	5	5	4	5	5	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.67	4.00	4.00	4.33	4.00	4.00	4.33	4.33	4.67	4.33	4.27	4.33	3.67	4.67	4.67	4.33	4.33	4.33	4.67	4.67	4.00	4.37
S4TDT370	Student1	4	4	4	4	4	4	4	4	5	4		4	5	4	4	5	5	4	4	4	5	
	Student2	2	2	2	4	3	4	4	4	4	4		3	3	4	4	4	4	3	3	3	3	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		3.33	3.33	3.33	4.00	3.67	4.00	4.00	4.00	4.33	4.00	3.80	3.67	3.67	4.33	4.33	4.33	4.67	3.67	4.00	4.00	4.33	4.10
S4TDT371	Student1	3	4	3	4	4	4	4	4	4	4		4	3	3	4	4	4	4	4	4	3	
	Student2	5	4	4	5	4	4	5	5	5	5		5	4	5	5	5	4	5	5	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.00	4.00	3.67	4.33	4.00	4.00	4.33	4.33	4.33	4.33	4.13	4.33	3.33	4.33	4.67	4.33	4.33	4.33	4.67	4.67	4.00	4.30
S4TDT372	Student1	5	4	5	5	5	5	4	5	5	4		5	4	5	4	4	5	4	4	4	4	
	Student2	4	5	5	4	4	4	4	4	4	4		5	5	4	4	4	4	5	4	4	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.33	4.33	4.67	4.33	4.33	4.33	4.00	4.33	4.33	4.00	4.30	4.67	4.00	4.67	4.33	4.00	4.67	4.33	4.33	4.33	4.33	4.37
S4CPT173	Student1	3	4	3	4	3	4	3	5	4	3		2	3	4	4	2	4	3	1	2	3	
	Student2	4	4	4	4	3	3	4	5	4	4		4	4	4	3	3	4	5	4	4	4	
	Student3	5	4	5	5	5	4	4	5	4	5		5	5	5	5	5	5	5	5	5	5	
		4.00	4.00	4.00	4.33	3.67	3.67	3.67	5.00	4.00	4.00	4.03	3.67	4.00	4.33	4.00	3.33	4.33	4.33	3.33	3.67	4.00	3.90
S4CPT174	Student1	5	4	5	5	5	5	4	5	5	5		5	5	5	5	5	4	4	5	5	5	
	Student2	4	4	5	4	4	4	4	4	4	4		5	4	4	4	4	4	4	4	4	4	
	Student3	5	4	5	4	5	4	4	5	4	5		5	5	5	5	5	5	5	4	5	4	
		4.67	4.00	5.00	4.33	4.67	4.33	4.00	4.67	4.33	4.67	4.47	5.00	4.67	4.67	4.67	4.67	4.33	4.33	4.33	4.67	4.33	4.57
S4CPT175	Student1	5	4	4	5	4	5	5	5	5	5		5	5	5	5	4	5	4	4	4	5	
	Student2	4	4	3	4	3	5	4	4	4	4		4	4	4	3	4	4	4	4	3	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.33	4.00	3.67	4.33	3.67	4.67	4.33	4.33	4.33	4.33	4.20	4.33	4.00	4.67	4.33	4.00	4.67	4.00	4.33	4.00	4.67	4.30
S4CPT176	Student1	5	5	4	4	4	5	4	4	4	4		4	5	4	4	5	5	4	4	4	5	
	Student2	4	4	4	4	4	4	5	4	4	5		4	5	4	5	5	4	5	4	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.33	4.33	4.00	4.00	4.00	4.33	4.33	4.00	4.00	4.33	4.17	4.00	4.33	4.33	4.67	4.67	4.67	4.33	4.33	4.67	4.67	4.47
S4CPT177	Student1	4	5	4	4	5	5	5	5	4	4		4	4	4	5	5	5	5	4	4	4	
	Student2	5	4	4	5	4	4	4	5	5	5		4	4	5	5	4	4	4	5	4	5	
	Student3	4	5	4	5	4	5	4	5	4	5		4	5	4	5	4	5	4	5	4	5	
		4.33	4.67	4.00	4.67	4.33	4.67	4.33	5.00	4.33	4.67	4.50	4.00	4.33	4.33	5.00	4.33	4.67	4.33	4.67	4.00	4.67	4.43
S4CPT178	Student1	5	5	5	5	5	5	4	5	4	5		5	5	4	5	5	5	5	4	5	5	
	Student2	5	4	5	5	5	4	4	5	5	5		5	5	5	5	5	5	5	5	5	5	
	Student3	4	4	3	4	4	3	4	4	4	5		4	5	3	5	4	3	4	3	4	4	
		4.67	4.33	4.33	4.67	4.67	4.00	4.00	4.67	4.33	5.00	4.47	4.67	5.00	4.00	5.00	4.67	4.33	4.67	4.00	4.67	4.67	4.57
S4CPT179	Student1	5	4	5	4	4	4	4	5	4	4		4	5	4	5	4	5	4	5	4	4	
	Student2	4	5	4	5	5	4	3	5	5	5		4	4	4	5	4	4	5	4	4	5	
	Student3	5	5	4	5	4	4	4	5	5	5		4	5	4	5	4	4	5	5	4	4	
		4.67	4.67	4.33	4.67	4.33	4.00	3.67	5.00	4.67	4.67	4.47	4.00	4.67	4.00	5.00	4.00	4.33	4.67	4.67	4.00	4.33	4.37
S4CPT180	Student1	4	5	4	5	5	4	4	5	5	4		4	5	5	4	4	4	5	5	4	5	
	Student2	4	4	3	2	2	1	3	3	3	3		2	2	3	3	3	3	3	3	3	3	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.00	4.33	3.67	3.67	3.67	3.00	3.67	4.00	4.00	3.67	3.77	3.33	3.33	4.33	4.00	3.67	4.00	4.00	4.33	4.00	4.33	3.93
S4CPT181	Student1	4	5	4	5	4	5	4	5	4	5		5	5	4	4	5	5	4	4	5	4	
	Student2	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	5	
	Student3	5	5	5	4	5	5	4	5	5	5		4	5	4	5	5	4	4	4	4	5	
		4.67	5.00	4.67	4.67	4.67	5.00	4.33	5.00	4.67	5.00	4.77	4.67	5.00	4.33	4.67	5.00	4.67	4.33	4.33	4.67	4.67	4.63
S4CPT182	Student1	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	5	
	Student2	5	4	5	5	4	5	4	5	4	4		5	4	5	5	4	5	4	4	5	4	
	Student3	5	5	5	4	5	5	4	5	5	5		4	5	4	5	5	4	4	4	4	5	
		5.00	4.67	5.00	4.67	4.67	5.00	4.33	5.00	4.67	4.67	4.77	4.67	4.67	4.67	5.00	4.67	4.67	4.33	4.33	4.67	4.67	4.63
S4CPT183	Student1	5	4	5	4	5	4	5	4	5	4		4	4	5	5	5	4	5	5	4	5	
	Student2	4	5	5	4	4	5	4	5	5	4		4	4	5	5	4	5	4	5	5	4	
	Student3	5	5	5	4	5	5	4	5	5	5		4	5	4	5	5	4	4	4	4	5	
		4.67	4.67	5.00	4.00	4.67	4.67	4.33	4.67	5.00	4.33	4.60	4.00	4.33	4.67	5.00	4.67	4.33	4.33	4.67	4.33	4.67	4.50
S4CPT184	Student1	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	5	
	Student2	4	5	4	5	4	5	4	5	4	5		5	5	4	4	5	5	4	4	5	4	
	Student3	5	4	5	5	4	5	4	5	5	4		4	5	5	4	5	4	4	5	4	5	
		4.67	4.67	4.67	5.00	4.33	5.00	4.33	5.00	4.67	4.67	4.70	4.67	5.00	4.67	4.33	5.00	4.67	4.33	4.67	4.67	4.67	4.67
S4CPT185	Student1	5	3	3	4	3	4	3	5	5	5		5	4	5	4	5	4	3	3	4	5	
	Student2	4	5	5	5	5	4	5	5	4	5		4	4	4	5	5	5	5	4	4	5	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.33	4.00	4.00	4.33	4.00	4.00	4.00	4.67	4.33	4.67	4.23	4.33	3.67	4.67	4.67	4.67	4.67	4.00	4.00	4.33	5.00	4.40
S4CPT186	Student1	4	4	4	5	5	5	4	4	4	4		4	5	5	4	4	5	4	5	4	4	
	Student2	5	5	5	4	4	4	5	5	5	5		5	4	5	5	4	5	5	5	5	5	
	Student3	1	3	1	3	3	4	3	4	3	2		4	1	2	3	4	5	2	3	4	3	
		3.33	4.00	3.33	4.00	4.00	4.33	4.00	4.33	4.00	3.67	3.90	4.33	3.33	4.00	4.00	4.00	5.00	3.67	4.33	4.33	4.00	4.10
S4CPT187	Student1	5	4	5	4	5	5	4	5	4	5		5	4	4	5	4	5	5	4	5	4	
	Student2	5	5	4	4	5	5	4	4	5	5		5	4	4	5	4	5	5	4	5	4	
	Student3	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	5	
		5.00	4.67	4.67	4.33	5.00	5.00	4.33	4.67	4.67	5.00	4.73	5.00	4.33	4.33	5.00	4.33	5.00	5.00	4.33	5.00	4.33	4.67
S4CPT288	Student1	5	5	5	5	4	4	4	5	5	5		4	5	5	5	4	4	5	4	4	5	
	Student2	5	4	5	3	3	4	4	4	4	4		4	3	4	4	5	5	2	3	3	4	
	Student3	4	4	5	5	5	4	5	5	4	4		4	4	5	5	5	4	5	4	5	4	
		4.67	4.33	5.00	4.33	4.00	4.00	4.33	4.67	4.33	4.33	4.40	4.00	4.00	4.67	4.67	4.67	4.33	4.00	3.67	4.00	4.33	4.23
S4CPT289	Student1	5	5	4	4	4	4	4	4	4	4		5	4	5	4	4	4	4	4	4	4	
	Student2	5	4	4	4	5	5	4	5	4	5		5	4	5	5	5	5	4	5	4	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.67	4.33	4.00	4.00	4.33	4.33	4.00	4.33	4.00	4.33	4.23	4.67	3.67	5.00	4.67	4.33	4.67	4.00	4.67	4.33	4.33	4.43
S4CPT290	Student1	5	4	4	5	5	5	4	5	4	5		5	5	5	4	5	5	4	4	5	4	
	Student2	4	5	5	5	5	4	5	5	5	4		5	5	5	5	5	5	4	5	5	1	
	Student3	4	4	5	4	4	4	5	4	5	4		5	4	5	5	4	5	5	5	4	5	
		4.33	4.33	4.67	4.67	4.67	4.33	4.67	4.67	4.67	4.33	4.53	5.00	4.67	5.00	4.67	4.67	5.00	4.33	4.67	4.67	3.33	4.60
S4CPT291	Student1	5	5	5	5	5	5	5	5	5	5		5	4	5	4	5	4	5	4	5	4	
	Student2	4	5	5	5	5	5	5	5	5	4		4	5	5	5	5	5	5	5	4	1	
	Student3	4	4	3	4	5	5	4	5	4	5		4	5	5	4	5	4	4	5	4	4	
		4.33	4.67	4.33	4.67	5.00	5.00	4.67	5.00	4.67	4.67	4.70	4.33	4.67	5.00	4.33	5.00	4.33	4.67	4.67	4.33	3.00	4.43
S4CPT292	Student1	4	4	5	5	5	4	3	4	3	4		3	4	4	4	4	3	4	3	4	3	
	Student2	5	4	4	5	4	4	5	5	5	5		5	4	5	5	5	4	5	5	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.33	4.00	4.33	4.67	4.33	4.00	4.00	4.33	4.00	4.33	4.23	4.00	3.67	4.67	4.67	4.33	4.00	4.33	4.33	4.67	4.00	4.27
S4CPT293	Student1	5	5	5	4	4	5	5	5	5	5		4	5	5	5	5	5	4	5	5	5	
	Student2	5	4	5	4	4	5	5	4	5	5		5	4	5	5	4	4	5	5	4	4	
	Student3	5	5	5	5	5	5	4	5	5	5		5	4	5	5	5	5	5	5	5	1	
		5.00	4.67	5.00	4.33	4.33	5.00	4.67	4.67	5.00	5.00	4.77	4.67	4.33	5.00	5.00	4.67	4.67	4.67	5.00	4.67	3.33	4.60
S4CPT294	Student1	3	4	4	4	4	4	4	4	4	5		4	4	4	4	4	4	4	4	4	3	
	Student2	4	5	5	5	4	5	4	4	5	5		4	4	5	5	5	5	5	5	4	5	
	Student3	3	3	4	4	4	4	3	3	4	4		5	4	5	4	4	4	4	3	3	5	
		3.33	4.00	4.33	4.33	4.00	4.33	3.67	3.67	4.33	4.67	4.07	4.33	4.00	4.67	4.33	4.33	4.33	4.33	4.00	3.67	4.33	4.23

APPENDIX O-2. STUDENTS SEMESTER FOUR'S RESPONSES OF LIKERT-SCALE PEER-ASSESSMENT.

S4CPT295	Student1	3	3	4	4	4	3	3	4	4	4		5	4	5	4	4	4	3	3	3	4	
	Student2	4	4	5	5	5	4	5	5	4	4		4	4	5	5	5	4	5	4	5	4	
	Student3	3	4	4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4	4	3	
		3.33	3.67	4.33	4.33	4.33	3.67	4.00	4.33	4.00	4.00	4.00	4.33	4.00	4.67	4.33	4.33	4.00	4.00	3.67	4.00	3.67	4.10
S4CPT296	Student1	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	4	
	Student2	5	5	5	5	5	5	5	4	4	5		5	5	4	4	5	5	4	5	5	5	
	Student3	5	5	4	5	4	4	5	4	5	5		4	4	5	4	5	4	5	5	4	5	
		5.00	5.00	4.67	5.00	4.67	4.67	5.00	4.33	4.67	5.00	4.80	4.67	4.67	4.67	4.33	5.00	4.67	4.67	5.00	4.67	4.67	4.70
S4CPT297	Student1	4	4	4	4	3	4	3	3	4	4		4	4	4	4	5	5	4	5	4	4	
	Student2	5	4	4	5	4	4	5	5	5	5		5	4	5	5	5	4	5	5	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.33	4.00	4.00	4.33	3.67	4.00	4.00	4.00	4.33	4.33	4.10	4.33	3.67	4.67	4.67	4.67	4.67	4.33	5.00	4.67	4.33	4.50
S4CPT298	Student1	5	5	5	5	5	5	5	5	5	5		4	5	4	5	4	5	4	5	4	5	
	Student2	5	5	5	4	4	5	5	5	5	5		4	5	5	5	5	4	5	5	4	5	
	Student3	5	5	4	4	5	4	4	3	5	5		4	5	3	4	5	4	4	5	4	5	
		5.00	5.00	4.67	4.33	4.67	4.67	4.67	4.33	5.00	5.00	4.73	4.00	5.00	4.00	4.67	4.67	4.33	4.33	5.00	4.00	5.00	4.50
S4CPT299	Student1	3	4	4	4	4	4	4	4	4	4		4	3	4	4	4	3	4	4	4	4	
	Student2	5	5	5	4	5	5	5	4	5	5		4	5	4	5	5	4	5	4	5	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.00	4.33	4.33	4.00	4.33	4.33	4.33	4.00	4.33	4.33	4.23	4.00	3.67	4.33	4.67	4.33	4.00	4.33	4.33	4.67	4.33	4.27
S4CPT3100	Student1	5	4	5	5	5	5	4	4	5	5		5	5	5	5	4	4	5	4	5	5	
	Student2	4	4	4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4	4	4	
	Student3	4	5	5	4	4	5	5	4	4	4		4	4	5	5	5	4	5	4	5	5	
		4.33	4.33	4.67	4.33	4.33	4.67	4.33	4.00	4.33	4.33	4.37	4.33	4.33	4.67	4.67	4.33	4.00	4.67	4.00	4.67	4.67	4.43
S4CPT3101	Student1	5	5	4	4	4	5	4	5	4	4		5	4	5	4	5	4	4	5	5	4	
	Student2	4	4	4	4	4	4	4	4	4	4		5	4	4	4	5	5	5	4	4	4	
	Student3	5	5	5	4	4	4	4	4	3	3		4	4	5	4	3	3	4	3	4	3	
		4.67	4.67	4.33	4.00	4.00	4.33	4.00	4.33	3.67	3.67	4.17	4.67	4.00	4.67	4.00	4.33	4.00	4.33	4.00	4.33	3.67	4.20
S4CPT3102	Student1	5	5	5	4	5	4	4	5	4	4		5	5	4	5	5	4	4	4	5	5	
	Student2	5	4	5	4	5	5	4	5	4	5		5	4	4	4	4	4	5	4	5	5	
	Student3	5	4	4	5	5	4	4	5	5	4		5	4	5	5	4	4	4	5	5	5	
		5.00	4.33	4.67	4.33	5.00	4.33	4.00	5.00	4.33	4.33	4.53	5.00	4.33	4.33	4.67	4.33	4.00	4.33	4.33	5.00	5.00	4.53
S4CPT3103	Student1	5	4	4	4	5	4	4	4	5	4		4	4	5	5	5	5	5	5	5	5	
	Student2	5	4	5	5	4	4	5	5	4	4		4	5	5	5	5	4	5	4	4	5	
	Student3	5	5	5	5	5	4	4	5	5	5		4	4	4	4	4	4	4	4	4	4	
		5.00	4.33	4.67	4.67	4.67	4.00	4.33	4.67	4.67	4.33	4.53	4.00	4.33	4.67	4.67	4.67	4.33	4.67	4.33	4.33	4.67	4.47
S4CPT3104	Student1	4	5	4	5	4	5	4	5	4	5		4	5	4	5	4	5	4	5	4	5	
	Student2	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	5	
	Student3	4	4	5	5	5	5	4	4	5	4		4	4	5	4	4	4	5	4	4	4	
		4.33	4.67	4.67	5.00	4.67	5.00	4.33	4.67	4.67	4.67	4.67	4.33	4.67	4.67	4.67	4.33	4.67	4.67	4.67	4.33	4.67	4.57
S4CPT3105	Student1	3	4	4	4	4	4	4	4	4	4		3	3	4	4	4	4	3	4	4	4	
	Student2	4	4	4	4	4	4	4	4	4	4		5	4	4	4	5	5	5	4	4	4	
	Student3	4	3	4	3	3	3	4	3	4	3		4	3	4	3	4	4	3	4	3	4	
		3.67	3.67	4.00	3.67	3.67	3.67	4.00	3.67	4.00	3.67	3.77	4.00	3.33	4.00	3.67	4.33	4.33	3.67	4.00	3.67	4.00	3.90
S4CPT3106	Student1	5	4	4	5	5	4	5	4	5	4		4	5	5	5	4	4	5	5	5	5	
	Student2	5	4	5	4	4	5	5	4	4	4		5	4	4	4	4	5	5	4	4	5	
	Student3	5	4	4	5	5	5	4	4	5	5		4	5	5	4	4	5	4	4	5	5	
		5.00	4.00	4.33	4.67	4.67	4.67	4.67	4.00	4.67	4.33	4.50	4.33	4.67	4.67	4.33	4.00	4.67	4.67	4.33	4.67	5.00	4.53
S4CPT3107	Student1	4	4	4	3	4	5	4	3	4	4		4	4	4	3	5	5	5	4	4	4	
	Student2	4	4	4	4	4	4	4	4	4	4		5	4	4	4	5	5	5	4	4	4	
	Student3	5	4	4	4	4	4	5	4	3	3		5	4	4	3	4	3	4	3	4	3	
		4.33	4.00	4.00	3.67	4.00	4.33	4.33	3.67	3.67	3.67	3.97	4.67	4.00	4.00	3.33	4.67	4.33	4.67	3.67	4.00	3.67	4.10
S4CPT3108	Student1	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	3	
	Student2	4	5	5	4	5	4	5	4	5	5		5	5	5	5	5	4	5	4	5	4	
	Student3	5	5	5	4	5	4	5	5	5	5		5	5	4	5	4	5	4	4	4	4	
		4.67	5.00	5.00	4.33	5.00	4.33	5.00	4.67	5.00	5.00	4.80	5.00	5.00	4.67	5.00	4.67	4.67	4.67	4.33	4.67	3.67	4.63
S4CPT3109	Student1	4	4	4	4	4	4	4	4	4	4		4	4	4	4	5	5	5	4	4	4	
	Student2	4	4	4	4	3	4	4	4	4	4		4	4	4	3	3	4	4	4	5	5	
	Student3	5	4	5	4	5	5	5	4	4	4		4	4	5	5	5	4	5	4	4	5	
		4.33	4.00	4.33	4.00	4.00	4.33	4.33	4.00	4.00	4.00	4.13	4.00	4.00	4.33	4.00	4.33	4.33	4.67	4.00	4.33	4.67	4.27
S4CPT3110	Student1	4	4	4	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4	4	4	
	Student2	4	4	4	4	4	5	5	4	5	5		5	5	4	5	5	5	4	4	5	5	
	Student3	5	4	4	5	5	5	5	4	5	5		4	5	5	5	5	4	4	5	5	5	
		4.33	4.00	4.00	4.33	4.33	4.67	4.67	4.00	4.67	4.67	4.37	4.33	4.67	4.33	4.67	4.67	4.33	4.00	4.33	4.67	4.67	4.47
S4CPT3111	Student1	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	5	
	Student2	5	4	5	4	5	4	5	4	5	4		5	4	5	4	5	4	5	4	5	4	
	Student3	4	5	4	4	4	5	3	4	4	4		4	4	4	4	4	4	4	4	4	3	
		4.67	4.67	4.67	4.33	4.67	4.67	4.33	4.33	4.67	4.33	4.53	4.67	4.33	4.67	4.33	4.67	4.33	4.67	4.33	4.67	4.00	4.47
S4CPT3112	Student1	5	4	5	4	5	4	5	4	5	4		5	4	5	4	5	4	5	4	5	4	
	Student2	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	5	
	Student3	5	4	5	4	5	4	5	4	5	4		5	4	5	4	5	4	5	4	5	4	
		5.00	4.33	5.00	4.33	5.00	4.33	5.00	4.33	5.00	4.33	4.67	5.00	4.33	5.00	4.33	5.00	4.33	5.00	4.33	5.00	4.33	4.67
S4CPT3113	Student1	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	3	
	Student2	4	5	4	4	5	4	5	5	4	4		5	4	4	4	5	5	4	4	5	4	
	Student3	4	4	5	5	4	4	4	5	5	5		4	4	5	4	4	5	5	4	5	4	
		4.33	4.67	4.67	4.67	4.67	4.33	4.67	5.00	4.67	4.67	4.63	4.67	4.33	4.67	4.33	4.67	5.00	4.67	4.33	5.00	3.67	4.53
S4CPT3114	Student1	5	5	4	5	5	5	4	4	4	4		4	4	5	5	5	4	5	4	5	4	
	Student2	4	4	4	4	4	4	4	5	5	5		5	4	5	4	4	5	5	4	4	5	
	Student3	5	4	4	4	3	4	3	3	4	3		4	3	3	4	3	4	5	4	3	4	
		4.67	4.33	4.00	4.33	4.00	4.33	3.67	4.00	4.33	4.00	4.17	4.33	3.67	4.33	4.33	4.00	4.33	5.00	4.00	4.00	4.33	4.23
S4CPT3115	Student1	4	5	4	5	4	5	4	5	4	5		4	5	4	5	4	5	4	5	4	5	
	Student2	5	4	5	4	5	4	5	4	5	4		5	4	5	4	5	4	5	4	5	4	
	Student3	4	4	4	3	4	3	3	3	4	4		4	4	4	4	3	3	4	4	4	4	
		4.33	4.33	4.33	4.00	4.33	4.00	4.00	4.00	4.33	4.33	4.20	4.33	4.33	4.33	4.33	4.00	4.00	4.33	4.33	4.33	4.33	4.27
S4CPT3116	Student1	5	5	4	5	5	5	4	5	5	5		4	5	5	5	4	5	4	5	5	4	
	Student2	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	3	
	Student3	4	5	5	5	4	4	5	5	4	4		5	5	5	5	4	5	5	4	5	4	
		4.67	5.00	4.67	5.00	4.67	4.67	4.67	5.00	4.67	4.67	4.77	4.67	5.00	5.00	5.00	4.33	5.00	4.67	4.67	5.00	3.67	4.70
S4MOT117	Student1	4	4	4	4	4	4	4	3	4	4		3	4	4	4	4	4	4	3	4	4	
	Student2	4	5	5	5	4	5	4	5	5	5		4	4	5	5	5	5	5	4	5	5	
	Student3	4	5	4	4	5	4	5	4	4	4		5	4	5	4	5	4	4	3	5	5	
		4.00	4.67	4.33	4.33	4.33	4.33	4.33	4.00	4.33	4.33	4.30	4.00	4.00	4.67	4.33	4.67	4.33	4.33	3.33	4.67	4.67	4.30
S4MOT118	Student1	5	4	5	5	5	5	5	5	5	5		5	4	5	5	5	5	4	4	4	5	
	Student2	5	4	4	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	4	
	Student3	4	4	3	5	4	5	4	4	4	4		4	5	3	4	5	5	4	4	4	2	
		4.67	4.00	4.00	5.00	4.67	5.00	4.67	4.67	4.67	4.67	4.60	4.67	4.67	4.33	4.67	5.00	5.00	4.33	4.33	4.33	3.67	4.50
S4MOT119	Student1	5	5	4	5	5	5	5	5	5	5		5	4	5	5	5	5	5	4	5	4	
	Student2	5	5	5	5	5	5	5	5	5	5		5	5	5	5	5	5	5	5	5	5	
	Student3	4	5	3	4	5	5	2	3	5	5		4	5	4	5	3	4	4	4	2	4	
		4.67	5.00	4.00	4.67	5.00	5.00	4.00	4.33	5.00	5.00	4.67	4.67	4.67	4.67	5.00	4.33	4.67	4.67	4.33	4.00	4.33	4.53
S4MOT120	Student1	4	5	5	5	5	4	4	4	5	5		4	4	5	5	5	5	5	4	5	5	
	Student2	5	5	5	5	5	5	4	5	5	5		4	5	5	5	5	5	4	5	5	5	
	Student3	4	5	4	4	5	4	4	5	5	4		4	5	5	4	4	4	5	5	4	4	
		4.33	5.00	4.67	4.67	5.00	4.33	4.00	4.67	5.00	4.67	4.63	4.00	4.67	5.00	4.67	4.67	4.67	4.67	4.67	4.67	4.67	4.63

S4MOT121	**Student1**	4	4	5	4	5	4	5	4	5	4		5	4	4	5	5	4	5	4	5	4	
	Student2	4	4	4	4	4	4	4	4	3	3		3	4	4	4	4	4	3	4	4	4	
	Student3	4	4	4	4	4	5	5	4	5	4		4	4	4	4	5	5	4	4	4	5	
		4.00	4.00	4.33	4.00	4.33	4.33	4.67	4.00	4.33	3.67	4.17	4.00	4.00	4.00	4.33	4.67	4.33	4.00	4.00	4.33	4.33	4.20
S4MOT122	**Student1**	4	4	4	4	4	5	5	5	4	4		4	4	4	4	4	4	4	4	4	4	
	Student2	4	4	4	4	4	4	4	4	4	4		4	3	4	4	5	5	4	4	4	4	
	Student3	4	5	5	4	5	3	4	4	4	4		3	3	4	3	4	4	4	3	3	4	
		4.00	4.33	4.33	4.00	4.33	4.00	4.33	4.33	4.00	4.00	4.17	3.67	3.33	4.00	3.67	4.33	4.33	4.00	3.67	3.67	4.00	3.87
S4MOT123	**Student1**	4	4	3	4	4	3	4	4	4	4		3	4	4	3	4	4	3	4	4	3	
	Student2	4	3	4	4	3	4	4	3	4	4		3	4	4	4	4	4	4	3	4	4	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		4.00	3.67	3.67	4.00	3.67	3.67	4.00	3.67	4.00	4.00	3.83	3.33	3.67	4.33	4.00	4.00	4.33	3.67	4.00	4.33	4.00	3.97
S4MOT124	**Student1**	4	5	4	5	4	3	4	5	4	5		5	4	4	4	4	3	4	4	4	4	
	Student2	3	4	4	4	4	4	4	4	4	4		4	3	4	4	4	3	4	3	4	3	
	Student3	4	4	4	4	4	4	4	4	4	4		4	3	5	5	4	5	4	5	5	5	
		3.67	4.33	4.00	4.33	4.00	3.67	4.00	4.33	4.00	4.33	4.07	4.33	3.33	4.33	4.33	4.00	3.67	4.00	4.00	4.33	4.00	4.03
S4MOT125	**Student1**	4	4	4	5	4	5	4	4	4	5		4	4	4	4	5	5	4	5	5	5	
	Student2	4	4	4	4	4	4	4	3	4	4		4	4	4	4	4	4	4	3	4	4	
	Student3	4	5	4	4	5	4	4	5	5	4		5	4	4	5	5	4	5	4	5	5	
		4.00	4.33	4.00	4.33	4.33	4.33	4.00	4.00	4.33	4.33	4.20	4.33	4.00	4.00	4.33	4.67	4.33	4.33	4.00	4.67	4.67	4.33
S4MOT126	**Student1**	2	3	4	4	5	2	2	5	5	3		3	4	3	4	3	3	2	3	2	3	
	Student2	3	4	4	5	4	3	4	5	5	5		4	5	5	5	5	5	4	4	4	5	
	Student3	4	4	5	4	3	4	4	3	5	3		4	5	4	3	5	5	4	3	2	3	
		3.00	3.67	4.33	4.33	4.00	3.00	3.33	4.33	5.00	3.67	3.87	3.67	4.67	4.00	4.00	4.33	4.33	3.33	3.33	2.67	3.67	3.80
S4MOT127	**Student1**	3	4	5	4	4	4	4	5	5	5		4	5	4	4	5	5	5	4	4	4	
	Student2	4	3	3	3	5	5	5	5	5	5		3	4	5	4	5	5	5	4	4	5	
	Student3	5	4	3	4	4	4	4	4	4	5		4	4	5	5	5	4	4	4	5	5	
		4.00	3.67	3.67	3.67	4.33	4.33	4.33	4.67	4.67	5.00	4.23	3.67	4.33	4.67	4.33	5.00	4.67	4.67	4.00	4.33	4.67	4.43
S4MOT128	**Student1**	5	4	3	4	3	4	4	3	4	3		4	4	4	3	4	5	5	4	4	5	
	Student2	4	5	5	4	4	4	4	4	4	4		4	3	4	5	5	4	4	4	4	5	
	Student3	5	4	5	4	5	4	4	4	4	3		3	3	3	4	4	4	3	4	4	5	
		4.67	4.33	4.33	4.00	4.00	4.00	4.00	3.67	4.00	3.33	4.03	3.67	3.33	3.67	4.00	4.33	4.33	4.00	4.00	4.00	5.00	4.03
S4MOT129	**Student1**	3	4	3	4	4	3	4	3	4	5		4	4	4	3	5	4	4	4	4	5	
	Student2	3	4	3	4	4	4	3	4	4	4		4	3	4	4	4	5	4	5	4	4	
	Student3	3	4	3	4	3	4	4	3	4	4		3	3	4	4	4	4	4	4	3	3	
		3.00	4.00	3.00	4.00	3.67	3.67	3.67	3.33	4.00	4.33	3.67	3.67	3.33	4.00	3.67	4.33	4.33	4.00	4.33	3.67	4.00	3.93
S4MOT130	**Student1**	5	4	5	4	5	4	3	3	4	4		4	3	4	3	5	5	4	3	4	5	
	Student2	4	2	3	3	5	5	3	2	4	4		3	4	4	2	5	5	3	3	5	3	
	Student3	4	4	4	4	3	4	4	4	4	4		3	3	4	4	4	4	3	4	4	5	
		4.33	3.33	4.00	3.67	4.33	4.33	3.33	3.00	4.00	4.00	3.83	3.33	3.33	4.00	3.00	4.67	4.67	3.33	3.33	4.33	4.33	3.83
S4MOT131	**Student1**	4	5	4	5	5	5	5	5	5	5		5	4	5	5	5	5	5	4	5	4	
	Student2	4	5	5	5	5	5	4	4	5	4		4	4	5	5	5	4	5	5	5	5	
	Student3	4	4	4	5	5	5	5	4	5	4		4	4	4	4	4	4	5	5	5	5	
		4.00	4.67	4.33	5.00	5.00	5.00	4.67	4.33	5.00	4.33	4.63	4.33	4.00	4.67	4.67	4.67	4.33	5.00	4.67	5.00	4.67	4.60
S4MOT132	**Student1**	5	3	5	5	5	4	4	5	5	4		4	5	4	4	5	5	5	5	4	5	
	Student2	4	5	4	4	5	3	4	4	5	5		5	4	5	5	4	4	5	4	4	3	
	Student3	4	5	5	4	5	1	3	4	3	4		4	4	3	4	5	4	3	3	2	2	
		4.33	4.33	4.67	4.33	5.00	2.67	3.67	4.33	4.33	4.33	4.20	4.33	4.33	4.00	4.33	4.67	4.33	4.33	4.00	3.33	3.33	4.10

Appendix P-1. Example of CNC Milling & Lathe Programming PBL1

CNC Programming – PBL1

CNC: history

Problem 1: A group of delegation from a secondary school is coming to GMI for a study visit. They would like to know the about CNC machines especially on how CNC machines is developed, advantages and disadvantages. You as a CNC expert will need to present on the development of CNC machines to the delegation. The duration of presentation is about 10 minutes.

Scaffolding:

- DEVELOPMENT OF CNC CONTROL
- NUMERICAL CONTROL
- COMPUTER
- FROM NC TO CNC
- DATA CARRIER PROPERTIES
- HOW DO COMPUTER WORKS
- COMPUTER NUMERICAL CONTROL
- DIRECT NUMERICAL CONTROL
- INTRODUCING CONTROL MODES
- TYPES OF INTERPOLATION
- APPLICATION OF COMPUTER NUMERICAL CONTROL
- ADVANTAGES OF COMPUTER NUMERICAL CONTROL

Appendix P-2. Example of CNC Milling & Lathe Programming PBL1 Guide

CNC Lathe Programming – PBL1
TTO (Facilitator) Guide

No.	Lecture/PBL	Description	Time Allocation
1.	Lecture	TTO (Facilitator) hand over the PBL1 and to briefly explain on the scaffolding's list given.	20 – 30 minutes
2.	PBL	**Refer Problem 1:** A group of delegation from a secondary school is coming to GMI for a study visit. They would like to know the about CNC machines especially on how CNC machines is developed, advantages and disadvantages. You as a CNC expert will need to present on the development of CNC machines to the delegation. The duration of presentation is about 10 minutes.	
		TTO (Facilitator) hand over the LO form to students. Students are to discuss in group (group discussion) to the list the: (for a & b) - Learning Objectives. - Know. - Don't Know. - What need to find out? **Completed**	15 minutes
		Students are to work individually (self-study) on "what need to find out". In this case, students' are to distribute the tasks within the group members accordingly to save time.	15 minutes
		Students are to work in group (group discussion) on PBL1. Students are to prepare a 10 minutes presentation.	120 minutes
		Students group presentation on: - DEVELOPMENT OF CNC CONTROL - NUMERICAL CONTROL - COMPUTER - FROM NC TO CNC - DATA CARRIER PROPERTIES - HOW DO COMPUTER WORKS - COMPUTER NUMERICAL CONTROL - DIRECT NUMERICAL CONTROL - INTRODUCING CONTROL MODES - TYPES OF INTERPOLATION - APPLICATION OF COMPUTER NUMERICAL CONTROL - ADVANTAGES OF COMPUTER NUMERICAL CONTROL	10 to 15 minutes (per group)
		Q & A session	5 to 10 minutes (per group)

		TTO (Facilitator) comments on the presentation	5 to 10 minutes (per group)
		Students' group and personal reflection on what have they learnt and experienced throughout the PBL process. - List the LO, know, don't know, what need to find out. - Self-study - Group discussion - Presentation Examples of TTOs' (Facilitator) projection questions: - What you have experienced during the discussion of "LO, know, don't know, what need to find out"? - What you have experienced during the self-study and seeking for information? - What you have experienced during the group discussion and presentation? Examples of TTOs' (Facilitator) projection questions: - What you have experienced during the group presentation? - What about the group members? Team work? Cooperation? Individuals' contribution? Etc.	5 to 10 minutes (per group)
		TTOs' (Facilitator) overall comments: Examples: - Students' progress on tasks given. - Students' time management. - Students' discussion activities. - Students' team work. - Students' problem solving skills. - Students' critical thinking. - Students' presentation. **The End PBL1**	10 minutes

Summary

Section	Lecture / PBL	Duration (minutes)
1	Lecture	30
2	PBL	235
Total		**265 (4.4Hrs)**

Appendix Q-1. Example of CNC Milling & Lathe Programming PBL2

CNC Programming – PBL2

Cutting technology:

- Cutting speed, feed rate, spindle speed and depth of cut.

Problem 2a: What is the surface speed of the earth? (1 hour)

Scaffolding:

http://www.thevlecks.net/rmj/earth.html

Problem 2b: Relate the problem 2a with cutting technology. (1 hour)

Scaffolding:

Cutting technology:

- Cutting speed and spindle speed

Appendix Q-2. Example of CNC Milling & Lathe Programming PBL2 Guide

CNC Lathe Programming – PBL2
TTO (Facilitator) Guide

No.	Lecture/PBL	Description	Time Allocation
1.	Lecture	TTO lecture on chapter 2 and 3	80 minutes
		TTO (Facilitator) hand over the PBL2 and to briefly explain on the scaffolding's list given.	5 – 10 minutes
2.	PBL	**Refer Problem 2:** 2a: What is the surface speed of the earth? Scaffolding: http://www.thevlecks.net/rmj/earth.html 2b: How you relate the problem 2a with cutting technology?	
		TTO (Facilitator) hand over the LO form to students. Students are to discuss in group (group discussion) to the list the: (for a & b) - Learning Objectives. - Know. - Don't Know. - What need to find out? **Completed**	15 minutes
		Students are to work individually (self-study) on "what need to find out". In this case, students' are to distribute the tasks within the group members accordingly to save time.	15 minutes
		Students are to work in group (group discussion) on PBL2. Students are to prepare a 5 minutes presentation.	60 minutes
		Students group presentation on: - What is the earth surface speed? - Why the surface speed varies at different location of the earth? (i.e. locations: London, Kuala Lumpur and Australia). - How you relate the surface speed with cutting speed? - Conclusion	30 minutes (5 mins per group)
		Q & A session	10 to 15 minutes (per group)
		TTO (Facilitator) comments on the presentation	5 to 10 minutes (per group)

		Students' group and personal reflection on what have they learnt and experienced throughout the PBL process. - List the LO, know, don't know, what need to find out. - Self-study - Group discussion - Presentation Examples of TTOs' (Facilitator) projection questions: - What you have experienced during the discussion of "LO, know, don't know, what need to find out"? - What you have experienced during the self-study and seeking for information? - What you have experienced during the group discussion and presentation? Examples of TTOs' (Facilitator) projection questions: - What you have experienced during the group presentation? - What about the group members? Team work? Cooperation? Individuals' contribution? Etc.	60 minutes (5 to 10 minutes per group)
		TTOs' (Facilitator) overall comments: Examples: - Students' progress on tasks given. - Students' time management. - Students' discussion activities. - Students' team work. - Students' problem solving skills. - Students' critical thinking. - Students' presentation. **The End PBL2**	10 minutes

Summary

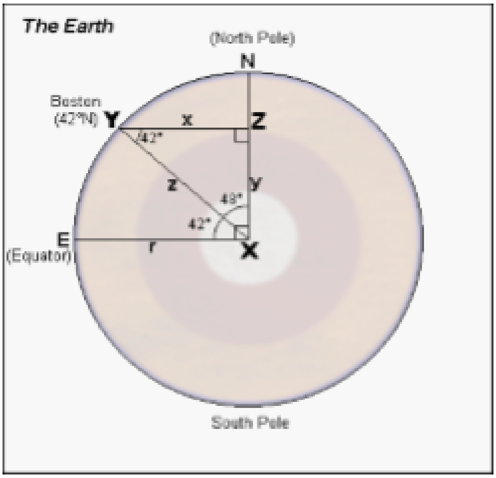
Section	Lecture / PBL	Duration minutes
1	Lecture	90
2	PBL	195 (3.25 Hrs)
Total		**285 (4.75 Hrs)**

Appendix Q-3. Example of Scaffolding for PBL2

Relative Speed of Rotation Around the Earth

First or all, let's pretend the Earth is a perfect sphere (it's not, but it puts the math within my realm of understanding.) Now according to my National Geographic map of the world, the earth's equatorial circumference is 24,902 miles. A person standing on the equator travels all the way around that 24,902 mile-long circuit in a 24 hour period. So, to find the speed of a person at the equator, we simply divide 24,902 miles by 24 hours, which equals 1037.5833333333... miles per hour. So, the equatorial person is traveling at about 1038 mph.

Now, let's look at this diagram of the earth:



x, y, and z are sides of a triangle formed by points X, Y, and Z. Let's call the circumference of the earth "C." The radius (distance from the center to any point on the surface) of the earth will be known as "r." In a perfect sphere, all radii are equal, so z = r.

The circumference of any circle = 2pi r, so C = 2pi r.

We know C (24,902 miles) so we can find r with the formula r = C/2pi.

Since z = r, z = C/2pi

Now, in order to find the speed traveled at a particular lattitude, we need to find the circumference of the circle formed when a plane parallel to the equator intersects the sphere of the Earth at the lattitude in question. To do that, we must first find the radius of this circle. Let's say that we want the speed that I'm traveling here in Boston. Boston is at point Y on our diagram, so the radius we need is line x.

Triangle XYZ is a right triangle, which means it has one right (90 degree) angle (angle YZX.) The interior angles of all triangles add up to 180 degrees, so if we have one 90 degree angle in triangle XYZ, we know that the sum of the other two angles must equal 90 degrees.

If the angles and the hypotenuse of a right triangle are known, the lengths of the two other sides, or "legs," can be caluclated using sine or cosine. The length of a leg equals the length of the hypotenuse times the sine of the opposire angle or the length of the hypotenuse times the cosine of the adjacent angle (the angle next to the leg other than the right angle itself.)

x = z(cosXYZ)

Since z = r = C/2pi

Then x = (C/2pi)(cosXYZ)

Now, remember, what we're really trying to find is not the radius of the Boston circle, but the circumference. So:

CircBos = 2pi x

CircBos = (2pi)[(C/2pi)(cosXYZ)]

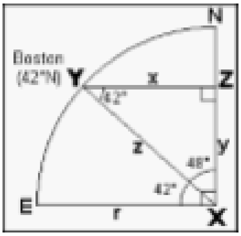
The two 2pi's cancel each other out, and we're left with:

CircBos = C(cosXYZ)

Now that we have the circumference at Boston's latitude, we can find the speed I'm traveling by dividing the circumference by 24 hours:

Speed = CircBos/24

Speed = [C(cosXYZ)]/24



What we need now are values for C and angle XYZ. We know from above that C = 24,902 miles. We can find XYZ with the latitude of Boston. Latitude is the angle from the equator, which on our diagram is angle EXY. Since angle EXZ is a right angle, we know that EXY + YXZ = 90°. Recall that triangle XYZ is a right triangle and therefore the two smaller angles must add up to 90° (XYZ + YXZ = 90°.) Therefore, latitude = EXY = XYZ. Thus:

Speed = (24,902 miles [cos(latitude)]) / 24 hours

Now all we have to do is plug in a latitude. Boston is at about 42 degrees north.

Speed = (24,902 miles [cos(42)]) / 24 hours

Speed = [24,902 miles (0.7431..)] / 24 hours

Speed = 18505.7924... miles / 24 hours

Speed = 771.0746... miles per hour

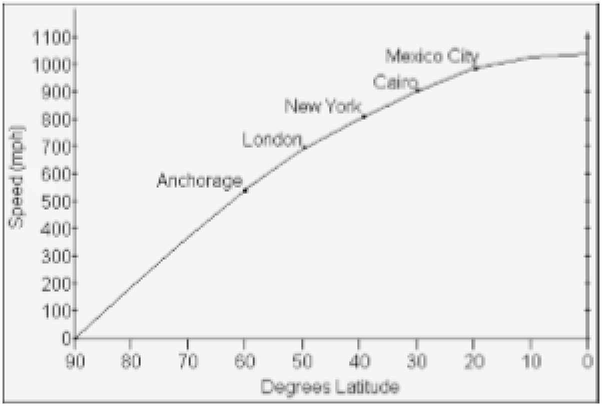
So, I'm traveling at about 771 mph. That's about 266 mph slower than someone at the equator!

Using the above formula, all we need is a latitude and we can calculate the speed for a any place around the globe. www.indo.com/distance is a useful site for finding your city's latitude. Here are the speeds for a number of different locations, organized north to south:

LOCATION	LATITUDE	SPEED
North Pole	90°N	0 mph
Alert (Nunavut, Canada)	82°N	144 mph
Nome, Reykjavik	64°N	455 mph
Anchorage	61°N	503 mph
Helsinki	60°N	519 mph
Oslo, St. Petersberg	59°N	534 mph
Edinburgh, Copenhagen, Moscow	55°N	595 mph
Dublin	53°N	624 mph
Berlin	52°N	639 mph
London	51°N	652 mph
Vancouver, Winnipeg	49°N	681 mph
Paris	48°N	694 mph

[illegible]	[illegible]	[illegible]
Seattle	47°N	707 mph
Quebec, Geneva	46°N	721 mph
Ottawa	45°N	734 mph
Chicago, New York, Rome	41°N	783 mph
Madrid, Ankara	40°N	795 mph
Beijing	39°N	806 mph
Wahsington D.C., Lisbon, Athens	38°N	818 mph
Tokyo	35°N	850 mph
Los Angeles, Kabul	34°N	860 mph
Baghdad	33°N	870 mph
Tripoli	32°N	880 mph
Jerusalem, Shanghai	31°N	889 mph
New Orleans, Cairo	30°N	898 mph
Houston, Lhasa	29°N	907 mph
New Delhi	28°N	916 mph
Miami	25°N	940 mph
Havana	23°N	955 mph
Honolulu, Cancun, Mecca, Hong Kong	21°N	969 mph
Mexico City	19°N	981 mph
Belize City	15°N	1002 mph
Madras	13°N	1011 mph
Bogota	4°N	1035 mph
Singapore	1°N	1,037 mph
Equator	0°	1,037.58 mph
Nairobi	1°S	1,037 mph
Brazzaville	4°S	1035 mph
Jakarta	6°S	1,032 mph
Lima, Darwin	12°S	1015 mph
Brasilia	15°S	1002 mph
Tahiti	17°S	992 mph
Rio De Janeiro	22°S	962 mph
Johannesburg	26°S	933 mph
Easter Island, Brisbane	27°S	924 mph
Santiago, Cape Town, Sydney	33°S	870 mph
Auckland	36°S	839 mph
Hobart	42°S	771 mph
Punta Arenas (Chile)	53°S	624 mph
McMurdo Station (Antarcica)	78°S	215 mph
South Pole	90°S	0 mph

You can see how the speed increases as one nears the equator in this graph:



Finally, if you don't feel like doing the math (and why wouldn't you? It's fun!) here's a handy speed calculator my friend Scott put together. Just enter your latitude (minutes and seconds are optional, use whole numbers for degrees and minutes) and find out how fast you're going.

Degrees: 5 Minutes: Seconds:

Calculate Speed (mph): 1033.635015495

Remember, these numbers are not in precise accordance with reality, since the earth is not a perfect sphere and I rounded off latitudes to a whole degree when compiling the chart above. Also, people at the poles are not really motionless as the chart suggests. The earth's tilt of the earth's axis varies slightly from 22.2° and 24.5°. The angle of tilt cycles back and forth between these extremes once roughly every 41,000 years. There is also a "wobble" in the earth's axis of rotation where the axis, while maintaining the same degree of tilt (or range of degree, rather) revolves around an invisible center, completing one full wobble every 25,700 years. Of course, this means the poles are only moving very slowly relative to the equator, but this does introduce another source of error for all speeds of rotation around the globe. Of course, the above is all relative as we are all moving with the earth around the sun, with the solar system around the galaxy, and with the galaxy through the universe.

Useful Links

www.indo.com/distance supplies latitude and longitude for any city around the globe. Will also calculate the distance between any two cities.

Geometry Reference Archives

Online Conversion Convert between miles and kilometers.

Mapquest World Atlas

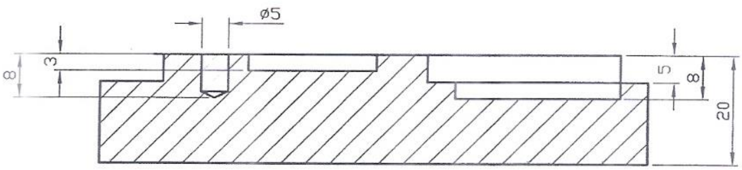
Earth Rotation Answers to questions about the movement of the earth, including the wobble in the earth's axis.

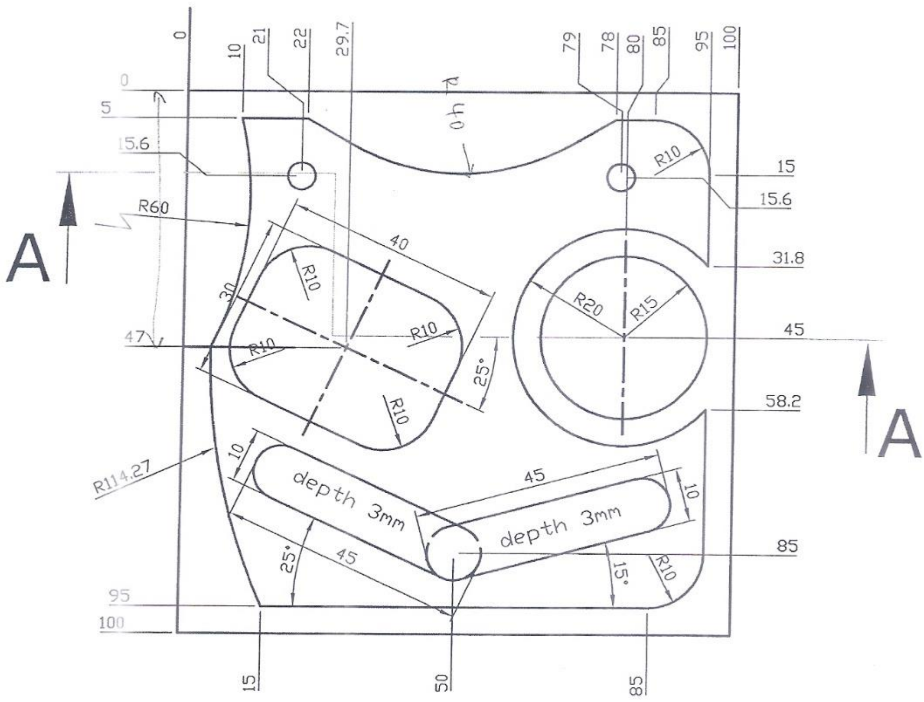
Earth and Moon Viewer Full color satellite image composites of the earth showing day and night or from above any point on the earth's surface. Also has similar images of the moon.

Appendix R-1. CNC Milling Programming PBL3.

CNC Programming – PBL3

Problem 3: You are an engineer in a manufacturing company. Your task is to prepare a part program (NC program) for a component that going to be machined using CNC machine.





CNC Programming – PBL3

Scaffolding 1: What preparation needed in writing NC programming?

a. List the cutting tools needed to machine the product.

b. Determine the technological data for each cutting tool.

c. Establish the Work-piece zero point in the part drawing.

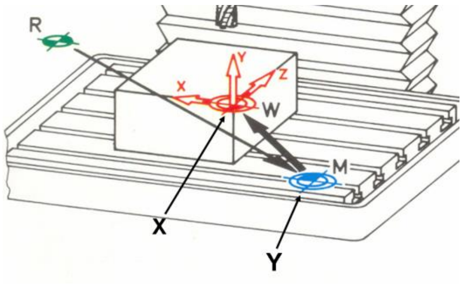
d. Write the NC program to machine the product.

Scaffolding 2: What you should know about writing NC programming?

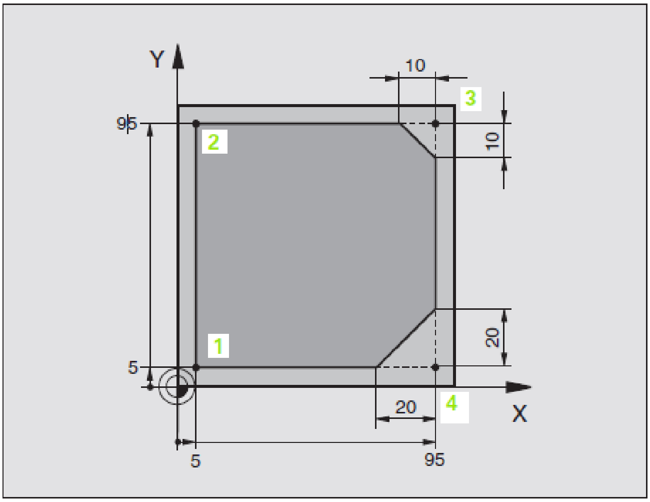
a. Identify the machine controller (Heidenhain).

b. The Coordinate system (X, Y and Z) of the machine (DMG).

c. Work-piece Zero point, Machine Zero point & Machine reference point according to the machine (DMG).



d. Programming structure or format according to the controller (Heidenhain).



N10 G30 G17 X+0 Y+0 Z-20 * Define blank form for graphic workpiece simulation
N20 G31 G90 X+100 Y+100 Z+0 *
N40 T1 G17 S4000 (Call tool in the spindle axis and with the spindle speed S)
N50 G00 G40 G90 Z+250 (Retract tool in the spindle axis at rapid traverse)
N60 X-10 Y-10 (Pre-position the tool)
N70 G01 Z-5 F1000 M3 (Move to working depth at feed rate F = 1000 mm/min)
N80 G01 G41 X+5 Y+5 F300 (Approach the contour at point 1, activate radius compensation G41)
N90 G26 R5 F150 (Tangential approach)
N100 Y+95 (Move to point 2)
N110 X+95 (Point 3: first straight line for corner 3)
N120 G24 R10 (Program chamfer with length 10 mm)
N130 Y+5 (Point 4: 2nd straight line for corner 3, 1st straight line for corner 4)
N140 G24 R20 (Program chamfer with length 20 mm)
N150 X+5 (Move to last contour point 1, second straight line for corner 4)
N160 G27 R5 F500 (Tangential departure)

N170 G40 X-20 Y-20 F1000 (Retract tool in the working plane, cancel radius compensation)
N180 G00 Z+250 M2/M30 (Retract in the tool axis, end program)

e. Programming codes (ISO) according to the controller (Heidenhain).

G0, G1, G2, G3, G17, G18, G40, G41, G42, G90, G91, G30, G31
M2, M3, M4, M5, M30
T, F, S

f. Programming contour (ISO) according to the controller (Heidenhain).

Tool call, straight line rapid traverse, straight line feed traverse, circular feed traverse, rounding, chamfering.

g. Programming Cycles according to the controller (Heidenhain).

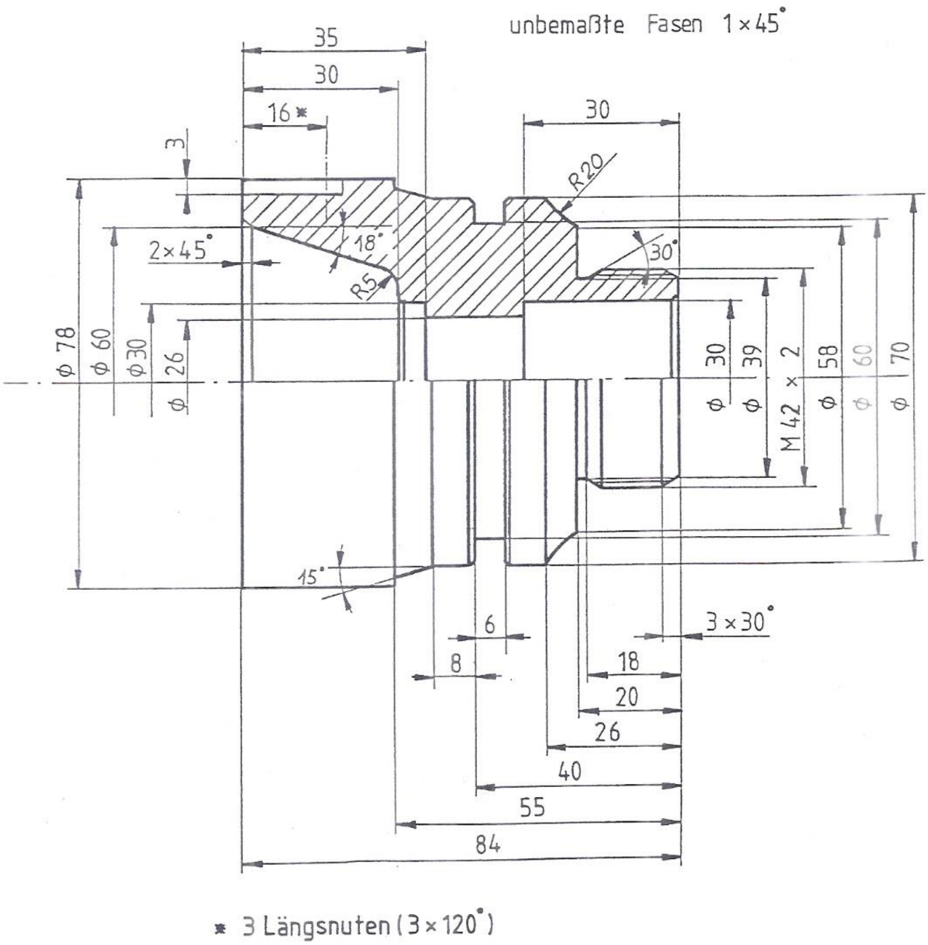
Drilling cycles, Slotting cycles, rectangular pocket cycles, circular pocket cycles, tapping cycles

Refer to Heidenhain programming manual

Appendix R-2. CNC Lathe Programming PBL3

CNC Programming – PBL3

Problem 3: You are an engineer in a manufacturing company. Your task is to prepare a part program (NC program) for a component that going to be machined using CNC machine.



CNC Programming – PBL3

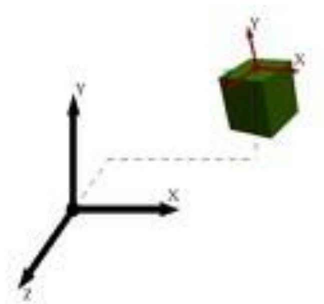
Scaffolding 1: What preparation needed in writing NC programming?

a. List the cutting tools needed to machine the product.
b. Determine the technological data for each cutting tool.
c. Establish the Workpiece zero point in the part drawing.
d. Write the NC program to machine the product.

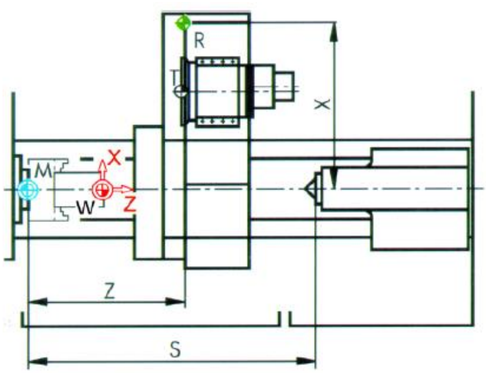
Scaffolding 2: What you should know about writing NC programming?

a. Identify the machine controller (Mitsubishi-Traub).

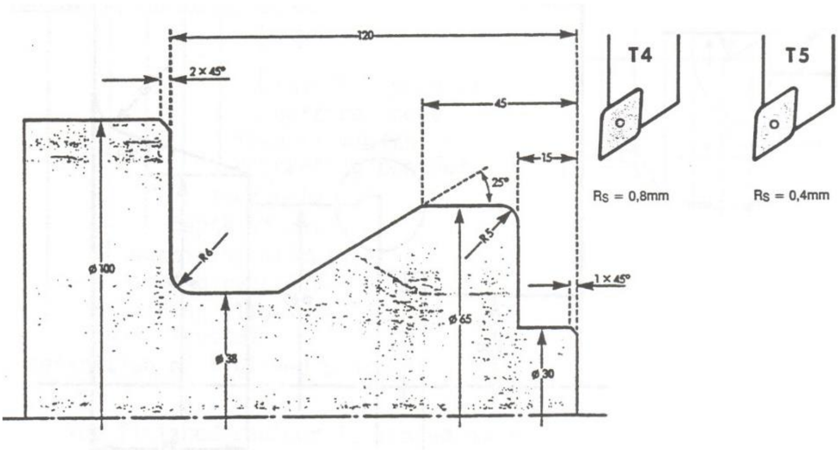
b. The Coordinate system (X, Y and Z) of the machine (Traub).



c. Workpiece Zero point, Machine Zero point & Machine reference point according to the machine (Traub).



d. Programming structure or format according to the controller (Mitsubishi-Traub).



G54 X0 Z250
G92 S3000 Q1000
G26
(ROUGHING)
G96 V160 T404 M04
G0 X100 Z2
G88
G71 P50 Q60 I0.5 K0.05
D4 F0.35 E0.12
89
G26 M09
(FINISHING)
G96 V200 T0505 M04
N50 G46
G0 X26 Z1 M08
G1 X30 D2 F0.15 E0.1
G1 Z-15
G1 X65 R5
G1 Z-45
G1 X38 A205 F0.1

```
G1    Z-120   R6 F0.15
G1    X100    D2
G1    W-4
```

N60 **G40**
G26 **M09**
M30

e. Programming codes (ISO) according to the controller (Mitsubishi-Traub).

G0, G1, G2, G3, G46, G40, G41, G42, G90, G91, G25, G26
M2, M3, M4, M5, M30
T, F, S, Q, V,

f. Programming contour (ISO) according to the controller (Mitsubishi-Traub).

Tool call, straight line rapid traverse, straight line feed traverse, circular feed traverse, rounding, chamfering.

g. Programming Cycles according to the controller (Mitsubishi-Traub).

Roughing cycles, Drilling cycles and Tapping cycles.

Refer to Mitsubishi-Traub programming manual

Appendix R-3. Example of CNC Milling & Lathe Programming PBL3 Guide

CNC Lathe Programming – PBL3
TTO (Facilitator) Guide

No.	Lecture/PBL	Description	Time Allocation
1.	Lecture	TTO (Facilitator) hand over the PBL3 and to discuss with students on how to read the part drawing. Q & A session	30 minutes
2.	PBL	**Refer 3.1:** a. List the cutting tools needed to machine the product. b. Determine the technological data for each cutting tool. **TTO (Facilitator) hand over the LO form to students.** Students are to discuss in group (group discussion) to the list the: (for a & b) - Learning Objectives. - Know. - Don't Know. - What need to find out? **Actions to be taken according to the timeline.** Completed **Students are to work individually** (self-study) on a & b **Students are to work in group** (group discussion) on a & b. Students are to prepare a 5 minutes presentation. **Students group presentation** on: - Machining process - Cutting tools used - Cutting technology for each tools **Q & A session** **Students' group and personal reflection on what have they learnt and experienced throughout the PBL process.** - List the LO, know, don't know, what need to find out. - Self-study - Group discussion - Presentation Examples of TTOs' (Facilitator) projection questions: - What you have experienced during the discussion of "LO, know, don't know, what need to find out"? - What you have experienced during the self-study	30 minutes 15 minutes 15 minutes 15 minutes 45 minutes 30 minutes (5 to 10 minutes per group) 30 minutes (5 to 10 minutes per group) 30 minutes (5 to 10 minutes per group)

		and seeking for information? - What you have experienced during the group discussion and presentation?	
		Examples of TTOs' (Facilitator) projection questions: - What you have experienced during the group presentation? - What about the group members? Team work? Cooperation? Individuals' contribution? Etc. **TTOs' (Facilitator) overall comments:** Examples: - Students' progress on tasks given. - Students' time management. - Students' discussion activities. - Students' team work. - Students' problem solving skills. - Students' critical thinking. - Students' presentation. **The End 3.1: a and b.**	15 minutes
3.	PBL	**Refer 3.2:** a. Identify the machine controller. b. The Coordinate system (X, Y and Z) of the machine. c. Workpiece Zero point, Machine Zero point & Machine reference point according to the machine. **TTO (Facilitator) hand over the LO form to students.** Students are to discuss in group (group discussion) to the list the: (for a, b & c) - Learning Objectives. - Know. - Don't Know. - What need to find out? **Actions to be taken according to the timeline.** **Completed** **Students are to work individually** (self-study) on a & b **Students are to work in group** (group discussion) on a & b. Students are to prepare a 5 minutes presentation. **Students group presentation** on: - Machine controller - Machine coordinate system - Zero points and reference point. **Q & A session**	15 minutes 15 minutes 15 minutes 15 minutes 30 minutes 60 minutes (5 to 10 minutes per group) (5 to 10 minutes)

		  TTO (Facilitator) comments on the presentation	(per group) 30 minutes (5 to 10 minutes per group)
		Students' group and personal reflection on what have they learnt and experienced throughout the PBL process. - List the LO, know, don't know, what need to find out. - Self-study - Group discussion - Presentation Examples of TTOs' (Facilitator) projection questions: - What you have experienced during the discussion of "LO, know, don't know, what need to find out"? - What you have experienced during the self-study and seeking for information? - What you have experienced during the group discussion and presentation? - What you have experienced during the group presentation? - What about the group members? Team work? Cooperation? Individuals' contribution? Etc. **TTOs' (Facilitator) overall comments:** Examples: - Students' progress on tasks given. - Students' time management. - Students' discussion activities. - Students' team work. - Students' problem solving skills. - Students' critical thinking. - Students' presentation. **The End 3.2: a, b and c.**	(5 to 10 minutes per group) (10 minutes)
4.	Lecture	**Refer 3.2:** d. Programming structure or format according to the controller. **TTO (Facilitator) is to demonstrate on how to use the simulator by key-in the program example in "d" and explain the program details:** - Program header - Program body - Program tail **TTO (Facilitator) is to explain the program structure with**	 90 minutes 30 minutes

		cycle (roughing cycle). Give one example on how to use the cycle by adding cycle into the program. **The End 3.2: a, b and c.**	
5.	PBL	**Students' are to refer back part drawing:** **Problem 3:** You are an engineer in a manufacturing company. Your task is to prepare a part program (NC program) for a component that going to be machined using CNC machine.	15 minutes
		TTO (Facilitator) hand over the LO form to students. Students are to discuss in group (group discussion) to the list the: (for a, b & c) - Learning Objectives. - Know. - Don't Know. - What need to find out?	15 minutes
		Actions to be taken according to the timeline. **Completed**	15 minutes
		Students are to work individually (self-study) on "what need to find out". In this case, students' are to distribute the tasks within the group members accordingly to save time.	30 minutes
		Students are to work in group (group discussion) on tasks given. Students are to prepare a 10 minutes presentation.	120 minutes
		Students group presentation on their part program: - Workpiece zero points. - Machining process, technological data and the cutting tools used. - How the contour program is done? - How cycles are used in the program for drilling, threading and roughing?	60 minutes (10 to 15 minutes per group)
		Q & A session	(5 to 10 minutes per group)
		TTO (Facilitator) comments on the presentation	(5 to 10 minutes per group)

		Students' group and personal reflection on what have they learnt and experienced throughout the PBL process. - List the LO, know, don't know, what need to find out. - Self-study - Group discussion - Presentation Examples of TTOs' (Facilitator) projection questions: - What you have experienced during the discussion of "LO, know, don't know, what need to find out"?	60 (5 to 10 minutes per group)
		- What you have experienced during the self-study and seeking for information? - What you have experienced during the group discussion and presentation? - What you have experienced during the group presentation? - What about the group members? Team work? Cooperation? Individuals' contribution? Etc. **TTOs' (Facilitator) overall comments:** Examples: - Students' progress on tasks given. - Students' time management. - Students' discussion activities. - Students' team work. - Students' problem solving skills. - Students' critical thinking. - Students' presentation. **The End PBL3**	(10 minutes)

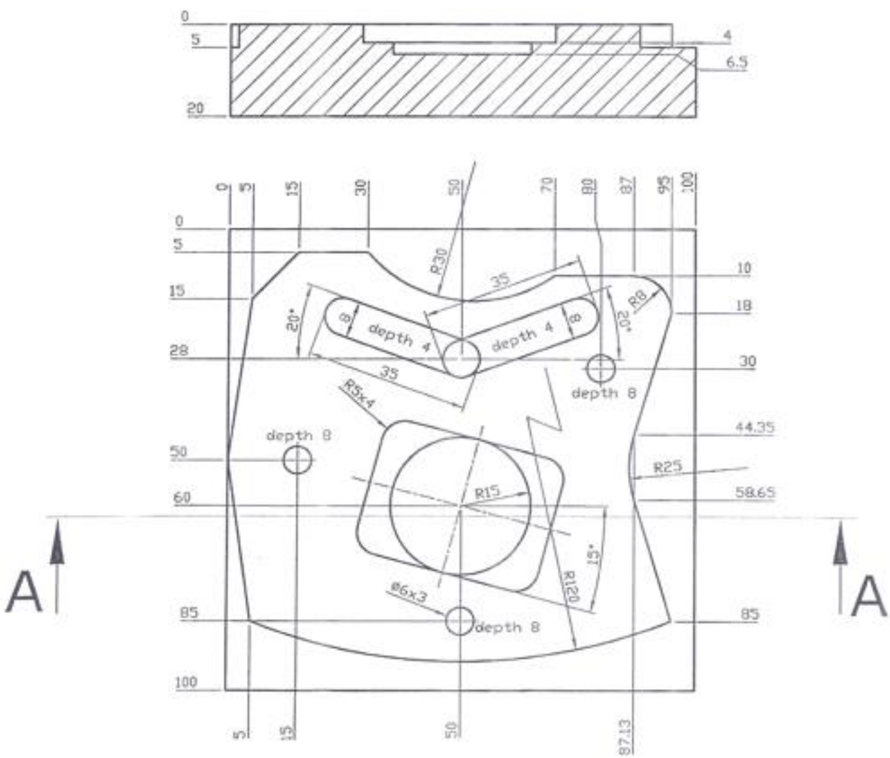
Summary

Section	Lecture / PBL	Duration (minutes)
1	Lecture	15
2	PBL	190
3	PBL	175
4	Lecture	105
5	PBL	220
Total		**705 (8.5Hrs)**

Appendix S-1. CNC Milling Programming PBL4

CNC Milling Programming – PBL4

Problem 4: You are an engineer in a manufacturing company. Your task is to prepare a part program (NC program) for a component that going to be machined using CNC milling machine. However, the CNC milling controller in the manufacturing company uses conversational programming format.



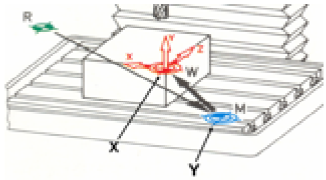
CNC Milling Programming – PBL4

Scaffolding 1: What preparation needed in writing NC programming?

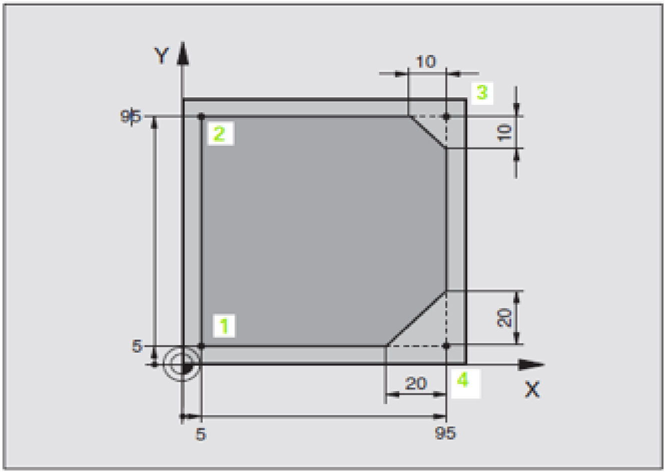
a. List the cutting tools needed to machine the product.
b. Determine the technological data for each cutting tool.
c. Establish the Workpiece zero point in the part drawing.
d. Write the NC program to machine the product.

Scaffolding 2: What you should know about writing NC programming?

a. Identify the machine controller.
b. The Coordinate system (X, Y and Z) of the machine.
c. Workpiece Zero point, Machine Zero point & Machine reference point according to the machine.



d. Programming structure or format according to the controller (Heidenhain).



1 BLK FORM 0.1 Z X+0 Y+0 Z-20 (Define blank form for graphic workpiece simulation)
2 BLK FORM 0.2 X+100 Y+100 Z+0
4 TOOL CALL 1 Z S4000 (Call tool in the spindle axis and with the spindle speed S)
5 L Z+250 R0 FMAX (Retract tool in the spindle axis at rapid traverse FMAX)
6 L X-10 Y-10 R0 FMAX (Pre-position the tool)

7 L Z-5 R0 F1000 M3 (Move to working depth at feed rate F = 1000 mm/min)
8 APPR LT X+5 Y+5 LEN10 RL F300 (Approach the contour at point 1 on a straight line with tangential connection)
9 L Y+95 (Move to point 2)
10 L X+95 (Point 3: first straight line for corner 3)
11 CHF 10 (Program chamfer with length 10 mm)
12 L Y+5 (Point 4: 2nd straight line for corner 3, 1st straight line for corner 4)
13 CHF 20 (Program chamfer with length 20 mm)
14 L X+5 (Move to last contour point 1, second straight line for corner 4)
15 DEP LT LEN10 F1000 (Depart the contour on a straight line with tangential connection)
16 L Z+250 R0 FMAX M2 (Retract in the tool axis, end program)

e. Programming codes (conversational) according to the controller (Heidenhain).
L, C, CR, RAN, CT, CC, CHF, BLK FORM 0.1, BLK FORM 0.2, R0, RL, RR
M2, M3, M4, M5, M30
T, F, FMAX, S

f. Programming contour (Conversational) according to the controller (Heidenhain).
Tool call, straight line rapid traverse, straight line feed traverse, circular feed traverse, rounding, chamfering.

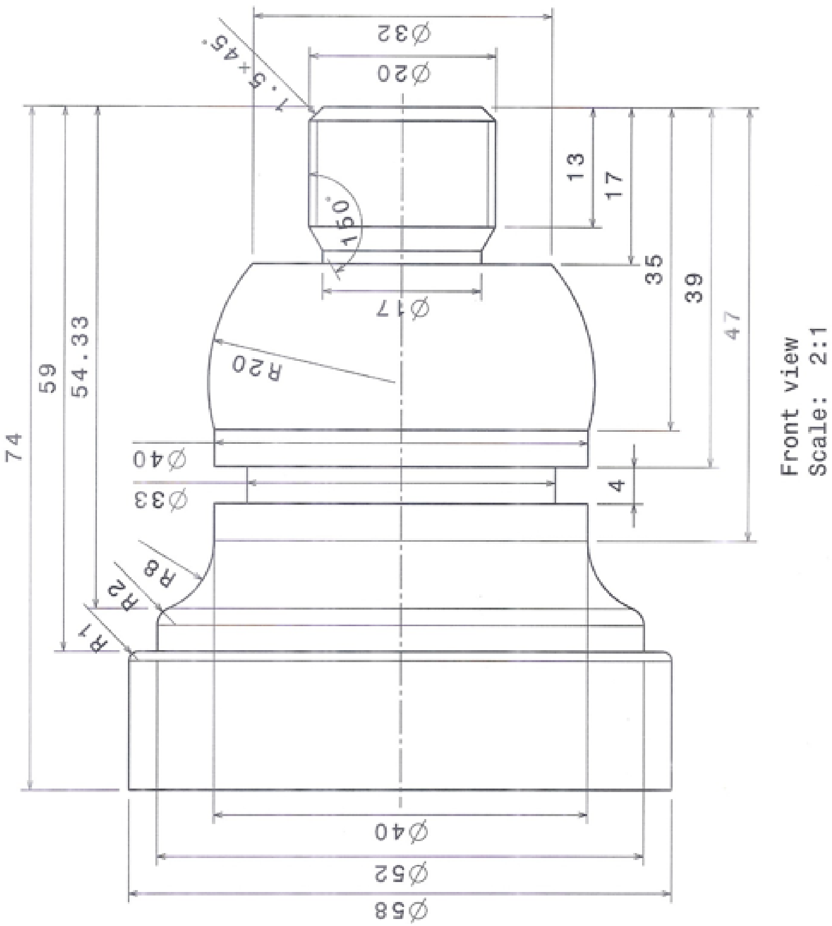
g. Programming Cycles according to the controller (Heidenhain).
Drilling cycles, Slotting cycles, rectangular pocket cycles, circular pocket cycles, tapping cycles.

Refer to Heidenhain conversational programming manual

Appendix S-2. CNC Lathe Programming PBL4

CNC Lathe Programming – PBL4

Problem 4: You are an engineer in a manufacturing company. Your task is to prepare a part program (NC program) for a component that going to be machined using CNC Lathe machine. However, the CNC Lathe controller in the manufacturing company uses conversational programming format.



CNC Lathe Programming – PBL4

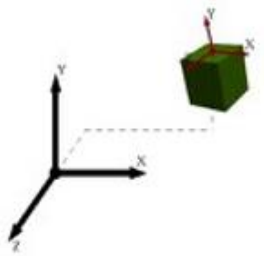
Scaffolding 1: What preparation needed in writing NC programming?

a. List the cutting tools needed to machine the product.
b. Determine the technological data for each cutting tool.
c. Establish the Workpiece zero point in the part drawing.
d. Write the NC program to machine the product.

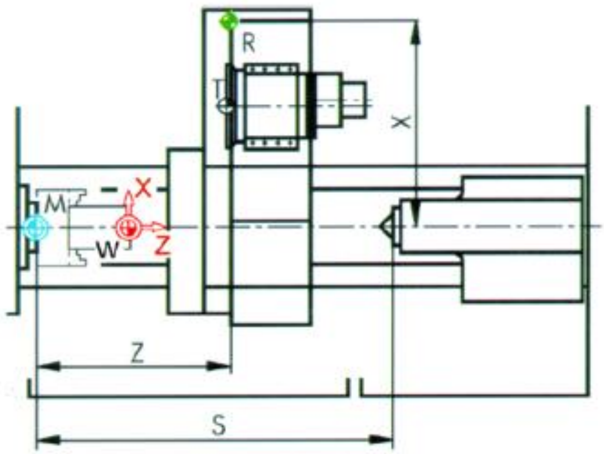
Scaffolding 2: What you should know about writing NC programming?

a. Identify the machine controller.

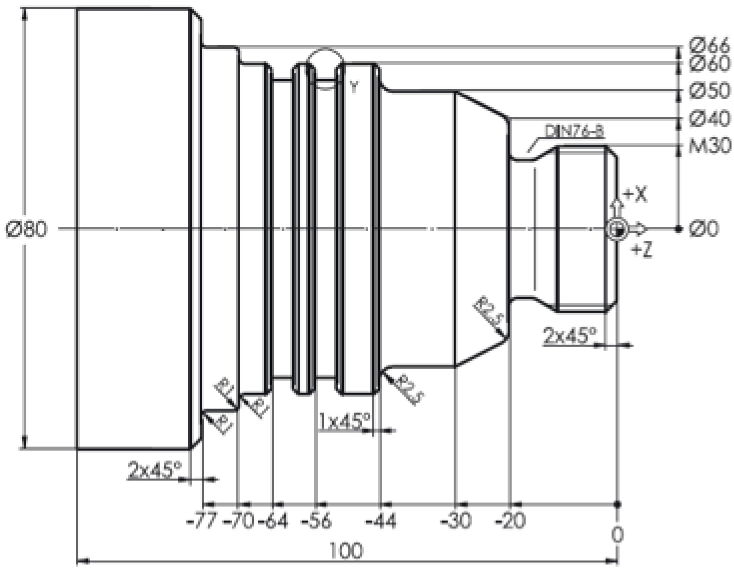
b. The Coordinate system (X, Y and Z) of the machine.

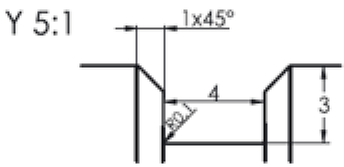


c. Workpiece Zero point, Machine Zero point & Machine reference point according to the machine.



d. Conversational programming format according to the controller.





a. Program cutting tool, cutting speed, spindle speed, cutting feed, spindle speed limitation according to the controller (conversational).

b. Programming contour (conversational) according to the controller. Straight line rapid traverse, straight line feed traverse, circular feed traverse, rounding, chamfering.

c. Programming with cycles (conversational) according to the controller. Roughing cycles, Drilling cycles, Threading cycles, Tapping cycles, etc.

Refer to page 90 in 840d_shop-turn.pdf file for the conversational programming example.

Appendix S-3. Example of CNC Milling & Lathe Programming PBL4 Guide

CNC Lathe Programming – PBL4
TTO (Facilitator) Guide

No.	Lecture/PBL	Description	Time Allocation
1.	Lecture	TTO (Facilitator) hand over the PBL4 and to discuss with students on how to read the part drawing. Q & A session	(5 minutes)
2.	Lecture	**Refer page 90 in "840d_shop-turn.pdf" shop-turn programming manual:** a. Programming structure or format according to the controller. **TTO (Facilitator) is to demonstrate on how to use the simulator by key-in the program example in "d" CNC Lathe Programming – PBL4 and explain the program details:** - Program header - Program body - Program tail The End of TTO's demonstration	90 minutes
3.	PBL	**Students' are to refer to part drawing:** Problem 4: You are an engineer in a manufacturing company. Your task is to prepare a part program (NC program) for a component that going to be machined using CNC lathe machine. However, the CNC lathe controller in the manufacturing company uses conversational programming format. **TTO (Facilitator) hand over the LO form to students.** Students are to discuss in group (group discussion) to the list the: (for a, b & c) - Learning Objectives. - Know. - Don't Know. - What need to find out? **Actions to be taken according to the timeline.** **Completed** **Students are to work individually** (self-study) on "what need to find out". In this case, students' are to distribute the tasks within the group members accordingly to save time.	15 minutes 15 minutes 15 minutes 30 minutes

		Students are to work in group (group discussion) on tasks given to complete the programming. Students are to prepare a 10 minutes presentation.	120 minutes
		Students group presentation on their part program: - Machining process - Cutting tools used - Cutting technology for each tools - Workpiece zero points. - How the contour program is done? - How cycles are used in the program to drill, pocketing, slotting etc? **Q & A session** **TTO (Facilitator) comments on the presentation** **Students' group and personal reflection on what have they learnt and experienced throughout the PBL process.** - List the LO, know, don't know, what need to find out. - Self-study - Group discussion - Presentation Examples of TTOs' (Facilitator) projection questions: - What you have experienced during the discussion of "LO, know, don't know, what need to find out"? - What you have experienced during the self-study and seeking for information? - What you have experienced during the group discussion and presentation? - What you have experienced during the group presentation? - What about the group members? Team work? Cooperation? Individuals' contribution? Etc. **TTOs' (Facilitator) overall comments:** Examples: - Students' progress on tasks given. - Students' time management. - Students' discussion activities. - Students' team work. - Students' problem solving skills. - Students' critical thinking. - Students' presentation.	60 minutes (10 to 15 minutes per group) (5 to 10 minutes per group) (5 to 10 minutes per group) 60 minutes (5 to 10 minutes (per group) (10 minutes)

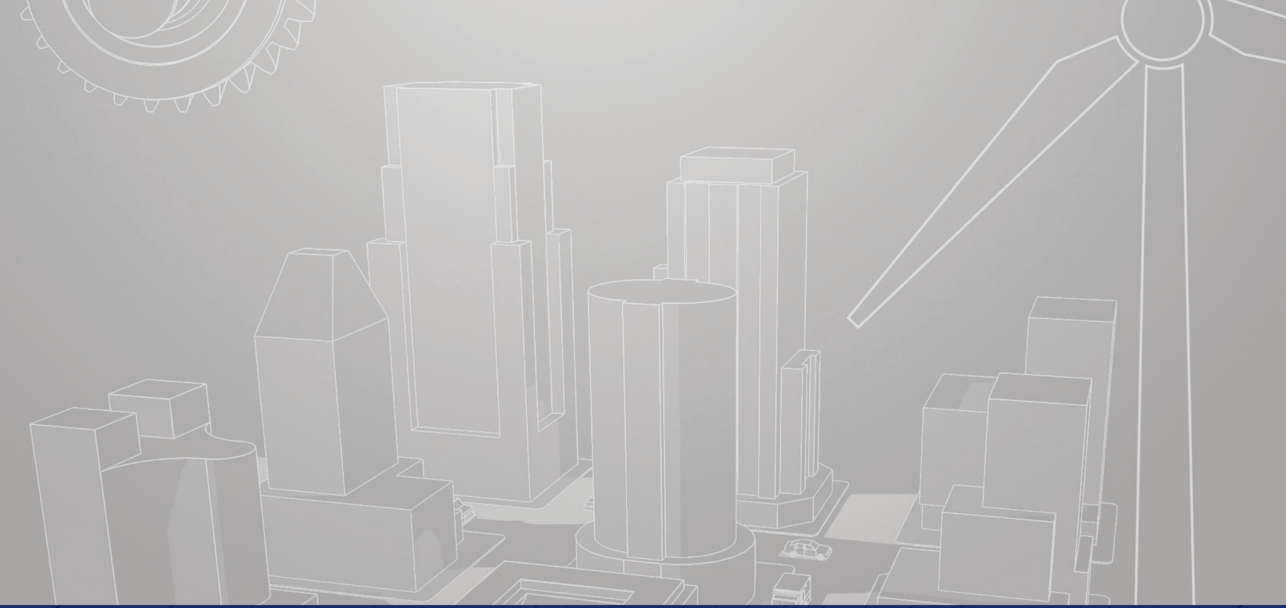
		The End PBL4	

Summary

Section	Lecture / PBL	Duration (minutes)
1	Lecture	5
2	Lecture	45
3	PBL	235
4	-	-
5	-	-
Total		**285 (4.8Hrs)**

Appendix T-4. List of Conference Papers

No.	Paper Title	List of Authors	Publication Outlet
1.	The Effectiveness of Problem-based Learning Approach on Students' Skills in Technical Vocational Education and Training (TVET) Specifically on Programming Course Using a Computerized Numerical Control (CNC) Simulator.	Hashim Mohamad[1*] Erik de Graaff[2]	4th International Research Symposium on Problem-Based Learning (IRSPBL) 2013 (Kuala Lumpur, Malaysia)
	Citation: Mohamad, H. B., & de Graaff, E. (2013). The Effectiveness of Problem-based Learning Approach on Students' Skills in Technical Vocational Education and Training (TVET) Specifically on Programming Course Using a Computerized Numerical Control (CNC) Simulator. In K. Mohd-Yusof, M. Arsat, M. T. Borhan, E. de Graaff, A. Kolmos, & F. A. Phang (Eds.), PBL Across Cultures (pp. 126-130). Aalborg: Aalborg Universitetsforlag.		
2.	Reliability and Validity of a Questionnaire for Students' Perception of Problem-Based Learning	Hashim Mohamad[1*] Erik de Graaff[2]	4th International Problem-based Learning Symposium 2015 (Singapore)
	Unpublished		



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