Strategies for Constructing Problem-Based Learning Curriculum in Engineering Education

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Abstract — *The new era of knowledge -based economy coincides with the age of globalization defines the human factor as the main differential elem ent in entrepreneurial competitiveness; this is why it is so important for the educational system to fulfill the requirements of workplace. It means that the curriculum in engineering education ought to be flexible and the instructors must care for it. T o response the requirements of new age, the quality engineering education which is making entrepreneurial engineers who will be prepared for innovations, increase production processes understanding with management vision, is the only way of developing the top industry and satisfies the post -industrial society needs. Most recently, the decentralization of decision and production process, as well as the new ways of production such as modular industry, outsourcing and global mobility had call for the new comp etence in engineering education. Therefore, it is important to cultivate the student 's diversified abilities, for instance the ability to solve problems, ability to use theory in practice, team working, self -evaluation, strategic thinking and realization of complex project through innovated teaching and learning method s.*

The Problem -Based Learning (PBL) refers to an instruction method in which the teacher builds his instruction around a practical problem and encourages pupils to discuss the problem in smal l groups, with an aim to cultivate active learning, critical thinking, and problem -solving skills among them. Evidences shown that PBL is an effective tool to foster students develop ing the critical and creative thinking skills as well as enhance their innovation capabilities through the process of problem solving. This article addresses some strategies to show how to construct the PBL teaching curriculum in engineering education efficiently. These strategies were made in two aspects . First of all, the process of d esign a PB L curriculum can be divided into six steps , namely, understand ing curricular outlines, structuring modular curricul ar, designing a comparative table of modular curriculum levels, select ing an appropriate themes or unit titles, transfo rming a scene , determining learning goals . Second ary, make a checklist for assessing curriculum design, and use the curriculum structure, modular curriculum, curriculum level, available resources, content of scenes that are transformed from units, problem statement for specific goals, and motivation as the benchmarks for assessment .

Index Terms — *Curriculum Design , Engineering Education, Problem -Based Learning*

INTRODUCTION

In a knowledge-based economic era, knowledge is advancing at a rapid pace, and innovation, speed and flexibility are much emphasized. In such a time, the mindset of knowledge worker needs to be changed and knowledge needs to be reused. From an educational perspective, what one learns at school is no longer enough. In the future, the ability of self-study is essential or one may be obsolete by the society [1]. Therefore, it is important that a student's diversified abilities are cultivated through innovated teaching and learning methods [2]. The constructivist spirit of thematic instruction, which comprises project-based learning and problem-based learning, can be better materialized through cooperative learning [3].

Problem-Based Learning (PBL) is to cultivate students' ability to learn actively, to think critically and to solve problems through an instruction process that focuses on actual problems and encourages students to have group discussion [4]. In other words, PBL is an effective tool to help cultivate a student's critical and creative thinking abilities and hence enhance his or her innovation ability [5]. As outlined above, the cultivation of self-study ability and innovation ability is so important that the design and development of curricula and teaching materials can no longer just take core knowledge, the assimilation and application of knowledge, and knowledge innovation into account. The elements relating to learning attitude, learning methods, interest, habits, human relationship and personality should also be taken into account. PBL helps students to learn cooperatively in a group form, assimilating and applying knowledge through discussion, deduction and induction. It also encourages students to solve problems through creative and innovative abilities [6]. Therefore, PBL is a learning method that meets the needs in a knowledge-based economic era. This is also why the article aims at to discuss the different aspects of designing PBL curricula and proposing responsive strategies.

STRATEGIES FOR CONSTRUCTING PBL CURRICULAR

The two most important features of PBL are to cultivate students' active learning ability and to help them identify problems through brainstorming. Hence the curricula must be designed so that it can help students to learn actively if a PBL process is to be carried out smoothly. This paper addresses some strategies to show how to construct the PBL teaching curriculum efficiently. These strategies were made in two aspects. First of all, the process of design a PBL curriculum can be divided into six steps, namely, understand curricular outlines, make the structural map of modular curriculum, make the comparative concept map of modular curriculum levels, select appropriate unit titles, transform units into scenes, generate content of each scene. Then, authors also developed a checklist as a tool to evaluate the results of curriculum design.

Understanding Curricular Outlines

Each subject has its own uniqueness and can be divided into different scopes and levels of difficulty, so teachers must fully understood its curricular outline and students' background before designing any curriculum. To find out which chapters

and contents under the outline are more suitable for PBL learning is very importance in this step. Considering either using these chapters and contents separately or organizing them into a single theme. Meetings of instructing and researching or boards of school-based curriculum design also suggested and selected these suitable contents according to different learning fields or different disciplines that can be integrated together.

Structuring Modular Curricular

Next, adopting concept map technique to establish modular curricula based on the size of subject-specific or cross-discipline chapters and contents. Then, a structural table of also established according to the structure of curricular. There is an example of 'Introduction of Computers' shown in Figure 1. Table 1 is a structural table for 'laser printer' in details that was extended from one of the unit in the concept map of modular curricular.

Designing a Comparative Table

Then, a comparative table was designed based on different levels of abilities. Here, 'laser printer' was selected as a example. For the same theme, different levels of contents should be decided to suit the needs of students of each level. For example, first level is suitable for elementary schools and junior high schools; second level is suitable for general and vocational senior high schools; third level is suitable for electronics and information department of vocational senior high schools and general department of universities and colleges; fourth level is suitable for information-related departments of universities and colleges. The learning level also divided into must learn, should learn and nice to learn according to students' achievement level. See Table 2.

Selecting an Appropriate Theme or Unit Name

How to select themes or unit names for the problem is a critical issue. According to the nature of PBL, they are usually encountered in daily life or in work place in order to arouse students' interest and encourage their brainstorming. Students can extend more complex problems on their own and then find out their learning goals through induction and deduction too. Table 3 is a printer example of suitable unit names for PBL learning. Guidences for selecting a suitable themes or unit names are following.

1. Themes (unit names) must be clear and precise.

2. PBL is student-centered, so the themes (unit names) must be able to guide students to think and are attractive to them in order students are willing to learn actively and make learning goals on their own.

3. Unstructured themes are themes that can help students to practice divergent thinking. These themes must be able to generate 10 ideas in brainstorming.

4. Units that are sensational, urgent, dangerous or task-related in nature.

Social issues: domestic violence, school violence, how students can relieve their schoolwork pressure, how to handle

depression, suicide behaviour, jailbreak, juvenile sub-culture, etc.

Problems in daily life: What can I do if I have a flat tire, if the chain on my bicycle is loosened, if the car engine starts to overheat, if the printer has a paper jam, if blurry pictures come out from the printer or else.

Curricular issues: Environment education, gender education, life education, information education, and so on.

Tasks: Plan how to showcase a successful project, how to establish a new club.

Transforming a Scene Based on a Specific Themes (or Unit Names)

It's better that each theme or unit has 3-5 scenes according to the scope it covers and students' needs. The scenes must be well organized to suit different levels of abilities. Chu, Lin and Chu had proposed an flow chart [6] to assist thinking about how to transform a theme or unit into learning scenes. For example, if there is unit that contains three scenes, the first scene can emphasizes core knowledge — by drawing the concept map and explainning it; the second scene should emphasizes the understanding and application of that unit — propose problems that students need to solve; and the third (last) scene emphasizes the expansion and extension of knowledge — propose development plans.

Determining Learning Goals for Each Scene

The most important and final step is to determing learning goals for each scene. Learning goals must be specific and include A, B, C, and D four elements to describe behavioral objectives, that is, Audience, Behavior, Condition and Degree[7].

A:'Who' executes this behaviour. This can be omitted if it's the students who execute the behaviour.

B: What is the 'actual behavior' that can achieve the goal?

C: 'Related conditions' that help achieve the behaviour.

D: How successful is the behaviour or what are the standards for a successful behaviour?

Besides, the content of each scene is divided into three parts based on students' level of ability which is including must learn (core knowledge), should learn, and nice to learn. It's better for board of curriculum development board to vote on which learning goals should be listed in the curriculum based on their importance, how they are needed and how difficult it is to accomplish them [8].

CHECHLIST FOR ASSESSING PBL CURRICULUM

Based on author' work of 'PBL Assessment Strategy' [9], we have established a checklist to evaluate the results of curriculum constructed. The criteria in the checklist to evaluate a PBL curriculum include: curricular structure, modular curriculum, different levels of curriculum, available resources, scene contents, problem statements for specific goals, and whether the design can arouse motivation of not. See Table 4.

CONCLUSION

Two decades ago, Combs, A.W. in his work of 'What the future demands of education' mentioned that: 'Tomorrow's citizens must be problem solvers, persons able to make good choices, to create solutions on the spot. Effective problem solving is learned by confronting events, defining problems, puzzling with them, experimenting, trying, searching for effective solutions' [10]. In the era of knowledge-based and information driven, how to encourage students to learn through curriculum design, flexible use of teaching materials and diversified instructions is more important issue than ever that deserves thinking in education settings nowaday.

Problem-based learning is an efficient way to acquire new knowledge and learn how to learn. It combines aspects from the learning styles approach and from cooperative learning. The features of PBL areteamwork learning, problem-solving and self-directive studying. By way of PBL, it shows students the importance of interdisciplinary knowledge for the understanding of problems and they have to organize their learning process in groups. It also supports the acquisition of social skills and the reflection and development of attitudes. This article have demonstrated a procedural process to show some strategies about how to construct and evaluate a PBL curriculum. By way of these strategies and the process, the authors had coustructed many curricular [2,6] successfully and effectively. It is recommended for the use of PBL curriculum construction especially in Engineering Education.

REFERENCES

[1] C. Lee. "Impact of New Economy on the Society." *United News, Taiwan* , April 4, 2000, 8th page.

[2] Tien Chen-Jung, Chu Shao-Tsu, Liu Tsung-Cheng. "Activity-Teaching Design of Problem Based Learning: According to an Example of University Mechanical Engineering Department." *Proceedings of 4th Asia -Pacific Conference on Problem -Based Learning* , 11-13 Dec. 2002. Hat Yai, Songkhla, Thailand.

[3] J. H. Wang. "The Development of Educational Technology—From the Perspective of Digital Learning." *Educational Research Monthly* , August 8, 2003. Taipei, Taiwan.

[4] C.S. Wu. "Definition of Educational Terms: Problem-based learning." *Educational Research Monthly* , August 2002. Taipei, Taiwan.

[5] J.C. Hong. "Knowledge Innovation and Learning Organization." 2001, Wu-Nan Book Inc., Taipei, Taiwan.

[6] Chu Shao-Tsu, Lin Yi-Ping, and Chu Yu-Wen. "Some Strategies for Making Problem-Based Learning Teaching Plans." *Proceedings of 2004 International Conference on Engineering Education and Researc h. Czech Re public, Ostrava, 2004.*

[7] Z.L. Kang. "Theories and Practice of Competency-Based Curriculum Development for Industrial and Vocational Education." Department of Industrial Education, National Taiwan Normal University. Taipei, Taiwan.

[8] C.C. Huang. "Instructional Assessment." 1996, Shita Book.Taipei, Taiwan.

[9] Tien, Chen-Jung, Chu, Shao-Tsu, and Liu, Tsung-Cheng. "A Problem-Based Learning Assessment Strategy." *Proceedings of 9th IACEE World Conference on Continuing Engineering Education* , 15-20 May 2004. Tokyo, Japan.

[10] Combs, A. W. "What the future demands of education." *Phi Delta Kappan,* 62(5), 369-372. 1981.

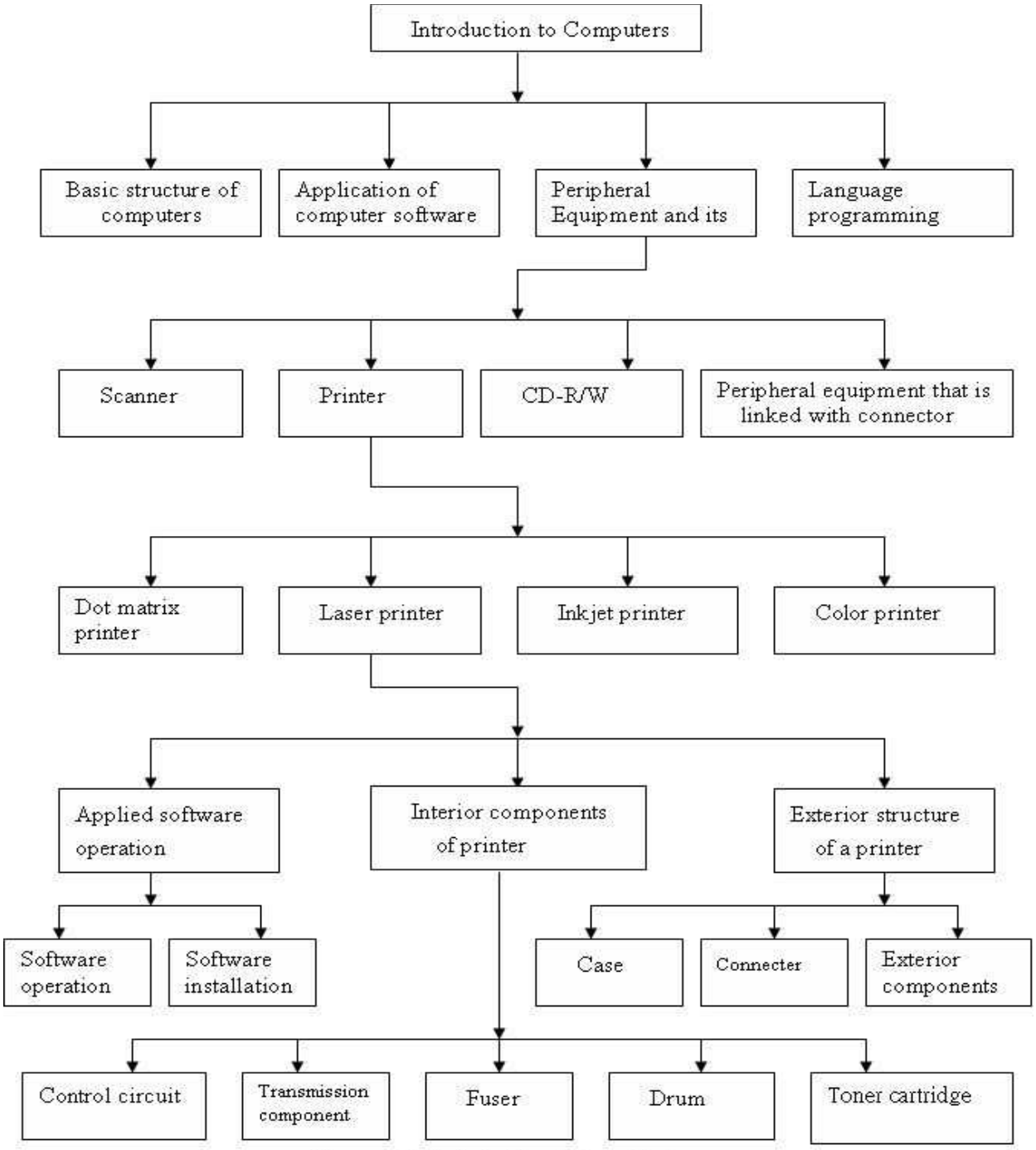

FIGURE 1

A STRUCTURE OF MODULAR CURRICULAR

	1st level	2nd level	3rd level	4th level
Laser Printer	Appearance (exterior structure)	Case	Molding assembly	Trip and screw
		Connector	Power and switch	Pin and shape
			Signal connector	
		Exterior kit	Paper feeder	
			Paper output	
			Chassis Set	
	Software operation	Software installation	Configuration and modification	Correction and adjustment
	Interior components	Control circuit	Power circuit	Laser control circuit
			Connection circuit	High voltage- transmitter circuit
			Panel circuit	Temperature-sensor Circuit
		Transmission kit	Feeder roller	Two-sided printing
			Output roller	
			Transmission roller	
		Fuser	Heat lamp	Temperature fuse
			Heat Roller	
		Drum	Pressure roller	Drum
		Toner cartridge	Magnetic brush set	Development kit
			Recycle set	

TABLE 1

A STRUCTURAL TABLE OF LASER PRINTER

Levels / Learning levels	1st level	2nd level	3rd level	4th level
must learn	Appearance	Case appearance Connector Exterior kit Software operation	Case appearance Connector Exterior kit Software operation Molding assembly Power and switch Signal connector Paper feeder/output Base Power circuit Connection circuit Software installation	Case appearance Connector Exterior kit Software operation Molding assembly Power and switch Signal connector Paper feeder/output Power circuit Connection circuit Software installation Configuration and modification Control circuit Transmission kit Temperature fuse
Should learn	Software operation	Software installation	Configuration and correction Control circuit Transmission kit Panel circuit Feeder drum Output roller	Panel circuit Feeder roller Output roller Transmission roller Heat lamp Heat roller Pressure roller Magnetic brush set Recycle set Temperature-sensor circuit
Nice to learn	Interior components & Software installation	Control circuit Transmission kit Molding assembly Power and switch Signal connector Paper feeder Paper output Base Power circuit Connection circuit Configuration and correction Control circuit Transmission kit	Drum Heat lamp Heater roller Pressure roller Magnetic brush set Recycle set Correction and adjustment Temperature fuse High voltage- transmitter circuit Temperature-sensor circuit Two-sided printing kit	Two-sided printing kit Correction and adjustment High voltage- transmitter circuit

TABLE 2

COMPARATIVE TABLE FOR DIFFERENT LEVELS OF ABILITIES

No.	Modular	Unit Names	Characteristics
1-1	Printer	1. Printer can not link to computer	1.Cosely related daily experience.
1-2		2. How to handle the paper jam in the printer	2.Ocuring frequently and are urgent.
1-3		3. What should we do blurry pictures come out from the printer	3.Ustructured themes. 4.Clear and precise.

TABLE 3

CHARACTERISTICS OF APPROPRIATE UNIT NAMES FOR PBL

No.	Checklist Items	Notes	Yes	No
1	Select contents suitable to PBL from curricular structure	1.take students' background into account		
		2.take cross-discipline contents into account		
2	Establish subject-specific or cross-discipline modular curriculum	1.Show curriculum design with tree diagram or concept map		
3	Make the structural table of modular curriculum	1.Extend the scope of knowledge		
		2.Extend the profundity of knowledge		
4	Design a comparative concept table based on different levels of abilities	1.find out the level in the comparative concept table that matches students' level		
		2.learning scope can be extended flexibly.		
5	Select a suitable theme or unit name for PBL learning	1.Problems that are usually encountered in daily life or in work place		
		2.Units that are sensational, urgent, dangerous or task-related in nature.		
		3.Unstructured themes (unit names)		
		4.Themes (unit names) can guide students to think and are attractive to them.		
6	Decide scene names based on specific themes (unit names)	1.Each unit has 3-5 scenes according to the scope that the unit covers and students' needs		
		2.The scenes must be well organized to suit different levels of abilities		
7	Decide learning goals for each scene	1.learning goal(s) of each scene must be written down in a specific way.		
		2.Contents that students must learn		
		3.Contents that students should learn		
		4.Contents that are nice to learn		
8	There should be a teacher-version and student-version of learning outline for each unit.	1.unit names and outline of teaching plan		
		2.scene name and learning goal(s) of each scene		
		3.situational drama of each scene		
		4.instruction guidance and reference		

TABLE 4

CHECKLIST FOR PBL CURRICULUM ASSESSMENT