Five Pilot Lessons for Preparing Students for Global Engineering Careers and as Researchers

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ABSTRACT

Nowadays, most technical universities in Vietnam are integrating their curricula to align with CDIO or ABET outcomes. To prepare for global engineering careers and researchers,the students must undertake active, cooperative, problem- and project-based learning focused on achieving the six levels of taxonomies of educational objectives. However, the teaching style in crowded classes does not provide significant appeal, and several surveys have reported that postgraduate students often struggle to complete research and capstone projects in international environments. In this study, five pilot lessons were proposed to prepare students for global engineering careers and as. The study indicated the importance of motivation in learning the given subjects. The focus was on employing real-world examples to teach students the work and communication skills needed to become researchers in the field of Engineering. Three principles from the book "How People Learn" were utilised in achieving educational objectives. For the bachelor students two different level objective education courses were used with two class sizes: three crowed class with around 120 students and a normal class with 30 students. Surveys consisting of 75 questions were used and averages with error bar for each class were used for analysis, comparison, and evaluation. The core characteristics of global engineering careers and researchers were defined, and include strong analytical thinking, critical thinking, research communication and leadership skills. Five pilot lessons with 30 credit hours included study concerns, problem-based learning, research paper-based learning, project-based learning and conference-based learning, and the map, framework, assignment and assessment of each lesson were established.

Keywords: *Global engineering, Active learning, Educational objectives, Analytical thinking, Critical thinking, Research communication, Leadership skill.*

INTRODUCTION

Nowadays, the engineering profession is very competitive in an international market. Global competency is essential for engineers from any country, and engineers need to have cultural sensitivity in designing products destined for diverse markets. Therefore, significant intercultural skills are required in order for engineers to form efficient and productive collaborations with diverse engineering colleagues at international locations or in multinational corporations. These

demands are increasing, not only for problem solving but also for running projects in a global environment, and strong analytical thinking, critical thinking, research communication and leadership skills are essential. Projects are distributed across sites and effective collaboration requires professionals who can work productively with colleagues from diverse backgrounds (Allert, Atkinson, Groll & Hirleman, 2007).

For adapting to international markets, universities strive to train students to become global engineers. In 1985, the National Research Council issued a study that spotlighted the need for universities to graduate engineers with professional skills (Committee on the Education and Utilization of the Engineer, National Research Council, 1985). This message was reinforced through a joint report published by the Engineering Deans Council and ASEE (Dowell, Baum, & McTague, 1994) that stated, "Today, engineering colleges … must educate their students to work as part of teams, communicate well, and understand the economic, social, environmental and international context of their professional activities". In 2002 at Job Outlook, the National Association of Colleges and Employers issued the top five new hiring skills for engineers: communication skill, honesty/integrity, teamwork, interpersonal skill and a strong work ethic. In 2008 a report from Educations Sector measuring skills for the 21st Century discusses assessment of these skills, and ASCD's 2009 publication "21st Century Skills: The Challenges Ahead" describes the goals and hurdles of the movement. These 21st century skills include personal and social responsibility; planning, critical thinking, reasoning, and creativity; strong communication skills, both for interpersonal and presentation needs; cross-cultural understanding; visualising and decision making; knowing how and when to use technology and choosing the most appropriate tool for the task. In today's globalised society, it is vital to train students in the knowledge, skills and methods necessary for them to lead the engineering profession. In this study, firstly the Global Engineers and Researcher (GEaR) were defined and then five pilot lessons for preparing GEaR were devised. Surveys were used with five classes and questionnaires consisting of 80 questions were used for evaluation.

METHODOLOGY

The pilot lessons were devised in order to improve the level of knowledge and skill needed for a global engineer and researcher. The tasks for student at each level in each lesson were carefully defined. Moreover, each lesson focused on employing real-world examples with real problem-based learning. To achieve the level of objective education, students were trained by the three principles outlined in the book "How People Learn" through active learning. Guest speakers and group discussion on future job possibilities were used to motivate students. Definitions gap and CV writing were used as class exercises. The social science, ethical engineering, engineer communication, etc. were trained with the real problem solving based on running projects. For checking the effectiveness of pilot lessons, there were two different level objective education courses for bachelor students: Energy and Environment course and Optimal Method course. Two class sizes were trialled: three crowed classes with around 120 students and a normal

class with 20 students. The surveys comprised 75 questions. The averages with error bar of each class were used for analysis, comparison, and evaluation.

RESULTS AND DISCUSSIONS

Core Characteristics of Global Engineers and Researchers (GEaR) Lessons Map, and GEaR Lessons Framework

The mission of almost every technical university today is to provide opportunities for students to participate in international educational experiences and help them to become global engineers and researchers. In this study, the core characteristics of GEaR are defined as strong analytical thinking, critical thinking, and research communication and leadership skills.

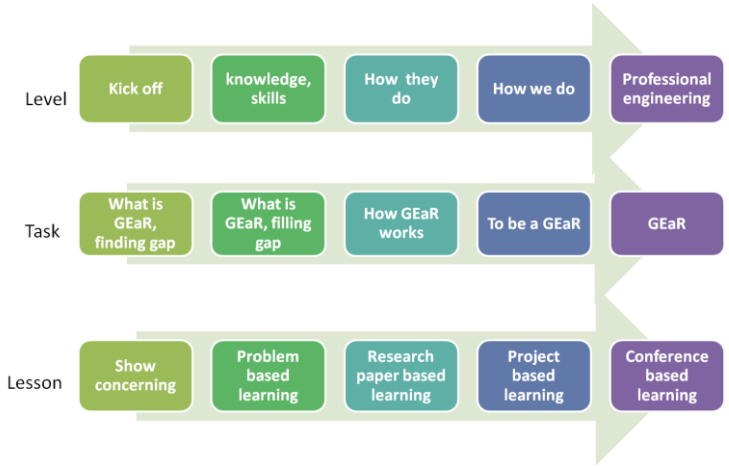


Figure 1: Five steps and three visions for GEaR

Compared with the conventional engineer, besides providing the knowledge and problem solving skills found in textbooks, GEaR must design the problem, do the analysis, solve the real problem, and successfully complete the project. Therefore, GEaR needs to train in two phase with five steps and three visions as show in Figure 1. The first phase is knowledge and second phase is proficiency in solving real problems based on project learning. The three visions are level, task and lesson name of GEaR and they are correlated in five steps. In the first lesson, students were motivated by an introduction from a guest speaker. In the second lesson, the basic knowledge and problem solving problem skills were provided through active based learning. In the third lesson, students learn how global engineers and researchers work through research paper-based learning. In this lesson, students also learn and practise engineering communication through individual comprehension, group presentation and discussions of research papers. In next lesson, the real problems were solved by means of a team project.

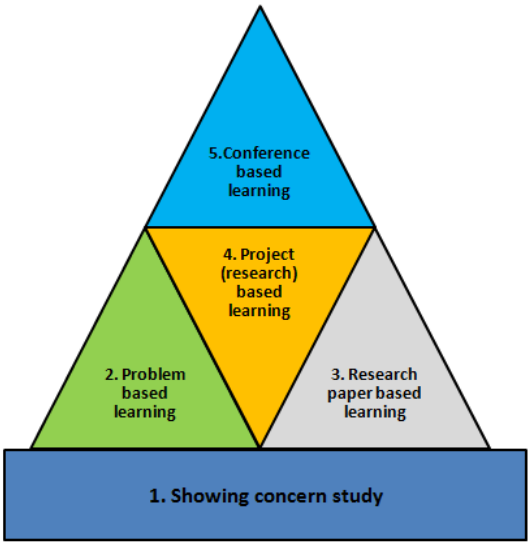


Figure 2: GEaR town.

In this lesson, students play the role of a GEaR and do realistic work as a GEaR, such as writing the proposal, project contract, running the project, submitting the result, and presenting and defending it. The last lesson is conference-based learning, which trains the students to become a professional engineer. In this lesson, the engineering communication and social research were built up and improved. Through five pilot lessons, the necessary knowledge and skill necessary for a global engineer and researcher are gradually improved. Each lesson provides a strong base for the next, and the last lesson is built on all the foregoing lessons. Figure 2 shows the lesson GEaR town. The important part in GEaR town concerns study. In the opposite situation, it is hard for students to become a GEaR without the belief that what they need to do and why are important steps for their future. The two next equally important parts are critical knowledge and problem solving proficiency. The project is built on both of these factors, and engineering communication is built on all of the above knowledge and skill. The reasons for building the GEaR course and what knowledge and skill are achieved from the course are shown in Table 1.

Figure 3 shows the framework of the five pilot lessons, starting from lesson one at the top. In each lesson, steps are outlined from left to right to show how the lesson is constructed. In the first lesson, the streamed steps concern how and what to prepare and the reasons for studying the five pilot lessons. The other lessons follow the same procedure, and the steps in each lesson are important for training and the instructor need to maintain it to achieve the training purpose.

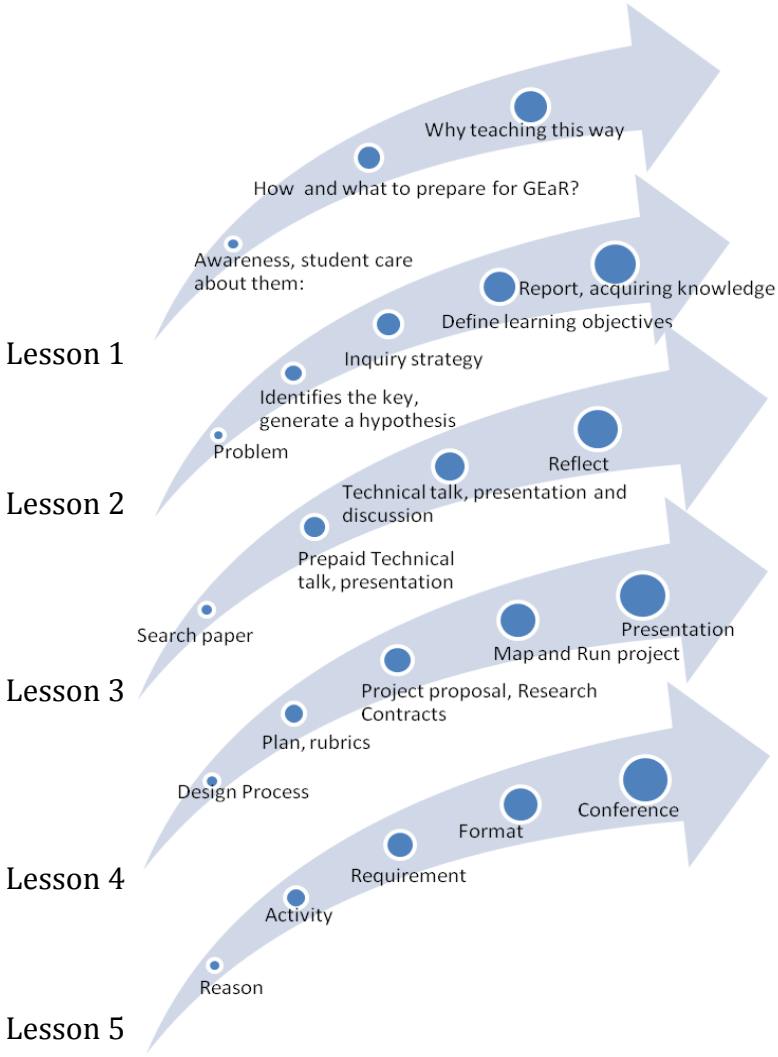


Figure 3: GEaR framework.

Outcome, assignment, instructor activity, assessment and evaluation (OAIA)

Table 2 (a, b) shows the outcome, assignment, instructors activity and assessment and evaluation (OAIA) of each lesson as aligned with ABET outcome criteria. The outcomes of this course are to fulfil ABET outcome criteria. Moreover, the research skill is added to solve real-world problems. Based on this table, the instructor can generate a new table for a particular course.

For checking the effectiveness of the pilot course, there were two different level objective education courses for bachelor students: Energy and Environment and Optimal Method course, Two class sizes were trialled: a large class with 150 students and normal class with 20 students. Three big classes were used to check the stability of pilot courses. The survey feedback from students using questionnaires is shown in Appendix 1. The questions were built on the comparison between class size and the level of objective education, and they focus on the knowledge and skill for GeaR to evaluation. Figures 4- 6 show the survey results from bachelor students (with number students took survey per total number students in class are 61/120 (BOM61/120), 62/110 (BOM62/110) and 66/100 (BOM66/100), respectively) The results are an average rating scale with an uncertainty error bar. The rating scale rank from strongly disagree 1 to strongly agree 6. The ranking result from three above class is 4.5 to 5. It shows that almost all students agree with the efficacy of the course. We can conclude that knowledge and skill leading to global engineering and researching for students in the big class trained with the five pilot lessons have improved. The five pilot lessons can be used for the big size class. Figure 7 shows the survey result for bachelor students who took the Energy and Environment class with 31 students took survey (BEEN31/31). The rate scales are around 5, which is higher than for the big size class. From the results of all the above classes it is demonstrated that analytical thinking, critical thinking, research communication and leadership skills and special ethical engineering were highly improved and fulfil the outcome criteria.

Table 1: The reasoning and know–how for GeaR

Lesion	Why	What
Show concerning	Awareness future, motivate learning.	GEaR, study and research style, knowledge and skill gap, future life, society and technology.
Problem based learning (PBL)	Student-centred approach and acquire knowledge, focuses on the process of solving a problem, embark on their PBL journey, teamwork, learn by trying.	Critical knowledge, problem solving proficiency, self-directed learning strategies, team participation skills, research skills, writing skills and social skills.
Research paper based learning	Contemporary knowledge source, individual work, defend, engineering communication standard, critical analysis, summarising and synthesising, critical thinking, engineering communication.	Critical knowledge, problem-solving proficiency, SOPs, communication format, engineering communication, ethics, individual work skill, analysis skill.

Project based learning	Knowledge restructuring; cooperation and teamwork, social knowledge construction; lead to leadership, critical thinking, lifelong learning.	Real problem solving based on theory; critical analysis, summarising and synthesising, inquiry, questioning and exploratory investigation, design problem and problem-solving skill.
Conference based learning	Professional communications skills, open doors to career, open eyes to future opportunities, international perspectives, meet practising engineers, life-long learning.	Competitions, teamwork, technical speaking skill, professional skill, networking, international trade, enhance soft skill.

Table 2 (a): OAIA of pilot lessons

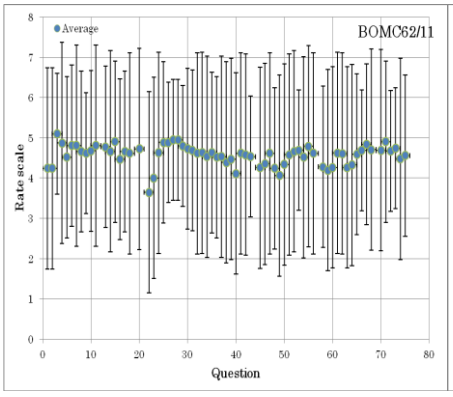
	Outcomes
Lesson 1	100% students aware of the importance of this subject for future job, 90% students are motivated to learn, 100% students can define GEaR, what and how to learn and graduate, 100% of students know ethics aligned with IEEE code of engineers.
Lesson 2	80% students can reach the level of education objectives (a), 100% students can use self-directed learning strategies (i), 70% students improve problem-solving proficiency (c), 80% students can find different resources (e.g. internet, library, community) for solving problems (k), 90% students are confident to work in a team (g).
Lesson 3	100% students clarify that research papers are important for GEaR (i), 100% students can use engineering communication form, research paper format (k, g, h), 80% students improve international communications and analysis skills (d, b), 100% students recognise the importance of ethics (f), 100% students improve individual work skill, defend and vote (g), 80% students know how to critically analyse, summarise and synthesise (b, c) 80% students practise inquiry, questioning and exploratory investigations (h), 100% students know how to design and solve real problems (c), 100% students realise use contemporary knowledge for research papers (j),

Lesson 4	100% students can write and present research proposal, research contracts and monitor projects (b, c, g), 100% students can use search tools (k), 100% students contribute to the mini-project to develop their teamwork (c, g), 80% student successfully create their prototypes in the project (b), 80% students can apply critical analysis, summarising and synthesising (b) 80% students improve inquiry, questioning and exploratory investigations (h), 100% students can design and solve problems (b), 80% students have leadership, cooperation and teamwork (g),
Lesson 5	80% students confident in competitions (g), 80% students improve their technical speaking skills (g), 80% students attain professional skills, 80% students express their desire to work for a multinational company, networking (g, h), 70% students are confident to communicate publicly (g), 70% students improve leadership skills.

Table 2 (b): OAIA of pilot lessons

	Assignment	Instructor support	Assessment and Evaluation
Lesson 1	What is (GEaR)? What knowledge and skill of this subject for GEaR? How to prepare/study for engineering careers today? Write future CV, identify any gaps and resubmit future CV.	Talk and invite guest speakers for future engineering, educating tomorrow engineering 2020, U.S goal, goal for graduate, manufacturing migration, What is GEaR?	GEaR objective and outcome, teaching and studying style, ethics, engagement.
Lesson 2	Identify the key problem and generate a hypothesis, inquiry strategy (what additional information is required?), define learning objectives (identify gaps) and report back to group, integrate new knowledge (how does this knowledge relate to other information in the field), present and share knowledge.	Devise groups (about 4-5 student), each group has some problems (curriculum), Take note: "How People Learn" principles, points of reflection for each class, final points of reflection.	Team problem solving and discussion, difficult points for next class discussion, solve problems relevant to the real world.

Lesson 3	Each student to select a research paper and speak about it in class using a PowerPoint presentation, all members attend the presentation and discussion	Standing operator protocols SOPs, research paper format, technical talk, suggestion for oral presentation, group discussion, reflect on paper.	Individual work ability, understanding the paper, technical communication, presentation, discussion, teamwork.
Lesson 4	Devise groups (about 4-5 students), each group to choose a problem (in the research field), write research proposal, write research contract, work on terms, submit the product and report, presentation.	Project proposal, research contracts, control project, safety notes, analysis data, criteria assessment.	Plan: formative assessment, working effectively in teams, collaboration, leadership, cooperation, attitude, demeanour.
Lesson 5	Registration, write abstract, proposal, peer review, submit full paper, PowerPoint and poster, oral presentations, poster presentation, discussion.	Reasons to attend conferences, requirements for participation, activities at conferences, common formats. conference, criteria assessment.	Preparation and delivery, presentation, slide, pre-presentation, self-evaluation.



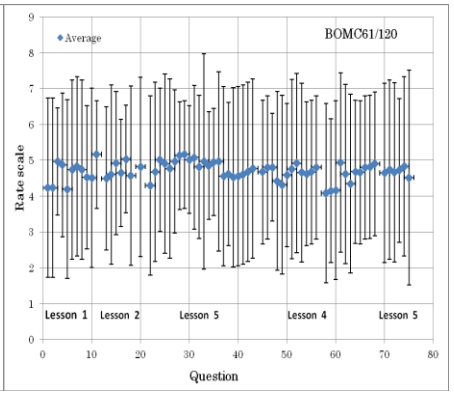
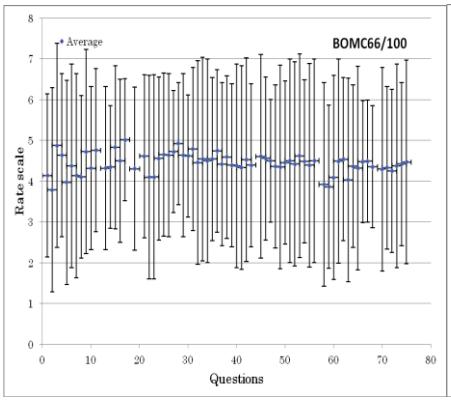


Figure 4: Results of BOMC62/110 **Figure 5: Results of BOMC61/120**



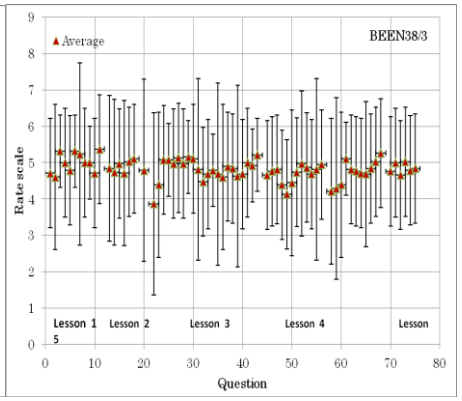


Figure 6: Results of BOMC66/100 **Figure 7: Results of BEEN38/38**

CONCLUSION

In this study, the core characteristics of global engineering careers were studied. A pilot course was designed for a crowded class with five lessons including the map, framework, outcome, students and instructor activity, assignment and assessment of each lesson. The survey results demonstrate that the students who completed the training showed significant improvement in their skills for global engineering careers and researchers such as skills in communication, decision making, ethical engineering, defining problems, teamwork and executing projects.

ACKNOWLEDGEMENT

I would like to thank the Engineering Education Alliance Program (HEEAP) and all lecturers in HEEAP, for giving me the opportunity to work in the global engineering field. Also, I would like to thank all members in Energy and Environment Lab. (EEL) for their teaching assistance and doing the survey. Furthermore, I would like to thank mechanical faculty member, Ho Chi Minh University of Technical Education for guidance and comments on this study.

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APPENDIX 1

Questionnaire

Please ratethe each item below using the following scale by writing the number for each on a piece of paper.

1	2	3	4	5	6
Strongly disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly agree

Lesson 1: Show concerning

1. _____ Have you controlled how you learned the course?
2. _____ Have you had flexibility in what you were allowed to do in this course?
3. _____ In general, was the coursework useful to you?
4. _____ Is the knowledge gained in this course important for your future?
5. _____ Were you capable of getting a high grade in this course?
6. _____Throughout the course, did you feel that you could be successful in the coursework?
7. _____ Have you enjoyed the instructional methods used in this course?
8. _____Was the coursework interesting to you?
9. _____Has the instructor cared about how well you did in this course?
10. _____Has the instructor been respectful of you?
11. _____Throughout the course, have you felt that ethics is importantyou're your future success?

Lesson 2: Problem-based learning

1. _____Have you found the course interesting?
2. _____ Have you enjoyed the course?
3. _____Did you find that the course focused on real engineering problems?
4. _____Did you find that the course was more relevant to your interests?
5. _____Working in groups, did you learn from one another?
6. _____ Have you understood the technical material of the course better than if it had been lectured in the conventional way?
7. _____ Do you think you have learned as much technical material as you would in a conventional lecture course?
8. _____Has this course taken more time than other conventional lecture courses?
9. _____Has this course taken fewer numbers of students than other conventional lecture courses?
10. _____Did you put your ideas forward during the group's brainstorming?
11. _____ Were you able to identify gaps in your knowledge in relation to the learning trigger/scenario?
12. _____ Could you confidently participate in determining the group's learning goals?
13. _____ Are you confident that your group chose learning goals that are relevant and useful?

14. _____ Have you had sufficient opportunities to discuss your learning related to the group's learning goals?
15. _____ Have you had sufficient opportunities to question other students about their contributions to the discussion?
16. _____ Were you able to build on the knowledge that you gained during independent study time?
17. _____Did team problem solving and discussion help?
18. _____ Did the hands-on activities support learning?
19. _____Did the Preview Problem help to prepare for the next class?
20. _____Would the content be valued after graduation?
21. _____ Are you confident that PBL prepares for future professional life?
22. _____Were unclear points clarified in the subsequent class discussion?
23. _____ Did you have the chance to give reflection of interest and puzzling problems?
24. ____ Did you discuss puzzling points at the next class?
25. _____ Did you have the chance to give reflection of interest and muddiest of final?
26. _____Would you recommend the class to a friend?
27. _____Would you like instructional strategies in other courses?
28. _____Is PBL is an effective method of learning for you?
29. _____Are you confident that PBL prepares for exams?

Lesson 3: Research paper-based learning

1. _____Do you consider that research papers are important for GEaR?
2. _____Did you get critical knowledge from research papers?
3. _____Did you improve problem solving proficiency?
4. _____Can you efficiently use standing operator protocols SOPs, research paper format?
5. _____Did you improve the international communication skill, defend and vote?
6. _____ Did you improve your analytical skills and critical analysis?
7. _____ Did you improve your individual work skill?
8. _____ Did you recognise the importance of ethics?
9. _____ Did you improve critical summarising and synthesising?
10. _____ Did you improve Inquiry, Questioning and Exploratory Investigations?
11. _____ Did you know how to design and solve problems?
12. _____ Did you improve your Technical talk?

Lesson 4: Project paper-based learning

1. _____ Can you write a research proposal and research contracts?
2. _____ Can you present the research proposal and research contracts?
3. _____ Can you monitor that project?
4. _____ Can you use search tools (e.g. Google, online library) for your project?
5. _____ Can you contribute to the mini-project to develop teamwork?
6. _____ Can you create the prototypes of the project?
7. _____ Can you apply critical analysis, summarising and synthesising?

8. _____ Did you improve inquiry, Questioning and Exploratory Investigations?
9. _____ Do you know how to design and solve problems?
10. _____ Did you improve your technical talk?
11. _____ Can you undertake leadership, cooperation and teamwork?

Lesson 5 Conference-based learning

1. _____ Are you confident in competitions?
2. _____Did you improve your technical talking skill?
3. _____How do you rate your professional skill?
4. _____How much do you express your desire to work for multinational company, networking company?
5. _____Are you confident to communicate publicly?
6. _____How are your leadership skills?