

Implementation of Problem-based Teaching and Learning in Advanced Professional Courses for Optics Related Majors

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ABSTRACT

Advanced professional courses (APCs) in the senior year will lay the foundation for further graduate study. Meanwhile, they are summaries and applications of the learnt fundamental professional courses (FPCs). Thus APCs form a connecting link between the preceding and the following studies. For example, Principles and Design of Optoelectronic Instruments (PDOI) is a lecture-based APC aiming at familiarizing students with the operating principles and basic design methods of commonly used optoelectronic instruments. Students will be able to describe the operating procedure of the instruments, distinguish the structure and function of each part, and present preliminary results of both overall design and parameter design. Problem-based approach with the following implementation is a good choice for such APCs. An assignment of system design is announced as the problem at the beginning of the semester. Students are asked to (1) describe the basic working principle, (2) do the overall design and draw the schematic diagram of the system, (3) do the module division as well as the budget, and (4) finally analyze a critical parameter of the system. Then during the explanation of corresponding chapters, four times of in-class practices are arranged to help the students finish the assignment question-by-question with the help of textbook, internet and the teacher. Compared with straightforward explanation of the chapters and leaving the assignment as a homework at last, the proposed problem-based approach helps improving the motivation and achievement of the students.

Keywords: problem-based learning, lecture-based learning, curriculum development, senior year, professional courses

1. INTRODUCTION

1.1 Introduction to Problem-based Learning

Problem-based learning (PBL) was proposed as an effective learning method as early as 1980s¹. In that literature, Boud stated that: “The principle idea behind problem-based learning is not new, indeed it is older than formal education itself. It is that the starting point for learning should be a problem, a query or a puzzle that the learner wishes to solve. Organised forms of knowledge, academic disciplines, are only introduced when the demands of the problem require them.” Along with this statement, Matthew² addressed that PBL is much more than problem solving. It is a kind of deep learning approach which can help improve the analysis, synthesis and evaluation abilities and those are of higher levels in human’s regnitive domain.

Since PBL can get students involved in deep learning by combining both knowledge acquisition and skill development, it had been applied to different technical fields, from computer science³ to medical education⁴. Curriculum designs^{5, 6} for optics-majored Freshman year were good examples of applying PBL in optics-related engineering courses. Recently, proposals of optics/photonics PBL in math classroom⁷, optical engineering studies⁸ and interactive multimedia teaching equipment⁹ for PBL show the popularity of it.

1.2 Objectives of Advanced Professional Courses

Advanced professional courses (APCs) in the senior year will lay the foundation for further graduate study. Meanwhile, they are summaries and applications of the learnt fundamental professional courses (FPCs). Thus APCs form a connecting link between the preceding and the following studies.

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For example, Principles and Design of Optoelectronic Instruments (PDOI) is a lecture-based APC aiming at familiarizing students with the operating principles and basic design methods of commonly used optoelectronic instruments. It has been lectured in School of Optics and Photonics, Beijing Institute of Technology for more than ten years. A scientific instrument is often a combination of precision mechanics, optical components, electrical systems and information processing unit like a computer. It is much more than a simple or complex physical principle, but a precise engineering product. The principle and design method for different instruments vary dramatically. However, something in common indeed exists in various instruments. These design criteria are the main content of the course PDOI.

The main content of PDOI includes basic concepts, accuracy analysis and modern design methods, typical modules (optical sources, elements, and detectors) and typical optical instruments (interferometer, spectrometer, and microscope, etc.). Students are required to master the physical principle, actual structure and main function of several instruments and be able to do simple design. So the teaching sections in the course consist of lectures about the principles and typical examples, several demonstration experiments about classical optical instruments in the classroom, assignments about basic physical principle, measurement data processing, instrument structure and systematical parameter design, and the final examination. The objectives and traditional approaches of realizing the objectives are listed in Table 1.

Table 1. Objectives of Principles and Design of Optoelectronic Instruments

Index	Objectives	Cognitive level	Traditional approaches
1	Recall the basic concept of optical instruments	Knowledge	Lecturing, final examination
2	Describe the principle of a given instrument	Comprehension	Lecturing, demonstration experiments, assignment, final examination
3	Do accuracy analysis of a given instrument	Analysis	Lecturing, assignment, final examination
4	Do overall design of an instrument with specific function	Synthesis	Lecturing, assignment, final examination
5	Do module design of an instrument	Application	Lecturing, assignment, final examination

1.3 Application of Problem-based Stragedy in APCs

As discussed above, an optical instrument is a comprehensive precise engineering product. Most people know that a positive lens can form a reduced image, but only those who are majored and experienced in optics, electronics, and mechanics working together can make a practical camera possible. After three years of study, the students have acquired basic knowledge in optics, mechanics, electronics, and computer science. They are ready to make a comprehensive application of the knowledge they have learnt in something really important. Like most APCs in engineering, PDOI needs practical section to turn students from armchair engineer to a real one. Without the practice section, theories in the textbook or on the slides will never turn into experiences and skills of the students.

As proposed above, PBL is an excellent approach for high-level cognitive and deep learning. So PBL was introduced to PDOI to help achieve high-level objectives, especially analysis and synthesis missions.

2. IMPLEMENTATION OF PROBLEM-BASED TEACHING AND LEARNING

2.1 Example of Traditional Assignment

The main objective of PDOI is to falimilize the students with the principle and design method of typical optoelectronic intrument, so the topics of the assignments are all about these two catagories, principle and design method. Traditional assignments include four sections corresponding to the four levels presented in Table 1. The type and function of the intruments vary every year but are not beyond the scope of the instruments explained during class. For example, the principle of phase contrast microscope, accuracy analysis of laser autocollimator, overall design of grating rulers and module design of laser interferometer. Each of the intrument has been lectured before the assignment is announced and the students can finish the assignment as long as they listened carefully during the class.

However, the feedbacks for the traditional assignment were not satisfactory at all. The students complained in two aspects. Some of them still did not know what to do and how to do the design because they just heard and remembered

all the results taught in class. Once they could not recall the details, they were passively waiting for the answer. The analysis and design methods remain “knowledge” to them and they can not use the methods if they have forgotten any details, which is very common. On the contrary, other students with good memories complained that the topic was too boring because it was already taught during class. Whether this portion of students really understood how to design an instrument remained unknown from this kind of assignment.

2.2 Proposal of Problem-based Assignment

Based on the above problems in traditional assignment, we designed a comprehensive assignment last year. 8 different instruments were set as the topics, including detector for average diameter of red blood cells, detector for the curvature radius of the cornea, wine alcohol detector, diamond authenticity discriminator, cave topography explorer, etc. These instruments were interesting and not mentioned in class but could be designed with the knowledge and methods taught in class. Then students were asked to (1) describe the basic working principle, (2) do the overall design and draw the schematic diagram of the system, (3) do the module division as well as the budget, and (4) finally analyze a critical parameter of the system.

2.3 In-class Practice of Problem-based Assignment

During the explanation of corresponding chapters, four times of in-class practices were arranged to help the students finish the assignment question-by-question with the help of textbook, internet and the teacher. Each student could pick his/her own topic and should finish the design in the name of himself/herself. The organization of the class was as follows. At the beginning of the class, the teacher announced the requirement of the class, i.e. finishing which part of the assignment. Then one of the instruments was taken as example to show the procedure of finishing the required part. Since the teacher had prepared the part before class, the details for thinking was not demonstrated. Only the results were described as the goal of the that class. Students were asked to finish that part in class with refer to the demonstration of the teacher. They could discuss with each other, surveying on the internet, or asking the teacher.

2.4 Summary and Report of Problem-based Assignment

After four times of in-class practices, the students were asked to hand in a report describing the procedure and result of his/her design two weeks after the last practices. A simple template was given as the guidelines of how to write the report.

2.5 Expected Contribution of the Above Strategy

The final score of the assignment was evaluated according to the follow criteria and the corresponding objectives of the course. (1) Objective 2: Is the basic principle of the instrument correct? (25%) (2) Objective 4: Is the overall design and schematic diagram of the system correct? (25%) (3) Objective 5: Is the module division and budget reasonable? (20%) (4) Objective 3: Is the critical parameter correctly analyzed? (20%) (5) Objective 1: Is the design of the four steps consistent and innovative? (10%)

The proposal and arrangement of problem-based assignment and the in-class organization are expected to contribute to the objectives of the course as shown in Table 2.

Table 2. Expected contribution of the each segment.

Segment	Expected contribution to the objectives
Problem-based assignment topic selection	1. Knowledge: Recall the basic concept of optical instruments
In-class practice	2. Comprehension: Describe the principle of a given instrument 3. Analysis: Do accuracy analysis of a given instrument 4. Synthesis: Do overall design of an instrument with specific function 5. Application: Do module design of an instrument
Summary and report	1. Knowledge: Recall the basic concept of optical instruments

3. FEEDBACK AND DISCUSSIONS

3.1 Statistic Data

We designed a questionnaire to survey the comments of the students towards problem-based assignment. The questions are listed in Table 3. The options were set as “Strongly Disagree”, “Disagree”, “Uncertain”, “Agree”, and “Strongly Agree”.

The questions can be classified into three categories according to the expected contribution proposed above. The 1st category (Q. 1~3) is asking the students if the problem-based assignment can help them understanding the core content of the course, including the overall design method, system and module design method, market survey and component selection. The 2nd one (Q4) is concerning if the problem-based assignment can help them review learnt fundamental professional courses including optics, mechanics, electronics and software coding. The 3rd one (Q5~7) tries to find out a way of creating more comfortable class atmosphere for active learning.

Table 3. Questionnaire to survey the comments of the students towards problem-based assignment.

Index	Questions
Q1	The introduction of problem-based assignment helped me understand the overall design method of optical instruments.
Q2	The accomplishment of the assignment helped me better understand the relationship between the system and independent modules.
Q3	Through market survey for different components, I got more perceptual knowledge of component selection, and enhance the feasibility of design.
Q4	Module design helped me review the knowledge of optics, mechanics, electronics and software coding.
Q5	According to the teaching progress of knowledge points, I finished the design assignments several times in class, which made me more clarified about the design objective and made my design more efficient.
Q6	Discussing design assignments with classmates or teachers in class helps me broaden my mind.
Q7	I could not do enough survey in class, so accomplishment of the design assignment was slow. I would prefer to finish it after class calmly by myself.

The feedbacks of the students are counted and plotted in Fig. 1. For the questions in the 1st category, more than 75% selected “Agree” to “Strongly Agree”, which implied active solution of technical problem can help them better understanding the design method taught in class than traditional assignment. It is worthy noticing that for Q3, the proportion of “Agree” decreased compared with the first two questions and several students even picked “Disagree”. The reason may be that the instruction on how to do the market survey and how to choose a proper component was not sufficient. Meanwhile, since most of the students had not taken part in professional competition or autonomous experiment, their experiments on market survey were not sufficient. Sudden exposure to independent market survey on the contrary made them anxious.

For Q4, most of the students were positive to the conclusion that problem-based assignment would help them review the old knowledge in FPC. This assignment as well as the whole course acts as a bridge between theoretical knowledge and practical applications, fundamental knowledge and comprehensive applications. Moreover, this review procedure helped them understand the application of the theoretical knowledge and offered a design clue of the optical instruments as a whole.

For Q5~8, the feedbacks are divergent. For Q5 and Q6, percentages of positive answers rised to more than 80%. The decomposition of the assignment to four parts simplified and clarified the target of each part. The students were clearer about their mission in each class and would be more active. The discussion with classmates in class on the assignment is a kind of flipped classroom. Through the discussion between students, they could understand the assignment better both from listening to their partners and teaching their partners. Not surprisingly, for Q7, 12% selected “Disagree” and 1% “Strongly Disagree”, which meant that they would prefer finish the assignment during the class than after class by themselves. The accompany of the teacher and the classmate would create a comfortable and efficient active-learning atmosphere. However, 33% selected “Uncertain”, 35% selected “Agree” and 19% even selected “Strongly Agree”, which means they still prefer traditional after-class assignment. Considering that most of the student approved the introduction of problem-based assignment, maybe the problem occurred because the classroom organization was not good enough.

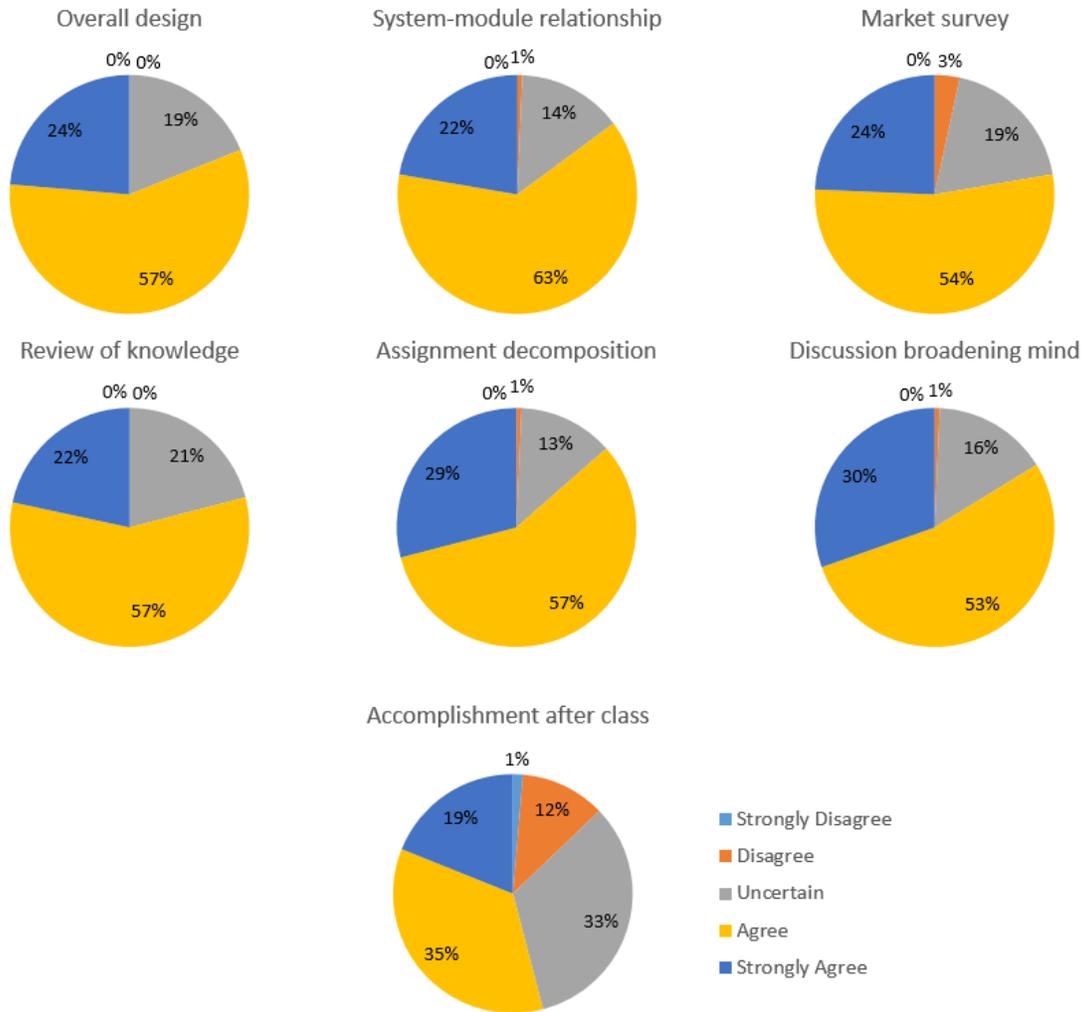


Figure 1. Statistic results of the questionnaire concerning the active influence of problem-based assignment.

3.2 Students' Subjective Feedbacks

Except for the optional questions, the students also submitted their subjective feedbacks of the problem-based assignment. Some of the typical statements are listed below. Most of them are very positive to the new strategy. Some even posted that finishing the assignment in-class would save after-class time and release the burden, which was out of the expectation. Some of them submitted good suggestions including increasing the topics of assignment or allowing autonomous topic selection. Some of them desired more complicated and systematical design assignment.

- *I like to finish the homework in class with the classmates.*
- *The use of the concepts and design methods learnt in previous class can deepen the understanding of them.*
- *Finally, I used the knowledge learnt in the past three years and got a detailed image of their functions.*
- *The assignment helped me get a clearer image of instrument design.*
- *The most impressive thing was that we finished the assignment together with the help of the teacher.*
- *The instruction of the teacher was clear and the assignment was better finished with the guidance of the teacher than with my own hands.*
- *Finishing the assignment in-class released the heavy burden.*

- *The number and diversity of the topics for the assignment should be increased. It is a little boring right now.*
- *What if I could determine the topic of the assignment myself?*
- *The assignment could be even more complicated. Right now it's simply module design. It should be more systematically and long-term.*

3.3 Suggestions on Future Improvement

According to the above feedbacks of the students, several suggestions on future improvement can be concluded.

- (1) The content and arrangement of in-class practice and discussion should be carefully designed so that the students could join in the discussion to the most extent. It was a little freestyle in the current try and some of the students felt boring, anxious, or helpless.
- (2) Questionnaire should be designed before assignment proposal to collect the students' comments on their lacking of knowledge or skills. Then lectures on specific topics of those knowledge or skills can be designed and given before assignment class to improve their participation.
- (3) Some of the excellent students can be qualified to selected topic autonomously according to their daily performance.
- (4) Team work could be allowed for complicated assignments.

4. CONCLUSIONS

Aiming at improving the participation of students in advanced professional courses given in big classes, we proposed the implementation of problem-based teaching and learning strategy. A typical design problem was proposed as the design assignment. Then four times of in-class practices were organized to finish the assignment module by module. In each class, the basic design principle was reviewed at the beginning. Then the students were allowed to discuss with the classmates, the teacher or surveying the internet. Finally, they were asked to hand in a design report summarizing the whole design procedure and the results. The reports were evaluated according to their correctness and completeness, and similar design was allowed while duplicated report was strictly prohibited. According to preliminary feedback, most of the students were more active and devoted to in-class assignment and approved that problem-based strategy helped them understanding the knowledge taught in previous class and three years better. Also some suggestions on classroom organization, teaching procedure and topic design are given based on this first try.

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