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# *Project-Based Hybrid Education of Graduate and Undergraduate Group*

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***Abstract*—Most of the professors majored in Engineering complete their education of graduates and Ph.D candidates during the progressing of their projects. Meanwhile, they encourage undergraduates to join their groups and learn how to do scientific research from real projects. Hybrid education of different students is a common situation most professors are facing. In China, because of the large student-professor ratio, only a few students can get the chance to communicate with the professor frequently enough. Many students just finish the technical tasks, but can seldom get pertinent feedback or further advice on future plan. In this paper, we propose a project-based hybrid education method to promote the growth of different students. We believe that attention should be paid to grouping of different students, respective goal clarification, teamwork encouragement and individual communication. Preliminary trial was carried out and the feedback from students was quite positive.**

***Keywords—project-based; hybrid education; teamwork; individual evaluation***

## I. INTRODUCTION

As engineering educators we view quality teaching of graduates and undergraduates as being on par with other scholarly responsibilities and achievements, and hence we must create new pedagogy to meet the changing student populations and changing societal needs [1]. As Edward F. Crawley said in his paper [2], there is a seemingly irreconcilable tension between two growing needs in contemporary engineering education: one is the ever-increasing body of technical knowledge that students must command; the other is a growing recognition that young engineers must possess a wide array of personal, interpersonal, and system building knowledge and skills that will allow them to function in real engineering teams and to produce new products and systems. The situation is similar in Chinese graduate and undergraduate education. Changes should be made from traditional approaches to engineering education that will be required to meet current and anticipated demands on the profession in the 21st Century.

The necessity of restoring the balance between practice and science in higher education has long been acknowledged in educational literature, which is now even more pertinent to engineering education. Project-based learning dealing with key aspects of product design and realization has been acknowledged by many academic institutions as an appropriate means in the training of adaptable, reliable and responsive engineering students [3]. Educators worldwide are developing project-based teaching styles [4-6].

Rather than with classroom education, professors would complete their education of graduates and Ph.D candidates during the progressing of their projects in the laboratory. Meanwhile, more and more undergraduates are encouraged to join the group and learn how to do scientific research or engineering development. In this case, the project which the professor is in charge of becomes the mutual task of the group and naturally the base of education.

However, in China, because of the large student-professor ratio and career pressure, professors could spare limited time on face-to-face communication with students. Moreover, when the students are diverse in professional background, grade, or research experiences, individualized teaching becomes very difficult in this hybrid education situation. Many students just finish the technical tasks, but can seldom get pertinent feedback or further advice on future plan.

The responsibility of colleges and universities should be education rather than pure scientific research. To solve the difficulty above, we propose project-based hybrid education pedagogy to promote the growth of different students. Here, with the phrase “hybrid”, we emphasize that 1) the educational objects are various in academic degree and major, and 2) the education executors are not limited to the professor but include all the group members. Our goal is to educate students how to learn rather than teaching them specific knowledges, so we focus more explicitly on skills including problem solving, communication, teamwork and leadership skills, and lifelong learning skills. The key of the pedagogy lies in grouping of different students, respective goal clarification, teamwork encouragement and individual communication. We will address them in details and show the preliminary results in the following sections.

## II. PROJECT-BASED HYBRID EDUCATION

The authors of the paper are majored in Optical Engineering, so here we take the project of developing optical measurement equipment for example. This is a typical engineering problem. The methodology for the project should make sense for other engineering projects.

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The procedure for developing a new equipment prototype is as follows. Firstly, a physical principle is selected to complete the basic function of the equipment. For example, imaging principle should be selected if a microscope is to be developed. Secondly, simulation experiments with both computer software and experimental apparatus should be carried out to verify the feasibility of the principle and estimate theoretical performance of the new equipment. In this stage, talents majored in Optical Engineering, Mechanical Engineering, Computer Science, Electronic Engineering and other professions should work together to complete the parameter design, systematic setup and testing. Finally, fabrication of the optical, mechanical and electronic modules of the equipment is done after reliability design. The prototype is installed, adjusted and tested.

During the research and developing process of new equipment, a group of student should cooperate. The education objective of different students is listed as follows.

- Ph.D candidate: be able to independently develop a new prototype with intermediate complexity after the education. He knows how to select the proper physical principle, design the system, do theoretical analysis of the performance, carry out simulation experiments, design modules with good reliability, install, adjust and test the prototype. Also he is able to decompose the project and be a leader of a technical team.
- Graduate: be able to complete simulation experiment with computer software or experimental apparatus, or install, adjust and test the prototype independently, if the equipment is complex. He should be able to independently develop a new prototype with low complexity.
- Undergraduate: be able to design and realize part of the simulation experiment, install or adjust or test the prototype.

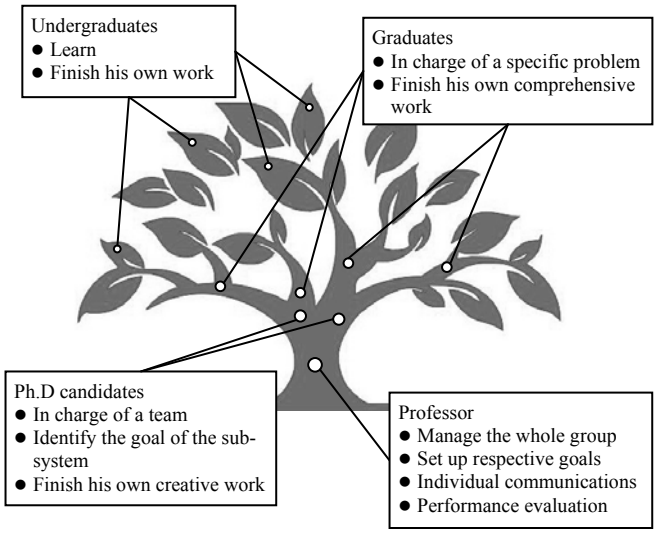


Fig. 1. Tree-type construction of project-based hybrid education of graduates and undergraduates.

If we compare a project as a tree, undergraduates just complete the job of some leaves; graduates can finish many leaves and a small branch, while the Ph.D candidates should be able to handle a big branch all way down to the leaves. The professor should take care of the trunk and review the project as a whole. With the above image shown in Fig. 1, we describe the education pedagogy in details.

### *A. Grouping of graduates and undergraduates*

The first step is to group the students according to their professional background, grade, or research experiences. It should be guided by two important criteria.

*1) Major or professional diversity should be gauranteed in a group.* Taking optical measurement equipment development for example, students majored in Optical Engineering, Mechanical Engineering, Computer Science, Electronic Engineering and other professions like Physics and Mathematics make a good combination. It is determined by the nature of equipment development project itself. An optical equipment offen includes different modules of optics, mechanics, electronics and computers to keep it functioning correctly. If the students are similar or same in the major, they would have similar way of thinking and professional knowledge accumulation. Problems out of their previous experience will be difficult and time-consuming to solve. Brain storming is quite an effective way for solving new problem and only brains with different perspectives and experiences can create new solutions together. This is true for other majors and projects because the more and more specified division of in modern science and technology.

*2) Students should be arranged to the proper post according to their background and experiences, not only by their academic qualification and grade.* If we consider Ph.D candidates, graduates and undergraduates to be senior, intermediate and junior students, and arrange their post according to Fig. 1, we should investigate their background and experiences first. Sometimes students' abilities are not in proportional to their academic qualification and grade. Senior students should learn from the beginning if they do not have enough research ability. Meanwhile, junior students can take more resposibility if they are well-trained.

After the group is formed, the professor could organize some ice-breaking activities to make the group cooperate more smoothly.

### *B. Respective Goal Clarification*

The goal we mentioned here includes both the overall goal for the group and respective goals for each individual. The overall goal of the group is often technical, including the deadline and prospective achievements. Professor should clarify the goal before the whole group and call on the members to forge ahead with all the enthusiasm and optimism.

The respective goals for each individual are not only technical but also include self-identification and cooperation. Technically, the professor can decompose the goal into several

smaller ones for each team and ask the team leader, often taken by a Ph.D candidate, to identify and claim it. For next step, the team leader can organize a brainstorm inside the team and further decompose the team goal into respective technical goals for each individual. In this step, the professor should act as an advisor instead of a commander. The decision should be made by the team leader and approved by the professor. In this case, the team leader starts to gain some authority and learn how to be a leader. Group management is also one of the respective goals for the team leader. Similarly, graduates should be in charge of a specific problem. Except for their own comprehensive technical work, they should take cooperating and advising some undergraduates as their goal. Undergraduates could just learn and finish their own job.

Adequate grouping and goal clarification is the foundation of successful project-based hybrid education. If the professor directly decomposes the project and assigns the work to each student, it is really difficult to follow all the progress. The project would be slowed down and many of the students would lose the chance to communicate with the professor frequently enough.

### *C. Teamwork and Individual Communication*

With proper grouping and goal clarification, the professor can be released from detailed technical queries during the progressing of the project. However, teamwork and individual communication turn to be the most important issues. To assure good teamwork, professor should check the daily heads together of each team to see if the leader has enough authority and academic ability. Also, the professor should set up periodic individual communication with each member of the group to check their progress, questions and suggestions. The progressing of the project is dynamic, with group member changing, unexpected problems and etc. The professor could relax only when the progressing is within expectation and hand over the education of intermediate and junior students to senior students. Otherwise, he should communicate with the team leader for new technical measures and inform the relevant members of the changes.

Timely individual communication is the guarantee of successful project-based hybrid education. Without it, educating the student in accordance with their aptitude and performance becomes impossible.

### *D. Performance Assessment*

Finally, the performance of each team should be evaluated regularly. Summary meeting of the whole group should be held every semester or so. Except for investigating the technical correctness, the teamwork, efficiency of communication should also be reviewed. Students could exchange their experience and lessons during the development. This is also a good chance for the professor to give pertinent feedback and further advice on future plan.

## III. PRELIMINARY TRIAL AND FEEDBACK

From 2014, the authors have undertaken a major research project aiming at developing a novel type of interferometer, which is a kind of precision measurement equipment. It is a 4-year project so it is still undergoing. The authors have tried the above education pedagogy and the feedbacks from the graduates are quite positive.

The construction of the research group is shown in Fig. 2. The students are numbered according to the time they started to join the project. The project was decomposed into three main topics and assigned to three Ph. D candidates. Three teams were formed for the topics and included different numbers of students depending on the difficulty and workload of the topic. The students were with different majors as described in Sec. II-A-1). The research direction of each student were discussed inside the group and finally determined by the student himself. Some students even changed their directions because of lack of previous knowledge or experience after a period of research.

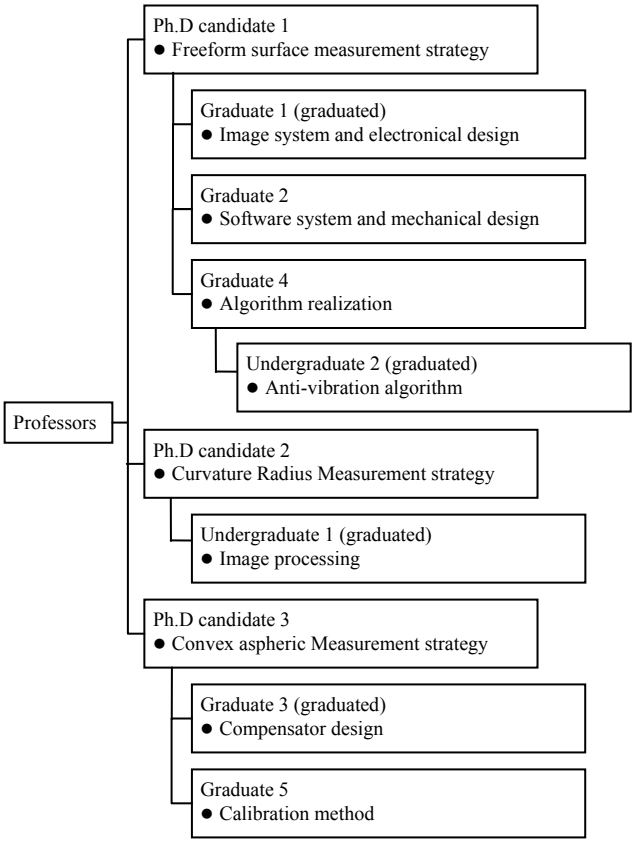


Fig. 2. Construction of the interferometer development group.

The professors have weekly meeting with each of the students and ask them to report the progress and problems. Most of the time, the professors just listen and give suggestions. The team leader – Ph.D candidate – will push the project and guide his team members as long as he is not confused about what to do. Once he is lost or his team members report serious problems, the professor will interpose and teach them how to find the answer to the new question, instead of solving the problem directly for them. Summary meeting is held at the end of each semester and both success and failure are welcome to be presented. After all, the most important thing is to teach the student how to solve problems by themselves.

The most difficult time was the beginning of the project. At that time, Ph.D candidate 1&2 just started their thesis with little experience of scientific research. Four professors in different majors had to push the project with their own hands while train all the students at the same time. After about a year, the graduates were able to work independently and the hybrid education group was ready to function well. After another two years, two graduates and two undergraduates graduated. All of them claimed that the project-based hybrid education gave them both clear goal of what should be done and the freedom to try different ways. Also, the daily team consisting of pure students is easy to get along, while the professors ready to listen to their reports make them feel secure. One of the Ph.D candidates even developed a new direction after discussion with his former classmate who is pursuing Ph.D degree in The Hong Kong Polytechnic University. The initiative and ability the students show are the greatest achievement of our education.

## IV. CONCLUSIONS

Most of the professors majored in Engineering complete their education of graduates and Ph.D candidates during the progressing of their projects. Meanwhile, they encourage undergraduates to join their groups and learn how to do scientific research from real projects. Hybrid education of different students is a common situation most professors are facing. In China, because of the large student-professor ratio, only a few students can get the chance to communicate with the professor frequently enough. Many students just finish the technical tasks, but can seldom get pertinent feedback or further advice on future plan. We proposed and demonstrated a project-based hybrid education method to promote the growth of different students. During the progressing of optical equipment development project, we formed a group of 10 students including Ph.D candidates, graduates and undergraduates. We paid attention to the grouping of different students, respective goal clarification, teamwork encouragement and individual communication. Three years of trial sees four graduates claiming that they have both clear goal of what should be done and the freedom to try different ways. We will continue considering about new measures for inspiring the students and form a set of procedures and regulations for the project-based hybrid education in the future.

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