Enhancing Complex Problem Solving Skills in a Typical Classroom:
Systematic Development using Cooperative Problem-Based Learning (CPBL)

Khairiyah Mohd Yusof, PhD
Professor and Director,
Centre for Engineering Education
Universiti Teknologi Malaysia

President
Society of Engineering Education Malaysia

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Figure 3: Evolution of the Four Industrial Revolutions

1.0 1784 - Based on mechanical production equipment driven by water and steam power - Brought mechanical innovations, such as the steam engine, cotton spinning and railroads

2.0 1870 - Based on mass production enabled by electrical energy and division of labour - Brought light bulbs, telephones and the assembly line

3.0 1969 - Based on electronics and information technologies to further automate production - Brought mainframe computers, personal computing and the internet

4.0 Now - Based on cyber-physical systems - Brought 3D printing, big data

Sources: Global Agenda Council on the Future of Manufacturing, Whitershield Partners framing

Source WEF via @mikequipdazzi
2022 Skills Outlook

Growing

1. Analytical thinking and innovation
2. Active learning and learning strategies
3. Creativity, originality and initiative
4. Technology design and programming
5. Critical thinking and analysis
6. Complex problem-solving
7. Leadership and social influence
8. Emotional intelligence
9. Reasoning, problem-solving and ideation
10. Systems analysis and evaluation

Declining

1. Manual dexterity, endurance and precision
2. Memory, verbal, auditory and spatial abilities
3. Management of financial, material resources
4. Technology installation and maintenance
5. Reading, writing, math and active listening
6. Management of personnel
7. Quality control and safety awareness
8. Coordination and time management
9. Visual, auditory and speech abilities
10. Technology use, monitoring and control
21st-Century Skills

Foundational Literacies
How students apply core skills to everyday tasks
1. Literacy
2. Numeracy
3. Scientific literacy
4. ICT literacy
5. Financial literacy
6. Cultural and civic literacy

Competencies
How students approach complex challenges
7. Critical thinking/problem-solving
8. Creativity
9. Communication
10. Collaboration

Character Qualities
How students approach their changing environment
11. Curiosity
12. Initiative
13. Persistence/grit
14. Adaptability
15. Leadership
16. Social and cultural awareness

Lifelong Learning

How to develop the required 21\textsuperscript{st} century skills, especially complex problem solving and deep learning in a typical classroom?
The Active Learning Continuum

1. Make the lecture active
2. Informal Group Activities
3. Structured Team Activities
4. Problems Drive the Course

Instructor Centered
Active Learning

Collaborative Learning
Cooperative Learning
Problem-Based Learning

Student Centered

From Prince, 2011
The Psychology behind using PROBLEMS...

Multi-dimensional and integrative

Leads to immersion and engagement

catalyst for inquiry, learning and problem solving

Mimic real world demands

Activates prior knowledge as a base to acquire new knowledge
Commonly used Teaching and Learning (T&L) Model

- Topic(s)
- Told what to learn
- Learn
- Give exercises for illustration

Deductive T&L

Problem-Based Learning Model

- Problem
- Identify what to learn
- Learn
- Apply

Inductive T&L

Powerful for engaging learning & developing self-directed learning
Problem-Based Learning Approach

Realistic Problem

LO: Content Attitude Skills

Lecturer as Designer & Coach
Facilitation skills required to make thinking visible. Proper assessment made on both content and process. Need TRAINING!

Student as Problem Solver
Do not readily have the skills for PBL – must be prepared and motivated by lecturers
Problem Solving Topology  

**Problem Solving**
- Process to obtain best answer to an unknown, subject to constraints
- Ill defined
- Novel
- No explicit statement
- More than one approach
- Algorithm to solve unclear
- Integration of knowledge
- Strong skills of presenting results

**Exercise Solving**
- Process to obtain the one and only answer
- Well defined
- Encounter similar problem before
- Explicit, hints given
- Usually one approach to one answer
- Recall familiar solutions – usual method
- Subject by subject
- Presentation skills not required

(What's the Difference?)

(Syed Helmi, 2011)
Dear candidates,

The selection committee of Polystyrene (M) Sdn. Bhd. is very interested in interviewing your team for the opportunity to undergo industrial training at our company. The interview session is scheduled on 28\textsuperscript{th} December 2009, from 10 a.m. to 12 noon, in the meeting room, Human Resource Department, Polystyrene (M) Sdn. Bhd.

With regards to the interview session, we would like you to demonstrate your understanding on one of our processing plants, the HDA Process, in a 3-5 page report. Please systematically describe the process from a system’s point of view. Be sure to include the input and output variables involved in the process. Explain all the automatic control systems: classify the variables, identify the control objective, and identify the control configuration used for each control loop. Please comment if the control configurations used are sufficient to tackle the disturbances. Enclosed are the process description and a simplified P&ID of the HDA Process for your reference.
DRAWING OWNED BY: PSM
PROJECT/PROCESS: Hydrodealkylation of Toluene to Benzene (HDA Process)
PIPING & INSTRUMENTATION DIAGRAM (P&ID): HDA Process (SECTION 01: REACTOR & FLASH VESSEL)

Figure 1: HDA Process
Problem-Based Approach

Realistic Problem

Lecturer as Designer & Coach / Facilitator

Student as Problem Solver
Scaffolding to support student learning

Zone of Proximal Development (ZPD) = Distance between individual performance and performance with social support (Vygotsky)
Can you get to the red door?
Scaffolding to reach the ILO

Intended Learning Outcomes (ILO)

Teaching and Learning Activities

Assessment Tasks
The PBL Process

- **Meet the problem**
- **Self-directed learning**
- **Peer teaching, synthesis & application**
- **Presentation & reflection**
- **Closure**

Typical PBL Medical School Model
Cooperative Learning Implementation: Performance Level of a Group (from K. Smith, 2007)

Cooperative Learning Principles:
- Positive interdependence
- Individual accountability
- Face to face interaction
- Appropriate interpersonal skills
- Regular group function assessment

Performance Level:
- Pseudo-group
- Traditional Group
- Cooperative Group
- High-performing Cooperative Group

Type of Group:
- Individual Members
- Pseudo-group
- Traditional Group
- Cooperative Group
- High-performing Cooperative Group
Pattern in Cooperative Learning Activities

- Individual construction
- Interaction with neighbor/team member
- Overall class interaction with instructor

Involves everyone in the class!
Cooperative Problem-based Learning (CPBL)

Phase 1
- Overall class problem identification & analysis
- Individual meet the problem, restatement & identification
- Team discussion & consensus in problem restatement & identification

Self-directed learning

Phase 2
- Individual notes, Peer teaching in team & overall class discussion
- Team synthesis & application for solutions formulation

Phase 3
- Team consensus on final solution generation
- Presentation, reflection & team feedback
- Closure

Cooperative Problem-Based Learning (CPBL) Model

* Insufficient understanding of learning issues to solve problem
** Incomplete or misunderstanding of problem requirements

Mohd-Yusof, et al 2011
Click the url link to watch the CPBL video

https://www.youtube.com/watch?v=XYBxa_YnCIi
Scaffolding in organization of problems for a whole semester in a course

STUDENTS as “Novice Problem Solvers”

1st Part of Problem

2nd Part of Problem

3rd Part of Problem

STUDENTS approaching “Expert Problem Solvers”

4th Part of Problem

Professional achievements

Complexity of engineering processes

Expectation

CPBL Problems
EXAMPLE OF PROCESS CONTROL & DYNAMICS COURSE

FINAL CASE STUDY

Design of Automatic Control System for CCM Chemicals (M) Sdn Bhd

The Scenario
Now that you have experience as a process engineer, you have decided to join a process control consultancy firm, PARAGON Consulting Sdn. Bhd. You are hired because of your knowledge in chemical engineering, experience as a process engineer, and credentials. Since many of the firm’s engineers are electrical and mechanical engineers, your job scope includes: i) provide expertise to other engineers to understand, describe, and analyze chemical processes, and ii) design automatic control systems for chemical processes.

One Tuesday morning, you received the following email from the general manager:

To: Design Team <design.team@paragon.my>
From: Abu Bakar Iman (abi@paragon.my)
Date: 25/03/2011 11:00AM
Subject: Design of automatic control system for CCM Chemicals

Good day engineers,

I had a meeting with CCM Chemicals’ plant manager last week. They are now having problems with the existing control systems of their chlorine gas absorption processes. To be specific, they are facing difficulty to maintain the process variables at the desired operating conditions. Plus, they are experiencing inconsistencies in the online measurement of the product specs too. There are two chlorine gas absorption columns operating, as part of Chloralkali Process for chlorine production, in the company. At the moment, CCM Chemicals is urgently looking for a prospective consultancy firm to solve these problems. Due to our excellent track record in the previous consultancy projects, they’ve invited us to bid for this project. Therefore, I want your team to do some research MODIFY THE
Integrating several courses with 1 problem
Coping with change – need to explain and rationalize => MOTIVATE!!

Need to support students to overcome frustrations

Woods, 1994
## Developing PS Skills

<table>
<thead>
<tr>
<th>Reflective Journal 1 (S3)</th>
<th>It is a big pressure for me to handle as it is not a thing that I really familiar with. We have to face the first stage of this PBL that involved a lot of group discussion, completing the report and presentation.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflective Journal 2 (S3)</td>
<td>I have to do a lot of research in order to get ideas on how to conserve energy in school. This is very stressful moment for me as the number of tasks to be completed was increased.</td>
</tr>
<tr>
<td>Reflective Journal 3 (S3)</td>
<td>Honestly, I am very happy with the report as each of us gives full commitment to complete it. All these work are not easy as abc as each of us need to brainstorm like a half dead person to come out with a good report. However, it taught me to be patient and don’t give up even though the challenges are big.</td>
</tr>
</tbody>
</table>
Cooperative Problem-based Learning (CPBL)

Syed Ahmad Helmi et al. (2013) found that CPBL enhances students’ motivation and learning strategies, problem solving abilities, and team working skills.
Part of FGD report on students who had undergone CPBL (Strobel, 2008)

Theme: Relationship between PBL class and industry experience

Students mentioned that they were not “afraid” or “unprepared” to get into their industry experience, since they counted their PBL class as a precursor or “small industry experience”. When pressed to compare the two, students acknowledged that the PBL class was small scale authentic compared to the industry experience.

Two students shared more details: They described how in both, the PBL class and in the industry setting, they had to perform a similar task. While in the PBL class the volume was a couple of pages, in industry the amount of material was several large manuals. The industry experience needed them to scale their experience up.
## What’s the difference?

<table>
<thead>
<tr>
<th>Problem-based</th>
<th>Project-based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acquisition of knowledge - Content/learning issues not taught/revealed (inductive)</td>
<td>Application of knowledge - Content already revealed (deductive)</td>
</tr>
<tr>
<td>Learning issues in problem well defined in the problem</td>
<td>No specific learning issues – depends on students</td>
</tr>
<tr>
<td>Starts with a problem</td>
<td>Some yes, some no</td>
</tr>
<tr>
<td>Process based</td>
<td>Task based, product based</td>
</tr>
<tr>
<td>Systematic facilitation throughout PBL process</td>
<td>Variety of approaches</td>
</tr>
<tr>
<td>Closure and process reflection</td>
<td>Some yes, some no</td>
</tr>
</tbody>
</table>
Does it really matter if it’s problem based or project based if real world problems are used?

What is more important is the learning that happens in the implementation
21st-Century Skills

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Lifelong Learning

Gradual move in SCL techniques ...

If unfamiliar with student-centered learning techniques, start gradually

Need to go for training & embrace lifelong learning!
Thank you

khairiyah@utm.my
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