Method of Problem Design and Problem Evaluation in Engineering PBL Education

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Abstract

At present, it is quite vital to make appreciate problems to apply to practical use for raising furthermore the effectiveness of engineering PBL teaching.

Especially, a practical methodology is being required by problem-makers to apply problem design theory to their teaching practice.

This paper refers to reviewing the preceding 3C3R problem design theory and its application method, and then presenting definition about PBL problem, the essence of problem design and general requirements arising in designing problems, and some steps of problem design in engineering teaching practice. In addition, we have offered an estimation model of a task amount of problem by means of relative level estimation value, and comprehensive quality estimation model of a problem and then illustrated its detailed applications to design and estimation of the problem.

Keywords: Problem; Problem Desigin; PBL; evaluation

1. Introduction

Problem-based learning (PBL) is a very effective teaching method that focuses on comprehensive and realistic problems and enhances students' ability to solve real-life problems [1, 2]. PBL was originally designed to increase students' ability to solve clinical problems in the field of medical education [3, 4].

The essence of PBL is a sort of teaching strategy to develop the ability of problem solution about practical problems in their real social activity where students may encounter significant and actual situations, the ability of critical thinking and self-study for acquiring any problem and analyzing its nature , joining and communicating skill through teamwork study and discussion. [5, 6]

Critical element in implementing PBL to actual teaching is problem that is just applied to it[7, 23, 24].

A carefully organized and designed problem makes it possible to realize teaching purpose of PBL to raise real problem solving skill of students, and whole all PBL teaching course is progressed on the basis of problem. Quality of problem is a vital and indispensible factor in optimizing PBL teaching and defining its effectiveness.[8]

All learning with PBL starts with understanding problems, and because problem solving steps and solving strategy, an environmental information of problem, context, boundary condition, etc. are determined on the basis of problem, so it constructs a learning environment.[9]

As problems are made on the basis of teaching content, students can acquire knowledge involving with problem while solving it and at the same time can enhance thinking competencies such as

understanding, analyzing, and judgment. Furthermore, students might have a strong intelligent curiosity and desire to challenge the world, which may serve as an important opportunity to stimulate learning motivation. Addtionally, meanwhile understanding the problem students have strong needs and stimulation to study it when realizing their poor knowledge. Especially the practical problems which are associated with professional fields give students a vivid expression about real-world involved in the problem and concrete utilizable meaning of professional knowledge. [10]

Making a problem is indispensible matter which constitutes an underlying of PBL course design for teachers. Thus, the effectiveness of PBL teaching entirely relies upon how we construct problem and how well we apply it. Problem making called 'problem design' is known to be a very complicated and difficult task. [11-12] In particular an effective and optimal problem design method is a great challenge for inexperienced teachers. This has been required systematic methodology and deep research in detail, but PBL researchers failed to pay attention to it and its study began a little later due to high difficulty of research[13,7]

In the past the important success in problem design was 3C3R problem design model and 9 step problem design process which played an important role in providing theoretical foundation of problem design and making problem design systematically and scientifically.

3C3R problem design model [14] is framework of problem design by which key elements of PBL problems and their main functions are given, which play important role as guide when teachers design efficient PBL problems acording to different professional discipline and for students with divers level. And it gave a great contribution to complehend the domain knowledge base and enhance students' problem solving skill and reasoning ability in that process and at same times professional major aptitude and cultural aptitude.

3C3R model largely consists of core components and processing components. The core component contains content, context, and connection, which mainly assure knowledge content, its relationship, and appropriateness and sufficiency of knowledge integration.

On the other hand, the processing components are composed of Researching, Reasoning, Reflecting which are related with learning process and problem solving skills of students and according to their cognitive abilities have a role of adjusting student working load and controlling problem so as not to deviate from learning goal.

The 9-step problem design process [14] is a step-by-step process specifically for designing PBL problems using the 3C3R model, which enables students to raise knowledge acquisition, self-study ability and problem solving skills. In this design process, the first three steps (Step 1: Set goals and objectives, Step 2: Conduct content/task analysis, Step 3: Analyze context specification) are a front-end analysis of the PBL module. Step 4(select/generate PBL problem) and Step 5(conduct PBL problem affordance analysis) are the analysis of the selected PBL problem. Step 6 (conduct correspondence analysis) and Step 7(conduct calibration processes) are the analyses of affordance and adjustment of the PBL problem. Step 8(construct reflection component) describes the design of the reflecting component. Finally, step 9(examine inter-supporting relationships of 3C3R components) examines the integrity of the 3C3R components of the problem.

Through the above problem design process to attain learning goal following a reasonable amount of information to be involved in the problem should be defined.

As 3C3R model and 9-step design process is aimed at providing a general framework to design for problem designers to design effective problems, so their application manners have some differences. In general, problem differs from each other, and a variety of problems are needed according to teaching

objective and learner levels. [15]

In particular, it is necessary to take detailed methodology to introduce 3C3R model for PBL problem construction in enginering subject. The preceding problem design theory proposed comprehensive and profound consideration about problem design, but as application situation of design factors were abstract and complicated, their practical adoption is still comparatively difficult. Especially, as for teachers this is considered to be a large and challengeable burden.[7,9]

Meanwhile, special property of problem itself is much dominant and even the same problem has different purpose and application, thus problem design method being different. Therefore, it is very essential to continue to create rational problem design method of greatly appropriate, more practical use.

In addition, analysis of essence and meaning of the problem, a set of reasonable steps of problem design and construction of quantitative estimation model falls into an important research category in problem design.

This paper is referred to solving some problem design methodology arising in applying it to detailed engineering teaching practice. The paper suggests to outline essence and characteristics of PBL problems, and estimation standard and its method on useful problem design chart of containing detailed step contents, and qualitative level of given problem.

2. Method

2.1 PBL problem

Definition of Problem

A problem implies very comprehensive meaning and its definition also varies according to its application area. It can be said that PBL problem, which is used in PBL teaching, is the whole of information on a certain background knowledge, object, and item. From the educational point of view, it is a demand of an intelligent activity for students in order to attain teaching purpose based on curriculum.

In general, object, aspect, item to be solved through problem solving are called problem points (required item), which is, in other words, a set of problem points for attaining teaching purpose. From the linguistic point of view, a probem is a combination of sentences where a series of problem points are contextually connected with a certain theme.

Problem Space

A problem space is multi-dimensional space which is composed of problem condition parameter space needed for problem solution and solution space resulted from process. Here problem condition parameter set and solution set are not invariable but are interchangeable according to problem composition. For example, in the case of a problem being made up of subtasks linked with chains, the solution set of the first problem might be the condition set of the followed problem.

Solving a problem stands for finding up solution space of meeting a certain requirement, which means that problem space is considered to be thinking space where such a process is made. [16,7]In problem space, path to solution space from problem condition is called solution path[17]or solution algorithm, whose path may be different based on property of problem and thinking manner of student. For example, even the same mathematic problem (for exaplem integral problem) may be different in solving method, whereas each solution method will be solution path. Moreover, according to problem, there might exist one more varied solution as befit with problem. Especially, in the case of finding a rational proposal like an optimal plan problem, the solution may be more than one. In most cases, the

range of problem space is usually an adjusting factor to regulate amount of information and difficulty of problem.[7,10]

PBL problem type is divided into simple problem and complex problem as required by problem solution requirement, and open problem and closed problem according to difficulty. Here, complex problem[11]is the problem of having one more sub-problems in the problem but a closed problem is the one which is well-structured and whose solving condition, background information, solving demand are all clear and are easy to solve. And open problem is called ill-structured problem, whose initial condition and solution path are found in hidden state, and is a high class problem where different solution may be found for each solver. [18,16]

2.2 Features of Engineering PBL Problem

It can be said that the nature of engineering PBL depends on the nature of engineering, the main area where the problem is applied.

The first feature of modern engineering is that it is not a single discipline dealing with technical problems, but a comprehensive multi-discipline covering the socio-economic domain. Whatever it may be, modern engineering problems are closely related to social development and human life, as well as economic problems, and their coverage has been enlarged daily.

The feature then has some distinction from basic science or medicine in view point of researching objective. Their subject of research are the non-organisms and the development, production and operation of products necessary for human life, and is distinguished from the pure science that deals with natural phenomena themselves, and the medical science which are objects of human organisms.

Next, in view point of researching mode. Engineering is a practical science that deals with more realistic problems with accompany of thinking activities. Unlike the theory-oriented past, modern engineering has set the main objective of solving practical problems and cultivating practical abilities, definitely turned into a practice-oriented discipline, and theoretical research and practical activities are carried out almost simultaneously. In this context, engineering approaches are also turning to new ways of practicing while learning and learning while practicing.

The nature of engineering also consists of problems with fixed items relatively, namely Conceive-Design-Implement-Operation. These four items, called CDIO, are the most universal and common thematic items that are going through the whole engineering, regardless of the specific subject of the engineering research.and CDIO teaching mode is the most typical in engineering

Engineering also attaches importance to synthesis rather than analysis in terms of way of thinking, and to application and creation rather than understanding. In pure science like mathematics and physics, the analysis of the causes of the phenomena is the main focus of thinking activity. However, in engineering, there are many brain activities, such as synthesis, conception, and thought activities, to how the principles or phenomena already identified apply to the realization of new goals or requirements.

These important features of engineering are important rational for designing engineering PBL problems. Hence, we can list some features of the engineering PBL problem as follows:

First of all, an engineering PBL problem is based on a reality problem and reflects multidisciplinary, interdisciplinary, cross-disciplinary subjects. Generally, a problem used for teaching is mostly written artificially on the basis of the teaching content, but an engineering PBL problem must be thoroughly a reality one that arises in reality and reflects reality, considering the purpose of the problem, which means that its solving requires knowledge not only in the major field of study but also in the adjacent and boundary field. In addition, one of the purposes of making a problem is not just for knowledge

acquisition, simple skills or revision but for building ability as an engineer such as research ability and cooperation ability. In this regard, a PBL problem must be organised so as to cultivate abilities to reason and judge, analyse and synthesize, discuss and present, cooperate and communicate.

Another feature of an engineering PBL problem is that it is a problem of multiple solutions, which means it should be large-scale and its solution should be obtained through several efforts and can have several solutions. This shows an engineering PBL problem is a relatively large-scale research problem that is clearly distinguished from any simple problems solved in lecture time or a particular academic design problem with a single solution or already-known solution. PBL problem is big in difficulty and solution space and long in solution time which will often take from 24h to 3 months, even during the whole semester. [19]

Such features consititute an important factor to be considered in designing an engineering PBL problem.

2.3 Characteristics of Problem

Qualitative Characteristics for estimating problem in problem design and analysis step are difficulty and task amount.

2.3.1 Difficulty of Problem

In general, difficulty of PBL problem is defined as probability to get exact answer of problem. [20] WeiHung defined difficulty mainly by complexity and structureness.[7,13]Complexity is sub-divided into problem scope, difficulty of understanding, solution procedure complexity, relational complexity. Here, the problem scope is a comprising breadth of knowledge domain needed to solve problem, and the wider its coverage, the higher its difficulty. Difficulty of problem implies difficulty of understanding conception involved in problem. And it is evaluated by advancement of concept, abstraction, and difficulty of knowledge blank. Complexity of problem solution is evaluated by solution path length, total number of solving steps, and solving difficulty at each step. Quesada et al. called this parameter "Computational Complexity", and evaluated it by time needed for solution. [21] Relational Complexity is defined as number to process in parallel in solving, and the more number of relation is, the more difficult problem is.

Structureness of problem is parameter of estimating well-known degree of problem core(idea) content. It is evaluated by uncertainty of problem solution, number of solution strategy, number of interdiscipline necessary for solving problem, instability of variable and answer of problem solution, and number of solution path possible in solution space. Problem easy to solve is a well- organized problem, which has one unique solution path.[18,13,7]

2.3.2 Task load Amount of problem

It represents the time needed to find the solution of problem. The task load amount of problem determines not only difficulty of problem, but also varies with intelligent ability of solvers. Teachers should predict the task amount about intelligent effort before giving a problem. In principle, the task amount should be fit to student's ability and not too little or too much.

2.4 Problem design

2.4.1 Conception of problem design

Problem design is the first process to ensure the success of teaching and an important teaching design process.[7-8] In the process of problem design a teacher predicts questions which might be asked by students and confirms steps of solving problems and guidance direction in each step. problem design is the process of setting theme, configuration, and content of problem, and fixing them into a certain

sentence pattern. In other word, it is the process of finding key points students should solve in teaching process, organizing teaching content so as for students to perform knowledge acquisition and thinking activity combined with practical problem, and completing problem by repeating constant evaluation-correction. The important tasks to solve in problem design are as follows; definition of problem and steps of problem design, problem configuration element and problem structure, problem thinking skill to reflecting teaching contents and estimating quality of problem. Futhermore, additional quary that may be to arise among student through problem solving should design.and direct actities content in every step to predict.

2.4.2 Requirements of Problem Design

It is very difficult to develop a problem with high educational effectiveness.[19] Well-posed problem results from deep thought, and profound and all-round analysis on the given professional fields. General requirements of engineering problem design are as follows;

Firstly, it should be able to acquire subject theory knowledge and adjacent knowledge dealt in given subject teaching, and at same times to cultivate problem discovery ability and problem solving ability throgh problem solving

Secondly, the theme,context and linguistic expression of problem should be chosen carefully so as to arouse strong academic interest, intelligent desire and the sprit of emulation.[7,12,13]

Thirdly, the theme of problem should be taken as actual one with which students actually experienced, and which is concerned with future work and job.[22]

Fourthly, difficulty hierarchy of every subtask should be suitable for educational requirement, and problem solving process should be suffiient so as to exchange opportunity between teacher-students and student-student.

Fifthly, time required for solution should not exceed a given period of the curriculum and the coverage of problem should be reasonable.

Sixthly, linguistic expressions should be clear and they should be written with
regularized academic and technical terms.

When designing problem, teachers should foresee possible questions in their guidance. It follows that designing problem refers to design problem system which problem given to students and its relevant subproblems.

2.4.3 Problem Design Steps

Problem is completed through certain sequential steps. Problem design schema shows a total procedure to establish problem. Problem is basically through preparatory step, main problem construction step (main step), problem evaluation and completion step. (Fig. 1) and every step consist of several sub steps.

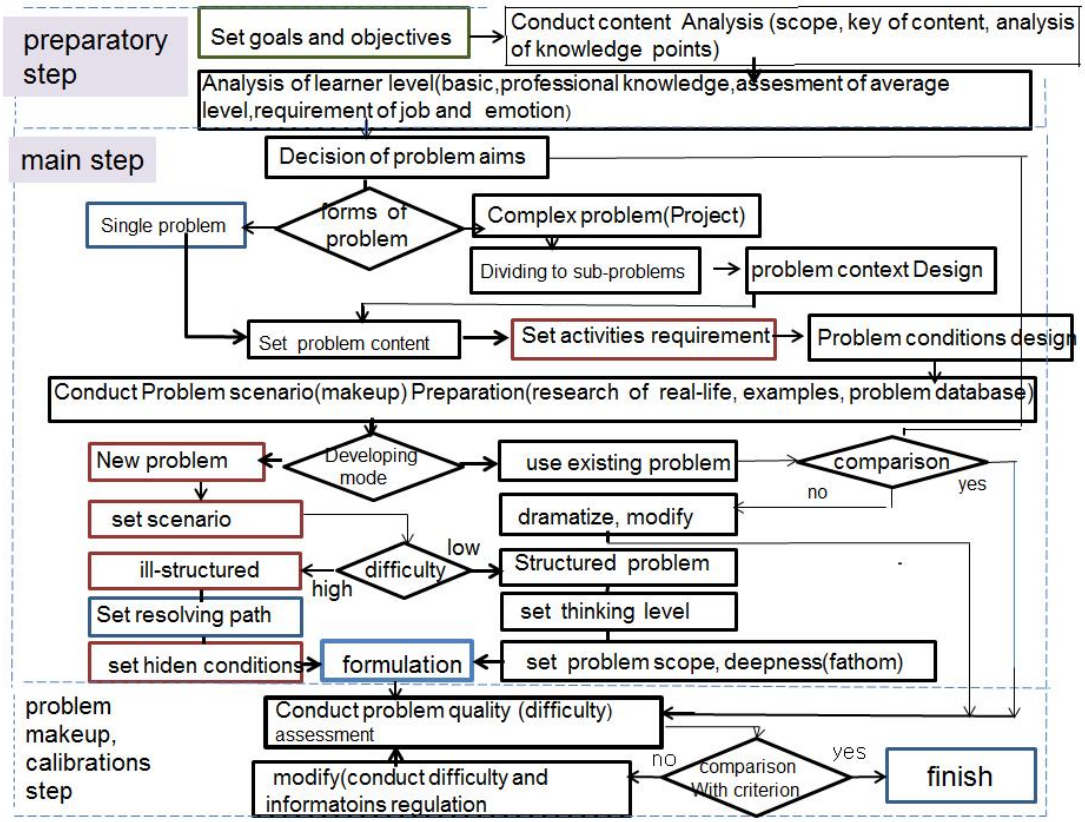

Fig. 1 Problem design schema

Preparatory step

This is the first step of problem design which stipulates general construction and drawing direction. This consists of three sub-steps; teaching purpose analysis, teaching content analysis, learner's property analysis.

In teaching purpose analysis step, curriculum and syllabus should be analyzed so as to coincide purpose and prerequisites of makeup problem. Especially what professional knowledge and capability training are needed in teaching should be comprehend

In teaching content analysis, we should define thesort of knowledge and property of teaching knowledge system extensively.

First of all, range of dealing with a given teaching contents confirmed, divided that into knowledge elements, is made in the form of knowledge structure. Next, its key point and difficulty, thinking point, basic knowledge and previous knowledge, a new content to be learned should be ensured. Each element in knowledge structure obtained above can be an elementary problem. For example, upper level elements of knowledge structure are to become general problem, and node elements detailed problem of general problems.

In learner property analysis step, teachers should understand

Students' knowledge standard, interest or hobby to a given subject, development prospect target of students, emotional requirement etc. This detailed analysis data plays an important role in determining the theme of problem, background information and style. All data obtained through an extensive and detailed survey about students are incorporated in the form of a list. In addition, based on this, the average property of students and average difficulty of problem to be written in the future are

determined preliminarily. Pre-Difficulty of problem is used as correspondingness standard of problem.

Main Step of Problem Making

This is detailed into problem form setting, problem structure(scenario) design, problem condition design, problem configuration design, and problem draft step.

Problem form determines scale of problem and coverage range, context, and decides overall style. Typical problem forms will be simple and combined form, positive and reverse form, event clarification form and free description form.

It can also be taken as makeup of actual product, and writing research report style, design report writing mode, analysis report mode, experiment report writing mode depending on results presentation and evaluation form.

The structure of problem is relationship of mutual connection and background information of problem solution space. In problem structure design, components of problem such as condition, environmental condition are defined and connection between their elements are established. And in combined problem, connection relation (sequential, parallel, hierarchical) between sub-problems are set. ［19］In setting connection relation, sequential transition should be ensured from base to application, from the ease to the difficulty.

What is important in problem design is that all elements of problem are associated with storyline (event). In this sense, problem structure is called context and shows evolution of problem. Context forms a sort of thinking space and problem solvers are well known to solve the same context problems with ease. Making a problem as an interesting story is important in raising study motivation and motivating interest and curiosity about problem solving. ［11,8］ It is important in problem design to approach problem to practice and ensure utility and scientific accuracy.

In the step of setting problem condition, initial condition, environment condition, requirement condition which are premise to solve problems should be set. Value range of each factor in problem elements should be determined considering value range of exact answers to be obtained finally. Also when presenting a requirement condition, level of students should be take into account. For instance, if too strict requirements were given to lower students, it would take long time to solve and some students might give up to carry out task.

In problem composition step, main frame of problem is made by incorporating all elements chosen to be suitable for purpose of problem drawing. In this step, scale and difficulty of problem are determined in line with the teaching purpose, researching activity to treat in problem, thinking activity type and level that problem requires, the storyline to introduce should be confirmed.

After making main frame, it should be determined to make a new problem or to use previous present problem. To study deeply the preceding problems is as important as to make new problem.

As all creation is achieved by inheritance and accumulation, a careful study of the preceding problems and an anatomical analysis are the prerequisites for creating a good problem. The advantages and shortcomings of the problems worked out by the preceding makers are studied in depth in combination with the development of the times, the good points should be sustained, the shortcomings and the backward aspects of the times should be well distinguished, and the well-written problems which are suited to the purpose of the work should be selected as candidate problems.

Not finding a proper problem, it is necessary to draw a new problem used in practice.

In this case, problems should be divided into low-level prolem (structure problem) and high-level problem (open problem). In the case of open problem, we should determine appropriate information to be intentionally hidden and increase its amount according to the difficulty level and diversify their

solution method (solution path). In addition, we can conclude some hints or clues that can lead to such hidden information.

In the case of low-level problem, we prepare nessary thinking activity level (memory, understanding, analysis, judgement), coverage of problem and its depth as well as detailed examples.

The next step of problem design is problem formalization, where by combining problem elements problem is produced in a certain sentence form. Here it should be clear in expression and obvious in requirement.

Problem Evaluation and Completion Step

In problem evaluation step, first property of problem, (scope, number of problem solving, cross discipline knowledge, solving possibility, problem size) is determined and then based on these items, the total difficulty of problem and amount of task are calculated.

In problem completion step, we should correct and add problem depending on evaluation results. For example, if difficulty and task quantity exceed its limit, some information should be exposed or task coverage should be decreased. After such a repetitive correction and supplement, all problems must be subjected to objective examination, strict inspection and discussion

2.4.4 Estimation Model of Problem

As a highly abstracted product, a problem has an unknown qualitative level in shape, so it is only estimated through teaching effectiveness of applied lecture. But it is possible to predict its qualitative level from the properties and specification of components before its application to the teaching. In addition, the estimating process of problem becomes just the analyzing process of problem. In order to account the qualitative level of a problem in quantity and quality, the estimation model of problem is used.

Estimation of Problem Difficulty

Estimation model of problem is in fact the estimation of problem Difficulty, Difficulty is the most important educational property and the starting point for evaluation of quantity of task. Though they are the same problems, difficulties appear to be different for each student. Thereby, we eliminate the unique properties of a solver and define the difficulty (conditional difficulty) representing the unique properties of only the problems.

In order to estimate the conditional difficulty, we made an estimate index system with the estimates based on difficulty estimate indices and levels using the difficulty factors available for the practical estimation in the components of structure and complexity. (Table 1)

Table 1. Estimating items of problem difficulty and level

№	Estimating Item	symbol	Estimatting criterion	Estimatting values (relative estimatting values), W(Zi)			Weight value
				1	2	3	
1	Heterogeneity of Analysis	Z_1	Number of Problem Solving method	1	2	More than 2	0.15
2	Problem solver's cognitive abilit y level	Z_2	Type of cognition activities in problem solving	Remember, understanding	Cognition, judgment application	Analysis, synthesis, idea, assessment	0.15
3	Diversity of knowledge in problem solving	Z_3	Number of discipline and interdiscipline to be applied in problem solving	Discipline-1, Interdiscipline -1	Discipline-2, nterdiscipline -1	Discipline-2 than more, Interdiscipline-2 than more	0.1
4	Skill(artificial) level in problem solving	Z_4	Type of problem solving method	Simple substitution.	Case reference	Creation	0.1
5	Perfection of problem conditions	Z_5	Number of hiden conditions	1~2	3~4	Than more 4	0.15
6	Scope of knowledge	Z_6	Breath of knowledge involved problem solving	Professional subject 1 chapter (section)	Professional subject2 chapter (section) than more	Professional subject overall+ professional basis	0.15
7	Deepness of problem	Z_7	Understanding difficulty for Concept, principal of problem	Fact data(example)	Concrete concept	Abstractive concept (principle)	0.1
8	Type of problem	Z_8					0.05

			Chracter of problem solving	Calculation of expression (imitative design)	Simulazation (partial simulation)	Overall simulation	
9	Difficulty of information gathering	Z_9	Type of information Resource necessary to problem solving	Native language textbook, References	Foreign language textbook, References	SCI journal, nonregulurity data	0.05

Based on the assumption that the difficulty components have the relative independence, the final estimate model of problem difficulty can be presented as follows:

$$d_k = k_s \sum_{i=1}^{9} \mu_i W(Zi)$$

where

Zi -ith relative estimation value of difficulty

k_s -subject influence factor

μ_i -weight value of ith estimating item

Table 2. Subject Influence Factor

Sort of displind	Elementary mathematics	Physics, engineering	Applied mathematics	Simulation by programming	Modern mathematics
k_s	0.1	0.15	0.2	0.25	0.3

Estimation of task load amount of the problem

Task Load amount and **difficulty** are closely related with each other but they are not the same in their meanings. Task load amount is related to the private property of problem solver and is presented by time in unit. But PBL problem difficulty represents the problem-property and it is unitless.

Task load amount is estimated in the different ways for the types of problems. In the case of a single problem, it can be done by the experimental method and according to the indirect quantity, or as the sum of the duration of processing the task. In the experimental method, some students of middle grades are given the task to solve by themselves and the average time value is recorded. As for the way of indirect quantity, a certain estimate standard is defined to account the difficulty of the given task and the resultant value is converted into the time value of the model difficulty as follows:

$$TQ_k^s = \frac{1}{P_k} Ts\left(\frac{d_k}{d_s}\right)$$

where

TQ_k^s -single task load amount (solving time) given to kth student (kth group or problem)

P_k -relative ability factor of kth student(group)

T_s – standard time of solving problem in the standard difficulty

d_k – overall difficulty for the kth problem

d_s – difficulty of standard problem used in the measuring the time converting coefficient in the given subject

Here, it is important to clarify the solving time of the standard problem and the standard problems with the equal estimation criteria which are made of different types are given to the students and their solution times are estimated, and also a regressive model based on the difficulty according to the various types can be used for estimation. In the summation method, the solving process can be classified to some stages: task cognition and data research for the solution, solution process, and it is estimated by summation of the wasting times for each stage. Also, student potential factor and average group ability factor are obtained by synthesizing weighted averages of the teacher's assessment and the students' assessment.

The task **load amount** of complex problem made of n subtasks is expressed as summation of each subtask quantity as follows:

$$TQ_k^c = \sum_{i=1}^{m} TQ_i^s$$

2.5 Examples of Problem Analysis and Evaluation

Example of Problem

As an example, we have the problems in Chapter 2 "Semiconductor Laser rangefinder" in the "Laser Application Technology" subject. This subject is aimed to give a comprehensive understanding for practical designing of semiconductor laser distance meter and to improve the practical ability.

General problem

An optical technology development company is going to develop a new semiconductor rangefinder (distance meter) for geographical measurement. The main purpose is to optimize the mass and volume, to enlarge the measurable distance to 20% and to improve the measurement accuracy by 35%. Supposing that you are a member of this team, make a researching plan for development and create a technical handbook and an academic essay. The measurement distance of present rangefinder is 8km, measurement density 3m and its weight 1.7kg.

Subtask

①Configuration solution and system design of semiconductor laser range finder.

②Optical system of transmission and design of transmitter of Semiconductor laser range finde

③Optical system of reception and design of receptor of semiconductor laser range finder

④Signal processor and power unit design

⑤Device layout and element configuration placement design

Among these items, let's have a look at the first subtask.

Main problem given to the student.

These problems are not given to the students but they are prepared for only the teacher.

- newly presented design requirements (which must be met by a laser range finder for geographical measurement)
- study on the dynamic behavior of the semiconductor laser and modeling
- technical means to improve measuring accuracy when enlarging the measurement range from the point of system configuration
- configuration method of optical system of the semiconductor laser (transmission and receptive optics)
- configuration principle of power unit circuit configuration in the way of programing control method
- weak signal processing technique (interpolation, codeband sampling method, statistical weight averaging method)
- layout and element placement mode design way to reduce the weight and volume

Difficulty Estimation and task load mount analysis

Table 3. Analysis of the problem quality for subtask 1

No.	Estimating Item	symbol	Estimating values W(Zi)	verification
1	Heterogeneity of Analysis	Z_1	3	Analysis method to be applied, systematic method, individual, sequential solving method, method to compare with prior data, experiential method
2	Problem solver's cognitive ability level	Z_2	3	Main thinking type: conception, idea,comparition, analysis, synthesis, application
3	Diversity of knowledge in problem solving	Z_3	2	Interdiscipline:optoelectrics, electrical circuit, signal processing, theory of optical system
4	Skill level in problem solving	Z_4	2.5	Precedent experience, creation Based example(case)

5	Perfection of problem conditions	Z_5	2	Hiden condition-requirement of optical instrument for geological measurement, working conditions, transmitting and receipting element data
6	Scope of knowledge	Z_6	1	1 chapter of Professional subject
7	Deepness of problem	Z_7	3	Abstractive Concept, theoretical cognition
8	Type of problem	Z_8	3	Design problem with an new idea
9	Difficulty of information gathering	Z_9	2	native language textbook, foreign textbook, references
10	disciplinary Factor	k_s	0.15	Engineering, applied mathematics

According to these values, difficulty of an example task can be calculated as follows:

$$d_1 = 0.15\sum_{i=1}^{9}\mu_i W(Zi) = 0.15\times(3\times0.15+3\times0.15+2\times0.1+2.5\times0.1+2\times0.15+1\times0.15+3\times0.1+3\times0.05+2\times0.05)=2.35$$

The average knowledge level of the student $P_1 = 0.77$, max difficulty of a standard problem d_s =0.4725,, level of the student who solved a standard problem P_s =1, the average time of solution for a standard problem T_s =142min , in this case, a given task quantity can be calculated as follows:

$$TQ_1^s = \frac{1}{P_1}Ts\left(\frac{d_1}{d_s}\right) = \frac{1}{0.77}\times142\times\frac{0.4725}{0.3525} = 246.9\,\text{min}$$

Based on this method, task load amount for the other subtasks is given in table 4.

Finally, the overall quantity of the task consisted of 5 subtasks is presented as follows:

$$TQ^c = \sum_{i=1}^{5} TQ_i^s = 246.9+223.3+210.6+196.8+207.4=1085\text{min}$$

Table 4. task amount in subtasks

Task number	Task designation	symbol	Task load amount, min
2	Design of transmitting optical system and transmitting signal module in Laser diode rangefinder	TQ_2^s	223.3
3	Design of recepting optical system and recepting signal module in Laser diode rangefinder	TQ_3^s	210.6
4	Design of signal processing and power source module	TQ_4^s	196.8
5	Design of outlook constructon and element arrangement structure	TQ_5^s	207.4

3. Discussion and Conclusion

Through the analysis of the example of the problem, we can see that the first subtask is the most workload-intensive in terms of the task **load amount**.

This means that students will be exposed to a strong psychological burden from scratch. In this sense, we can see that the construction of this problem is not optimal.

In the original well-posed problem, the difficulty and task **load amount** of problem are initially small and then gradually get large. Therefore, this issue should take into account the psychological characteristics of students and make some adjustments to the level of difficulty of the subtasks.

In this paper, we considered some solutions to improve the problem designing, one of the important components in PBL teaching. Especially, we reestablished the main concepts related to the problem design and gave more detailed explanation of its designing step with an example of the problem in the engineering subject. In particular, we presented the practical estimating model for quantitative estimation of the problem made up on the basis of 3C3R model which was precisely presented a conceptual model for the problem design and introduced the procedure through an example. The values obtained here are the subjective and relative ones using relative level estimates.

Through the analysis of an example, we can see that the main factor which defines the difficulty of engineering problems is the variety of cognition level and problem requirement range, solution procedure which is necessary in the solution of the problems.

In the future, the task to be solved in the design of the engineering problems is to find out an appreciate connection way of the teaching content and problems to ensure the reality and the truth of problems, a

reasonable configuration method of the context information to develop the synthetic thinking abilities, and a combination method of hiding information and exposure information of problems, etc.

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