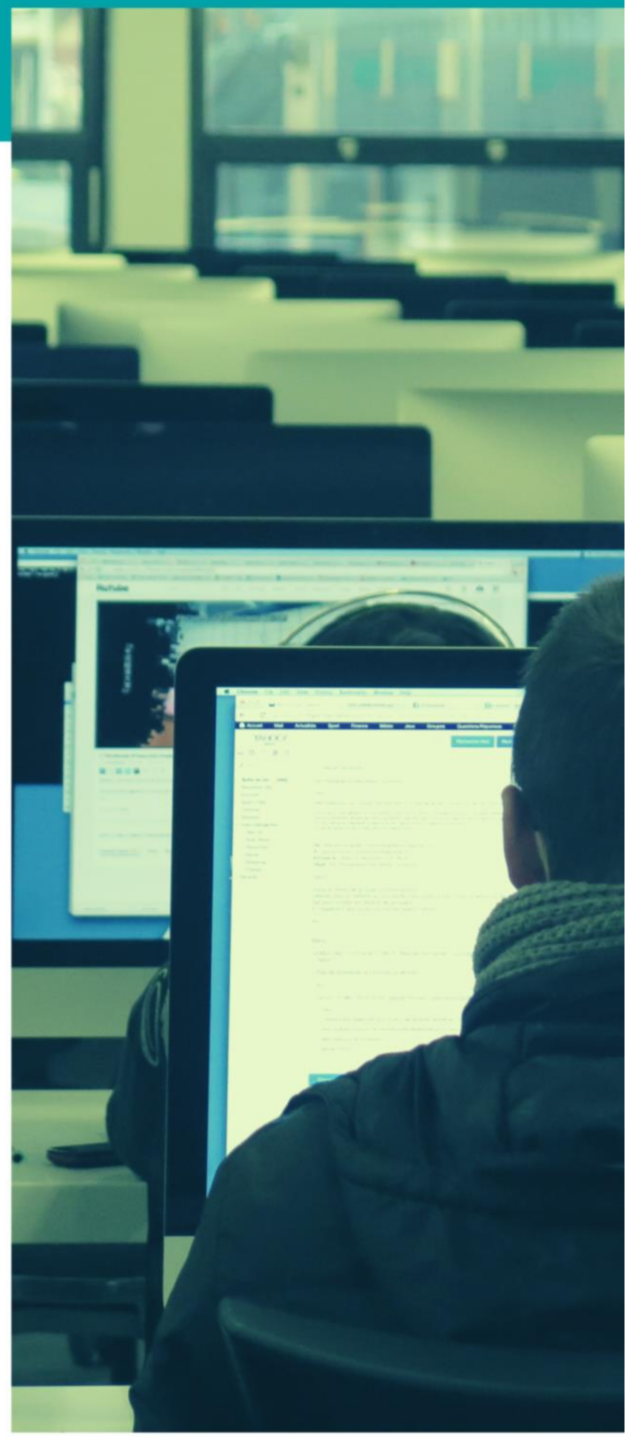
Envisioning 21st Century Education

Making the world a more thoughtful place and preparing students for a complex future

UTM CENTRE FOR ENGINEERING EDUCATION AROUND THE WORLD

CEE activities conducted around the world for awareness, training and mentoring in student-centred learning.

CREATING A 21ST CENTURY CLASSROOM ENVIRONMENT THAT PROMOTES STUDENT-CENTERED LEARNING (SCL)



Rapid changes in the advent of Industrie 4.0 require human capital who can adapt and face novel problems and situations, such as the Grand Challenges of the 21st Century. In addition to the requirement in knowledge and developing thinking and other skill sets such as communication, problem-solving team-working, the 21st Century also require holistic development of students, such as caring about sustainable development, which will translate to concerns and behavior towards sustainability. The 2015 World Economic Forum's "New Vision for Education Report" defined 3 domains of 21st century skills, with an all-encompassing life-long learning skill. The 3 domains are foundational literacies, competencies and character qualities.

The question is: how to nurture these essential 21st Century attributes among students in a typical course and curriculum? The urgency of this requirement is even more acute in engineering education which requires students to learn difficult content and to develop skills necessary to be good engineers who can face up to the requirements of today and the future. With the current discrepancy between what learners need and what higher education provides, it is not surprising to hear calls worldwide to change the way students are taught. Thus, there is a need to design a learning environment that can be implemented in a typical course to develop 21st Century graduates' attributes among students without a costly overhaul. While the initial aim was to focus on engineering students, the current work has been expanded and generalized into the whole of higher education and secondary schools.

Addressing these needs, Cooperative Problem-Based Learning (CPBL) model has held a reputation of an innovative teaching and learning technique that engage learners for deep learning, and develop essential professional skills, especially in self-directed learning and problem solving which are essential in graduates for the 21st Century.

Cooperative Problem Based Learning (CPBL): What is it and How it works?

Cooperative Problem-Based Learning (CPBL) is a model that provides a step by step guide for students to go through the PBL cycle in their teams, according to CL principles. It is a combination of Cooperative Learning (CL) principles and Problem-Based Learning (PBL). The CPBL framework guides students and facilitators to go through the process in a systematic and step by step manner, providing support in terms of giving the big picture and the break-down into simpler parts, making the complex practice of problem solving possible in a typical classroom. While it is challenging to monitor and support all groups closely, in a CL environment, part of the support is transferred to peers as part of the learning community, instead of solely relying on the facilitator.

CPBL is flexible and adaptable for problem-based or project-based approaches, or a hybrid of the two. Learning environments are designed so that the outcomes can be achieved when students have gone through the CPBL cycle to solve the problem. To provide learning context, problems should be realistic, or even real, representing professional practices that resemble working environment encountered in actual practice, with stakeholders coming from fictitious or real industries or communities.

Bransford's How People Learn framework and Bigg's Constructive Alignment formed the underlying principles in designing the learning environment. Keeping these principles in mind, Problem-Based Learning (PBL) is a natural choice, given its constructivist underpinnings and its use of realistic (if not real) problems as the starting point of learning. However, most PBL models are implemented in small groups with up to ten students per facilitator essential for cognitive coaching, causing it to be expensive to execute because of the intensive manpower, infrastructure and institutional support requirements.

An alternative is to have small groups (3-5 students) in a typical class. Instead of a dedicated tutor, floating facilitators are utilized during class. This requires higher commitment and accountability from students to go through the PBL cycle in teams. Since students do not automatically have team working skills, Cooperative Learning (CL), which is proven to promote accountability and cooperation, is chosen to develop team-based learning skills in accomplishing shared learning goals and maximizing learning. Hence, the objective of the project can be further refined to designing a framework for learning environment that integrates CL into PBL for developing team-based problem-solving skills that is practical for a typical engineering course.

The CPBL learning environment consists of a real-world open-ended problem and a CPBL framework as scaffolding for students to successfully undergo CPBL step by step in their learning teams as illustrated in the CPBL framework (Figure 1 as below). The CPBL framework also serves as a guide for instructors in planning and facilitating students. The full cycle of the CPBL framework consists of:

- Phase 1: Problem restatement and identification.
- Phase 2: Peer teaching, synthesis of information, and solution formulation
- Phase 3: Presentation, closure and reflection.

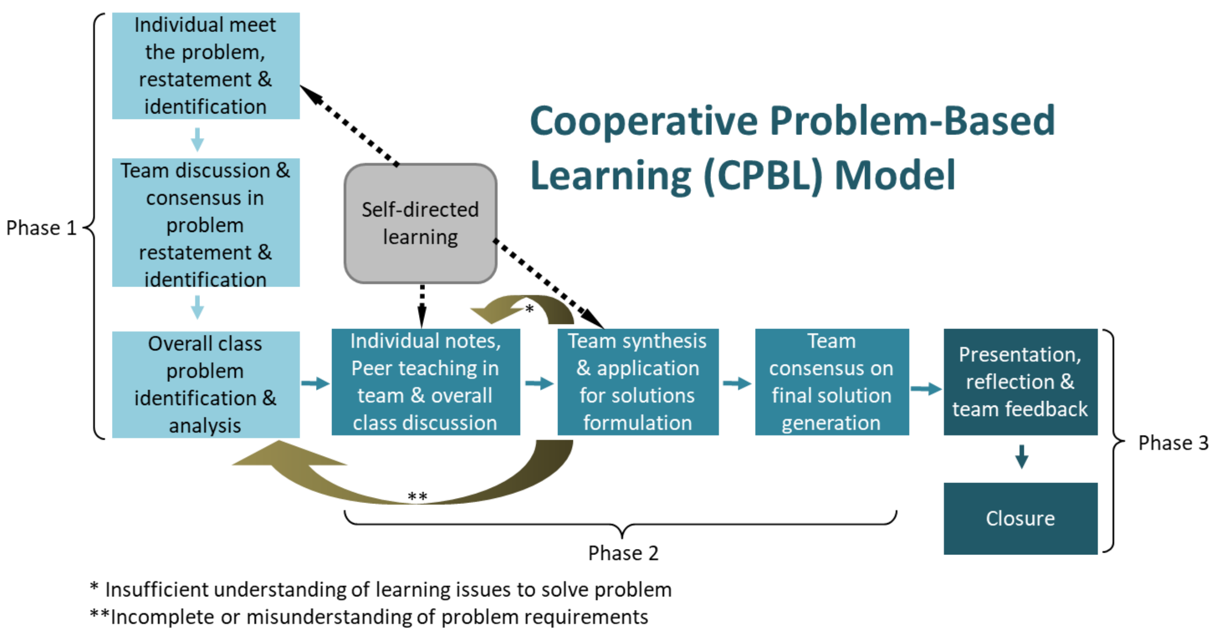


Figure 1: Cooperative Problem Based Learning (CPBL) Model

Students are given the CPBL model (shown above as Figure 1) prior to the commencement of the first problem. The framework can be used to visualize the CPBL process to support students in grasping the whole process, as well as for facilitators to explain the significance of each step in terms of the outcomes and activities in each block as they go through each of the three phases in the CPBL cycle. Students new to CPBL should be motivated by the facilitators on the rationale for learning through CPBL, briefed on the characteristics of the CPBL, the CPBL process, and expectations of students.

An important part of the CPBL is the formative assessment given in each phase, which may be in oral or written form, during the class or virtually outside of class time. Since it is not possible to monitor individual learning and all the discussions in the small teams, the assessment provided is aligned the learners' activities to provide feedback not only to facilitators, but also to students, on their progress towards achieving the desired outcomes. The assessment results can be used to further decide on the kind of scaffolding needed by learners.

CPBL is flexible and adaptable for problem-based or project-based approaches, or a hybrid of the two. Learning environments are designed so that the outcomes can be achieved when students have gone through the CPBL cycle to solve the problem. To provide learning context, problems should be realistic, or even real, representing professional practices that resemble working environment encountered in actual practice, with stakeholders coming from fictitious or real industries or communities. Industries that had been involved in problems for engineering courses in UTM include Dow Chemicals Malaysia, Shell Malaysia, Iskandar Region Development Authority, Southern Waste Management, On-Semiconductor, Kenwood Malaysia, Kempas Edible Oil, etc. Problems have also been designed to include laboratory-based skills, community engagement, and affective domain outcomes, such as sustainability awareness and behaviour.

Applications in Higher Institutions Level

PBL was initially implemented in a third year undergraduate Chemical Engineering course in UTM in 2003. The implementation was continuously improved and in 2009, CL principles were formally infused into the PBL model to effectively develop students into learning teams. The CPBL framework was then explicitly included into the learning environment for supporting students in undergoing the PBL process.

In a 14-week semester, students go through three to four problems or parts of a large problem, each with a complete CPBL cycle. Each successive CPBL cycle comes with a problem structured such that the next one brings students up to a higher level of expectation, which correspond to Wood's stages of development from novice to expert problem solver: build, bridge, extend, and apply. Currently, the full CPBL learning environment is consistently implemented in several Chemical and Mechanical engineering courses in UTM. Thus, the implementation of the CPBL framework for scaffolding learning in each problem, and the successive problems for a semester yields a powerful learning environment for developing 21st Century graduate attributes that can be implemented in a typical course.

CLASSROOM ACTIVITIES DURING CPBL LESSONS

Chemical and Mechanical Engineering Students


Photos : Industrial Problem on Control Systems Design for 3rd Year Chemical Engineering Students

Photos :Sustainable Development Problem for 1st Year Chemical Engineering Students


Photos : Industrial Problem for Final Year Mechanical Engineering Students

FINAL POSTER PRESENTATION

Chemical Engineering and Mechanical Engineering Students

THE APPLICATION OF CPBL IN SCHOOLS

The Application of CPBL in Schools
In early 2016, a three-year project for training teachers in CPBL from schools in the Iskandar Region of Johor Bahru in Malaysia by CEE was started in collaboration with the Johor State Education Department, led by the Kyoto Environmental Activities Association (KEAA) to implement low carbon education funded by Japan International Cooperation Agency (JICA). PBL for schools is intended to impart the 21st century skills such as critical thinking, problem solving, team-working, communication, and information management skills. It is also an example of STEM education where three subjects were taught in an integrated manner, namely Science, Mathematics and Living Skills. The teachers are trained and mentored to design and implement the CPBL environment framework for instilling low carbon awareness and consciousness among students. The problem is divided into three stages which increase the degree of difficulty aligned with the secondary school level of knowledge. The teachers work together in team teaching and the learning time is once a week after school so that they can teach as a team. Close monitoring is also made to provide better guidance and feedback.

After six months of implementation, both teachers and students gave positive results and feedback, although there were some complaints initially because they were not used to the student-centred approach. From the teachers' interviews and written reflections, they noticed that students became more confident and independent in their learning, gain skills such as communication, problem solving, critical thinking, team-working and information management skills, more environmentally conscious and took care of the cleanliness of the schools without any instruction from the teachers of what they see in their students. The students' reflections also show the same gains that were described. In addition, the teachers agree that PBL actually brings out the potential and talent of the students to go further in their learning.

The Impact: Rigorous Educational Research on The Effect of CPBL

Evidence on the impact of CPBL is necessary, given that CPBL requires more effort than traditional lectures from both the instructors and the students. Hence, studies have been conducted on courses that implemented CPBL to determine impact and continuous improvement. The findings demonstrated that students who had undergone CPBL significantly enhanced their team-based problem solving skills which can be used to develop holistic graduates.

Other than that, research and cooperation on improving PBL implementation was also conducted in collaboration with other institutions in and out of Malaysia, such as Purdue University in the US and Aalborg University in Denmark. A focus group discussion report conducted by Prof Johannes Strobel from Purdue University on students who had undergone PBL in UTM, and the e-learning forum discussion among students in UTM on PBL unveil that the learners began to be independent learners when the autonomous of the classroom is given to them instead of to the instructors. Besides that, it developed stronger dependency on each other in the collaborating team.

SOME OF THE EXCERPTS FROM THE FOCUS GROUP DISCUSSION:

STUDENT K

“Overall, I would say that this PBL process done in class is good in showing the students a different side of the learning process, if compared with the normal lectures given. If one participates well in the PBL, it can be very beneficial to improve generic skills, critical thinking skill, etc.”-going learning process”

STUDENT J

“The objective of PBL is to create a good learning habit amongst the students, promoting lifelong learning (peer teaching notes), learn how to get information (by asking the right question), and technics to learn in groups, and etc. Yes, I'm glad I’m in UTM, undergoing this PBL. I still can't say I’m a good learner, but with this PBL, I’m sure I’ve developed myself a lot. As an engineer, I'm sure I can be one, but to be a good engineer, there's still a lot of room for improvements and it's an on-going learning process”

STUDENT A

“I found that PBL does help me in my learning process, tough i didn't like it in the first place. Now I’ve realized that if lectures are given, it will deprive us from learning something new, which was said by Dr. Khairiyah and I think it’s true. In our PBL classes, teams are formed and we need to work in a team to solve a particular case study. working in a team is essential in developing our soft skills because we need to communicate with people of different behaviors when we work in future. hence, this PBL class is the first step in sharpening those skills"

AMONG THE OTHER FEEDBACKS FROM THE STUDENTS ABOUT PROBLEM BASED LEARNING (PBL) ARE:

"Frankly, the education system has really make me forget all about team work stuffs and I was too busy about the A or B that I might get in the end. This misconception has really drive me crazy all the semester. I think that the knowledge part is already a hard part but the biggest challenge isn't about process control, it's about how to get our team going. How to merge all people's idea into 1 great solution, how to transform members who are quiet into people who will talks a lot during the discussion, how to distribute task among members so that they don't think the leader is heavy one side...all these are the biggest challenges. With no team working spirit, I can guarantee you that you won't come out with a good solution for the case study. So I think that the core of PBL system isn't just about transforming the learning system from spoon feeding into peer to peer learning system, but it's about team working spirit"

" I had survived through separation I, chemical engineering thermodynamics, differential equation in which these subjects had presented me with the impression that as long as you study 24 hours 3 days before the test/exam, don't worry, it will cure your sickness of "Oh, I don't know anything about this subject". So by having this deep in my mind, I had the conception that "ok as long as I study hard 3 days before the test for Process Control. I won't die". So this is my initial hypothesis before entering the first class for Process Control. "Study hard like how I study before and I will survive."

Recognition and Collaborations

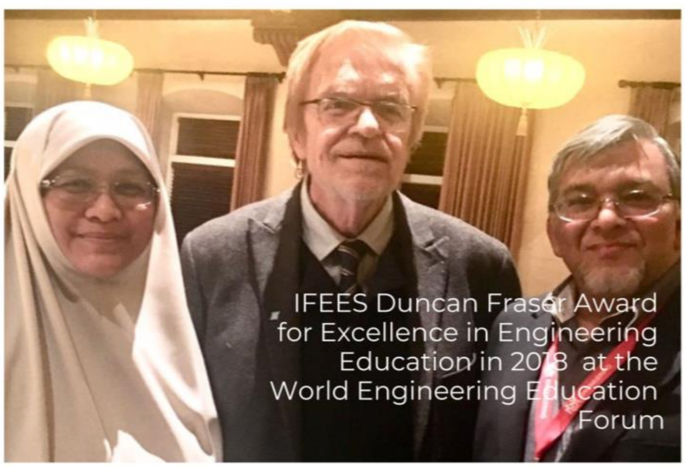
The implementation of CPBL is disseminated through publications, presentations and training workshops. Presentations (including webinars, keynote and plenary sessions) on CPBL are given in various countries in Asia, Australia, North America and Europe. Training were conducted throughout Malaysia in public and private universities, colleges and schools, and in countries, such as Singapore, Korea, Hong Kong, India and China. Publications on CPBL by practitioners and researchers from UTM and from others, such as the "PBL in Malaysia" report, which is part of the PBL in Asia series, have also generated interest on the implementation of CPBL. Meanwhile, industries that had been involved in problems for engineering courses in UTM include Dow Chemicals Malaysia, Shell Malaysia, Iskandar Region Development Authority, Southern Waste Management, On-Semiconductor, Kenwood Malaysia, Kempas Edible Oil, etc.

The paper that first published the CPBL framework won the “Best Paper Award” at the 2011 IEEE Global Engineering Education Conference in Amman Jordan. The CPBL model was also partly the reason for Prof Dr. Khairiyah, the main originator of the model, to be the recipient of the prestigious 2018 Duncan Fraser IFEES Global Engineering Education Award, the 2017 Global Student Platform on Engineering Education (SPEED) Mentorship Award, the 2015 Frank Morton Institution of Chemical Engineers (IChemE) Global Award for Chemical Engineering Education Excellence, the Best of the Best Award at the 2014 Innovative Practices in Higher Education Exposition and the 2013 IChemE Malaysia Award for Education and Training.

Figure 2: CEE around the World – CEE activities conducted around the world for awareness, training and mentoring in student-centred learning.

RECOGNITION & COLLABORATIONS

Student Platform of Engineering Education Development (SPEED) Engineering Education Mentorship Award at the Global Student Forum 2017



IFEES Duncan Fraser Award for Excellence in Engineering Education in 2018 at the World Engineering Education Forum

2015 Morton Medal IChemE Global Award on Chemical Engineering Education Excellence at the IChemE Awards Dinner 2016

Engineering Education for Sustainable Development Conference, University of Cambridge, Sept 2013

Workshop Speaker, Korean Society for Engineering Education, Jeju Island, Korea, Nov 2013.


Trainer, Workshop on SCL Part 1, Aston University, Birmingham, UK, May 2018.

Invited Speaker, Sharing Session in Hong Kong University of Science and Technology, 2012


Pleanary Speaker, IUCEE Conference on Transformations in Engineering Education, Hubli, India, Jan 2014


Workshop in Tsinghua University, Beijing China, July 2015


Panel Speaker at Opening of UNESCO Center for PBL in Aalborg Universityu, Denmark 2014.

Founder of CPBL

Prof. Dr. Khairiyah Mohd. Yusof

Khairiyah Mohd Yusof is a Professor in the Department of Chemical Engineering and the founding Director of Universiti Teknologi Malaysia (UTM) Centre for Engineering Education (CEE), which promotes scholarly and evidence-based practices in engineering education. She is the President for the Society of Engineering Education Malaysia (SEEM) and was Vice President for the International Federation of Engineering Education Societies (IFEES) from 2014 to 2018, and a Board Member for the International Research in Engineering Education Network (REEN) from 2010 to 2017.

Khairiyah is passionate in implementing and promoting meaningful learning in higher education, especially in engineering. After getting energized in seeing the impact of the innovative teaching and learning approaches on students in her own chemical engineering classes at the turn of the millennial, she began sharing these practices through publications, training and mentoring educators. Khairiyah has been invited to speak and conduct workshops throughout Malaysia and in various countries in Asia, Australia, Europe and North and South America. Her interest led her to take a scholarly path to deepen her knowledge, improve her practice and widen the impact through engineering education research, focusing on innovative teaching and learning practices, faculty development, curriculum design and Engineering Education for Sustainable Development. As part of her effort to learn and contribute to the scholarly engineering education community, she serves on the Editorial Boards of the ASEAN Journal of Engineering Education, the IChemE Journal of Education for Chemical Engineers, the European Journal of Engineering Education and was on the Editorial Board of the Journal of Engineering Education (2012-2018).

For her contribution in engineering education, she is the recipient of the prestigious 2018 Duncan Fraser IFEES Global Engineering Education Award. She had also previously won several awards, including the 2017 Global Student Platform on Engineering Education (SPEED) Mentorship Award, the 2015 Frank Morton Institution of Chemical Engineers (IChemE) Global Award for Chemical Engineering Education Excellence, the Best of the Best Award at the 2014 Innovative Practices in Higher Education Exposition and the 2013 IChemE Malaysia Award for Education and Training.

Conclusion

What is clear is that good teaching can be developed and shared to have great impacts, way beyond the four walls of our classrooms. Therefore, taking the scholarly path is important for sustainability and dissemination of ideas in creating a community, especially when implementing PBL in isolation. The challenge is the courage to shift our mental model from limiting our assessments of student performance to the short-term goals of a cognitive curriculum to expanding our assessments to the long-term, meta-cognitive curriculum of dispositions.

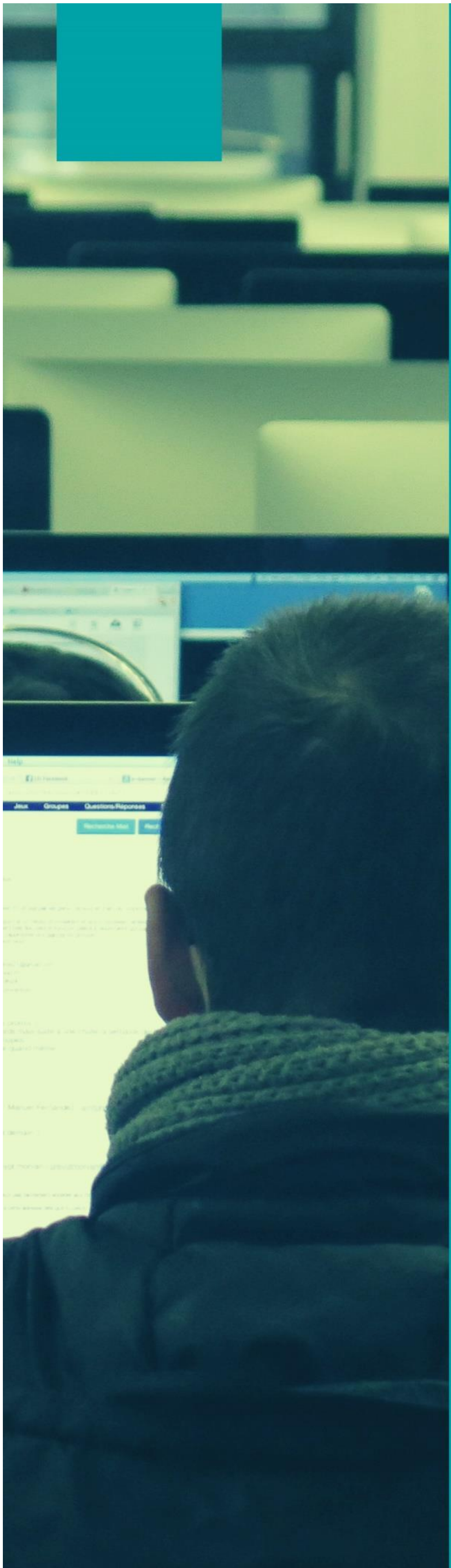
Some publications on CPBL:

1. Jumari, N. F., Mohd-Yusof, K. and Phang, F. A., (2018). Metacognitive Development in Engineering Students Through Cooperative Problem Based Learning (CPBL) in Auer, M. and Kim, K. S. (eds) Engineering Education for a Smart Society, Advances in Intelligent Systems and Computing, vol 627. Springer, Cham, pp. 107-120.
2. Sadikin A.N., Yusof K.M., Aziz A.A., Hassim M.H., Yamani Z.Y., Mustaffa A.A., Hamid M.K.A. (2017). A multi-year study of professional skills development among first year chemical engineering students, Chemical Engineering Transactions, 56, 1453-1458.
3. Syed Ahmad Helmi, Mohd Yusof, K., and Fatin Aliah P. (2016). Enhancement of Team-based Problem Solving Skills in Engineering Students through Cooperative Problem-based Learning, International Journal in Engineering Education, Vol. 32, No. 6, pp 2401-2414.

4. Mohd Yusof, K., Sadikin, A.N., Phang, F.A. and Aziz, A.A. (2016). "Instilling Professional Skills and Sustainable Development Among First Year Engineering Students", Int. J. of Engineering Education, Vol 32, Number 1(B), pp 333-347.
5. K. Mohd-Yusof, S. R. Wan-Alwi, A. N. Sadikin and A. Abdul-Aziz (2015). "Inculcating Sustainability Among First Year Engineering Students Using Cooperative Problem Based Learning", Sustainability in Higher Ed., J.P. Davim (Ed), Elsevier, Kidlington, UK, pp. 67-93.
6. Khairiyah Mohd-Yusof, Aziatul Niza Sadikin, Fatin Aliah Phang, "Development of Professional Skills through CPBL among First Year Engineering Students", in *PBL Across Cultures*, Proceedings for the International Research Symposium on PBL, July 2-3, Khairiyah Mohd-Yusof, Mahyuddin Arsat, Mohamad Termizi Borhan, Erik de Graaff, Anette Kolmos, Fatin Aliah Phang (Eds.), Aalborg University Press, Aalborg, Denmark, pp 74-79, July 2-3 2013.
7. Khairiyah Mohd-Yusof, Fatin Aliah Phang, Mohd Johari Kamaruddin, Mimi Haryani Hassim, Haslenda Hashim, Aziatul Niza Sadikin, Jamarosliza Jamaluddin, Norhayani Othman,Hashim Hassan, Syed Ahmad Helmi, Azmahani Abdul Aziz, and Zaini Ujang, "Inculcating Sustainable Development among Engineering Students, Part 1: Designing Problems and Learning Environments with Impact", Proceedings Engineering Education for Sustainable Development 2013, University of Cambridge, United Kingdom, Sept 20-22, 2013
8. Azmahani Abdul Aziz, Khairiyah Mohd-Yusof, Amirmudin Udin, Adibah Abdul Latif, and Jamaludin Mohamed Yatim, "Inculcating Sustainable Development among Engineering Students, Part 2: Assessing the Impact on Knowledge and Behaviour Change", Proceedings Engineering Education for Sustainable Development 2013, University of Cambridge, United Kingdom, Sept 20-22, 2013
9. Abdul Aziz, A., Mohd-Yusof, K., Udin, A., Abdul Latif, A. and Mohamed Yatim, J. (2013). "Development of Students’ Knowledge-Behavioural Changes in Relation to Sustainability through a Case Study", Procedia - Social and Behavioral Sciences Vol 102, pp. 568 – 576.

10. Mohammad-Zamry, J., Mohd-Yusof, K., Harun, N. F., Helmi, S. A. (2012). A Guide to the Art of Crafting Engineering Problems for Problem Based Learning (PBL), in Outcome-Based Science, Technology, Engineering, and Mathematics Education: Innovative Practices, Yusof, K. M., Azli, NA, Kosnin, AM, Yusof, SK, & Yusof, YM eds. IGI Global, Hershey, Pensylvania, USA, pp. 62-84.
11. Fatin Aliah Phang, Khairiyah Mohd-Yusof, Fatimah Mohamad Adi, Syed Ahmad Helmi, "Engineering Students' Perception on Learning through Cooperative Problem-Based Learning (CPBL) for the First Time", Proceedings 2012 ASEE Annual Conference, San Antonio, USA, June 2012.
12. Mohd-Yusof, K., Syed Hassan, SAH., Mohammad-Zamry, J. and Harun, NF. (2011). “Cooperative Problem-based Learning: A Practical Model for a Typical Course”, International Journal of Emerging Technologies in Learning, Vol. 6, Issue 3.
13. Helmi, S. A., Mohd-Yusof, K., Abu, S. and Mohammed, S. (2011). “An Instrument to Asses Students' Engineering Problem Solving Ability in Cooperative Problem-Based Learning (CPBL)”, Proc. ASEE Annual Conference on Engineering Education, Vancouver, Canada.
14. Azmahani Abdul Aziz, Khairiyah Mohd-Yusof, Amirmudin Udin, Jamaludin Mohamad Yatim, "Inculcating Awareness of Sustainable Development in First Year Engineering Students - A Comparative Study of Pedagogical Approaches", Proceedings 5th Research in Engineering Education Symposium 2013, Putrajaya, Malaysia, Paper Session 4.1, July 5-6, 2013.
15. Khairiyah Mohd-Yusof, Syed Ahmad Helmi Syed Hassan, Mohammad-Zamry Jamaluddin and Nor Farida Harun, “Motivation and Engagement of Learning in the Cooperative Problem-Based Learning (CPBL) Framework”, Proceedings for the 2011 ASEE Annual Conference and Exposition on Engineering Education, Vancouver, Canada, June 26-30, 2011.
16. Khairiyah Mohd-Yusof, Syed Ahmad Helmi Syed Hassan, Mohammad-Zamry Jamaluddin and Nor Farida Harun, “Cooperative Problem-based Learning: A Practical Model for Engineering Courses”, 2011 IEEE Educon, Amman, Jordan, 4-6 April 2011.

17. Khairiyah Mohd Yusof and S. A. Helmi, "Designing Effective Learning Environment for Cooperative Problem-based Learning (CPBL) for Engineering Courses", ASEE Global Colloquium Proceedings, Paper GC2008-87, Cape Town, South Africa, October 2008.
18. Khairiyah, MY, Z. Tasir, J. Harun & SA Helmi, *Inducting First Year Students into Problem-based Learning using Cooperative Learning*, International PBL Symposium 2007, Singapore, Mar 2007
19. Khairiyah, MY, Z. Tasir, J. Harun & SA Helmi, *Integration of E-learning and Problem-based Learning: Extending the Learning Environment to Cyberspace*, 2006, 6th Asia Pacific Conference on Problem-based Learning, Tokyo, Japan, 26 – 28 May 2006.
20. Khairiyah Mohd Yusof, Zaidatun Tasir & Syed Ahmad Helmi. *A Quest of Quality: An Account of a Transition from Lectures to Problem-Based Learning*, INCULT 2006, Shah Alam, Malaysia, 2006.
21. M. Y. Khairiyah, Z. Tasir, J. Harun, S. A. Helmi, "Promoting Problem-based Learning (PBL) in Engineering Courses at the Universiti Teknologi Malaysia", Global Journal on Engineering Education, Vol. 9, No. 2, 2005 (page 175 – 184).



PROF. DR. KHAIRIYAH MOHD. YUSOF

Director
Centre for Engineering Education
Universiti Teknologi Malaysia

Call us : +6 07 56 10225/10226

www.utm.my

Coordinated by :
Centre of Education Engineering
Office of Corporate Affairs
Universiti Teknologi Malaysia

innovative • entrepreneurial • global