Exploration of classroom teaching of the *Fundamental Industrial Engineering* course using project-based group study (PBGS)

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ABSTRACT: *Fundamental Industrial Engineering* is the core course of industrial engineering in China. Due to the existing gap between school teaching and practical applications, several attempts have been made to address and rectify this problem. One of those attempts is a classroom-teaching mode using the project-based group study (PBGS) method, which is explored in this article. The overall scheme, the classroom teaching system, the multi-task related project system and the comprehensive evaluation method are explained. The practical teaching effect shows that this classroom teaching mode can improve teaching quality.

INTRODUCTION

The Teaching Steering Committee Of Management Science and Engineering of the Chinese Ministry of Education defines *Fundamental Industrial Engineering* as one of the core undergraduate courses in Industrial Engineering (IE) and, hence, is important for the realisation of IE training goals. Fundamental Industrial Engineering provides the foundation for effective application of IE tools and methods in enterprises, which generally includes methods of study, operational measurement and on-site management [1]. These are critical for Chinese medium and small enterprises in transforming from an extensive, to a lean, management style by improving production efficiency and quality, while decreasing production costs [2].

Classroom teaching is the main mode of teaching at colleges and universities. Therefore, it is necessary to take the quality of classroom teaching as the starting point for identifying teaching quality improvements. However, current teaching reform and research on fundamental industrial engineering is mainly concentrated on engineering practice, such as the design of experimental projects [3] and production practice [4]. Although Chen et al have presented a practice teaching mode, which introduced regional industry demands into classroom teaching [5] compared with the demands of enterprises [6-7], there are still defects in classroom teaching viz:

1. The teacher *teaching* in the classroom without an autonomous learning platform is detrimental to the development of students' innovative abilities.

   The majority of Chinese colleges and universities adopted Fundamental Industrial Engineering as the textbook for the fundamental IE course [1], and the suggested teaching schedule for the course was 48 hours, of which 36 were theory and 12 were practical work. This classroom-oriented teaching puts the teacher's *teaching* central, thus making it hard to arouse students' interest in analysing and solving problems. Hence, it is detrimental to the development of students' innovative abilities. *There is always a better way* is the motto of IE. Thus, it is important for students of IE to be conscious of problem-solving and innovation, i.e. to solve problems of production systems by creatively applying knowledge of fundamental industrial engineering.

   An emphasis on *single knowledge point* practical skills to the neglect of the logical correlation between different knowledge points is detrimental to the cultivation of students' comprehensive abilities. The current teaching of fundamental industrial engineering emphasises practical training for *single knowledge points (such as procedure analysis, two-hand operation analysis, time measurement)*, but does not integrate this knowledge point with other knowledge points and students do not gain a systemic understanding of integrated practice across the whole course. Students have a fair understanding of a single knowledge point, but have not clearly understood the correlation and couplings between different knowledge points. This is detrimental to the cultivation of students' comprehensive

abilities. Realistic efficiency improvements to a production system is a complex problem, which may require comprehensive changes to the production process, operating method, standard operation, on-site management, etc. It is necessary that the teaching methods help students to understand the sequencing and hierarchical relations among course knowledge, and to optimise and standardise production systems following the process-operation-motion procedure.

2. Taking the *individual* student as the teaching unit is unfavourable for the cultivation of student team co-operative abilities.

   Traditional fundamental IE classroom teaching makes the teacher's *teaching* the main mode of knowledge delivery and the student an *individual* as the basic teaching unit. This limits communication and sharing among students, which is unfavourable for the cultivation of student team co-operative abilities.

   The importance of co-operation can be understood by example; the optimisation and improvement of a production system is a complex engineering problem, which is conducted commonly with exchanges and co-operation between different departments and workers covering the production process, quality assurance, raw material procurement, functional parts, and so on. Today, it is virtually impossible for an individual to complete a project on their own. Team co-operation is of great significance to the application of fundamental IE and, sometimes, it is even more important than professional knowledge.

As a popular teaching mode, the *project* is the main vehicle of the project-based group study (PBGS) method. The team and group learning are basic to the teaching, and the knowledge and skills are attained through the project process, with the teacher guiding, inspiring and encouraging [8-9]. Compared with the traditional learning, PBGS pays more attention to cultivating students' problem awareness, critical thinking, independent learning and teamwork.

In light of the above, a fundamental IE project classroom teaching mode is put forward in this article. Taking PBGS teaching as guidance, the teaching is driven by project tasks and student teams' autonomous learning. This cultivates innovative talent, equipped with team co-operative ability, and students can, as graduates, meet the demands of enterprise projects.

OVERALL SCHEME OF FUNDAMENTAL IE PROJECT CLASSROOM TEACHING ON THE BASIS OF THE PBGS TEACHING IDEA

Taking the cultivation of IE innovative talents, who have the ability to comprehensively solve real-life engineering problems by using the fundamental IE principles and techniques, as the goal, an overall scheme of fundamental IE project classroom teaching is put forward in Figure 1.

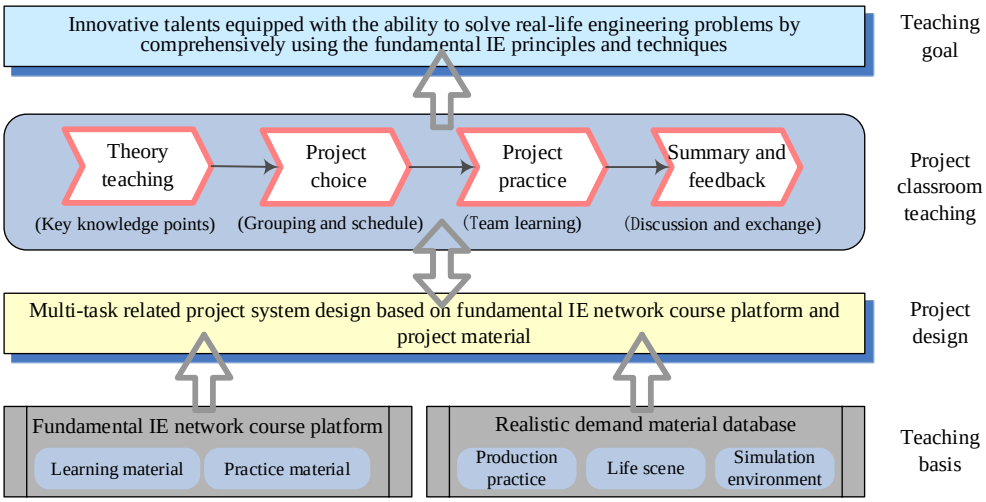


Figure 1: The overall scheme of the IE project classroom teaching based on PBGS.

As can be seen from Figure 1, the scheme for fundamental IE project classroom teaching is composed of four parts. Taking PBGS teaching as a guide and based on using the fundamental IE Web courses platform, the teaching process runs through the *project design* and *project classroom teaching* to realise the *teaching goal*.

The teaching basis includes two aspects: to establish the fundamental IE network course platform using network technology and to establish the project material database according to reflected real-life demands of enterprises. The network course platform can provide an on-line course introduction (key and difficult points, guidance to learning), electronic textbooks, teaching videos and practical material. It can also provide a project information distribution function, and interactive communication and information exchanges between teachers and students, which are important

for students' team learning. Meanwhile, a project material database is available for generating the project. This includes a large number of practical application requirements from enterprises that are classified according to industry, enterprise, application level, and so on. Later, the multi-task fundamental IE project system is designed in accordance with the interrelations of knowledge points and the characteristics of practical materials, to provide a foundation for project selection and practice. Project classroom teaching combines the teacher's *teaching* approach with team *learning* in and out of the classroom, to achieve the teaching goals.

PROJECT CLASSROOM TEACHING FOR THE FUNDAMENTAL IE COURSE WITH TEAM LEARNING

Fundamental IE classroom learning based on PBGS regards the completion of a series of *project* by teachers and students together as the main learning vehicle. This teaching system makes the student team the teaching unit, and the whole team is required to complete the project, proceeding step-by-step. The team designs the learning goals, breaks down the tasks and develops the project implementation plan according to the aims and requirements of each, specific *project*. After identifying a problem, the team develops a rectification plan, which involves collecting on-site data, analysing and solving the problem by using fundamental IE principles and techniques. The fundamental IE project classroom learning system covers theory, project selection, project practice, summary and feedback, as shown in Figure 2.

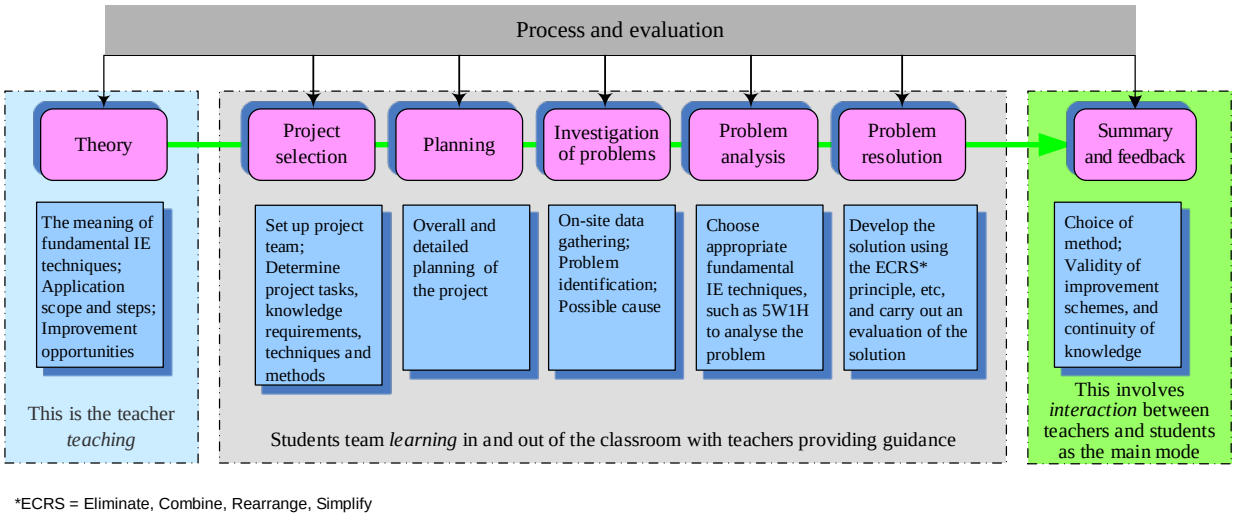


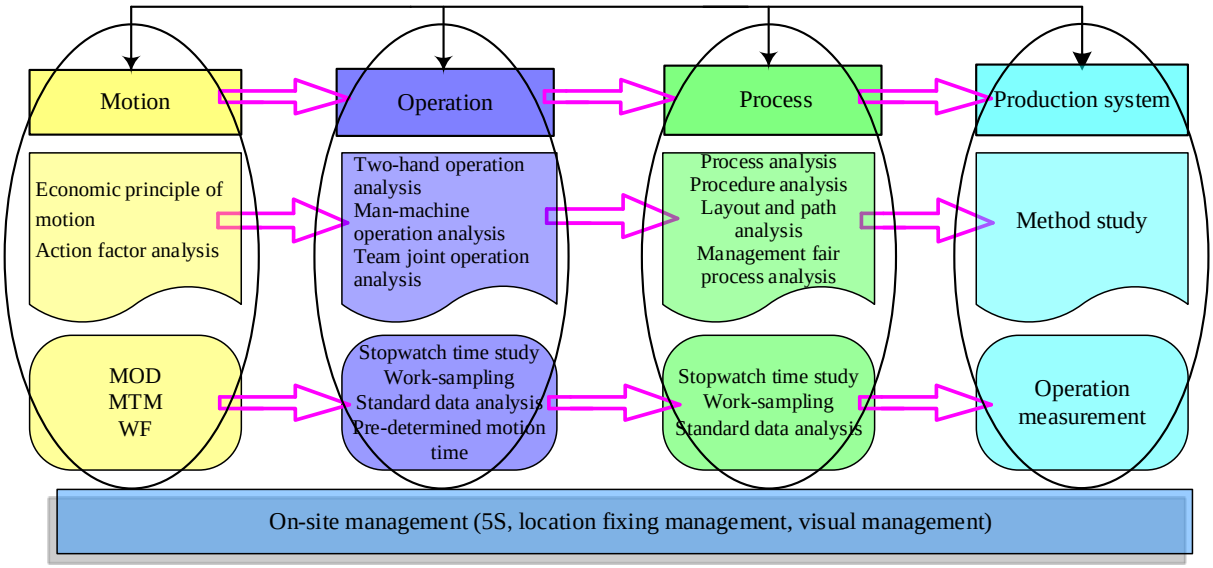
Figure 2: IE teaching based on PBGS.

It can be seen from Figure 2 that fundamental IE project classroom learning includes four modules: the first is theory and determines what teachers *teach*; the second and third are the project selection and practice that inform *what to learn* and *how to learn* and, finally, the project summary and feedback that learns from and validates the project practice, and how problems were solved; the project practice covers planning, progressing the project and problem resolution. The time spent on the different modules, viz. theory, project selection and practice, summary and feedback, is roughly in the proportions 2:5:3.

The *Theory* involves the teacher *teaching* as the main approach. This differs from *traditional teaching* in that the teaching under project teaching aims to help students to ascertain the key knowledge points, techniques, methods and logical relationships among different knowledge points (Figure 3), as well as to understand prerequisite application knowledge and the required range of techniques and tools. The effectiveness of the teaching is enhanced by releasing important and difficult points on to the network platform in advance, which students are required to preview before class. During class, the teacher covers points that students have not properly understood. After class, the students' problems will be solved via interactive commutations between students and teachers. Also, students can review the project practice materials on the Web site to consolidate the learning.

Project selection and practice involves team *learning* in and out of the classroom. A project team of 4-5 students is established; then, they work together to formulate project implementation plans, collect on-site information, select analysis tools and techniques, study problems, put forward solutions, and so on. This is accomplished via discussion, communications, exploration and co-operation among team members. To ensure the required learning effect in project practice, teachers need to provide necessary guidance.

Two measures are taken to avoid some possible drawbacks, such as members getting a free ride on the work of other members of the team or a project process getting out of control. The first is dealt with by a team-leader rotation system; each team member has to be a team leader. By sharing responsibilities among students the overall students' ability of team co-operation, mutual learning and leadership will be strengthened. Hence, the gap between the students' project work and enterprise engineering demands is reduced. The second is handled by posting on the network public information about the project schedule. At specified times, each team must record actual project progress against the project schedule. This monitoring helps to ensure punctual completion.



Note: MOD: Modular Arrangement of Predetermined Time Standard; MTM: Methods Time Measurement; WF: Work Factor; 5S: Seiki, Seiton, Seiso, Seiketsu and Shitsuke

Figure 3: Knowledge points and their logical interrelationships in the fundamental IE course.

The *Summary and Feedback* module is mainly concerned with teachers' and students' interactions over problems. Each team is required to make a presentation of their project implementation, and the feasibility and disadvantages that occurred in the process are discussed. This means that students learn by *doing*. Meanwhile, it will introduce new project tasks according to the logic and coupling relationships among different project tasks. Through advancing and completing multiple projects gradually and continuously, the whole classroom teaching and practice is finished.

Whole process and multi-subject evaluation is a type of evaluation method, which transforms the result-oriented evaluation into a process-oriented and result-oriented, integrated evaluation method. The method evaluates the whole process of the project, on-site analysis, IE skills and techniques, improvement plan, etc. It is multi-evaluation, including teachers, group leaders and members, as well as self-assessments.

FUNDAMENTAL IE PROJECT SYSTEM AND MULTI-TASK SYSTEMS

The characteristics of multi-task project systems were identified by investigating enterprise system workers, e.g. production, operation. This was, then, used to inform the characteristics of the fundamental IE course. This is shown in Figure 4.

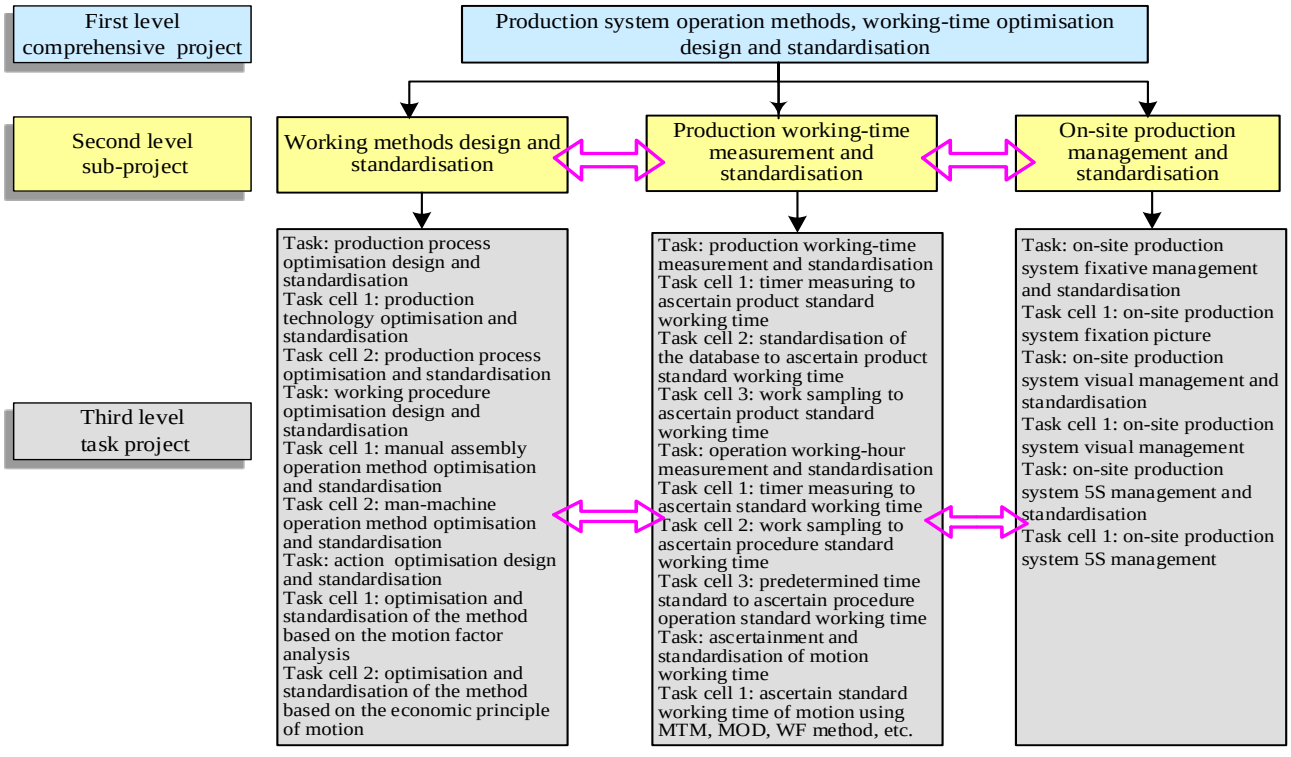


Figure 4: Multi-task industrial engineering project.

From Figure 4, it is clear that the multi-task project has three levels. From the top downwards the scope and scale goes from broadest is narrowest. The top, or first level, is the comprehensive project, with operation method optimisation design and standardisation of the whole production system as the goal. These, therefore, are the teaching goals. The first-level project is decomposed into three second-level sub-projects: working methods design and standardisation, production working-time measurement and standardisation, and on-site production management and standardisation.

Similarly, the second-level sub-projects are decomposed into third-level tasks covering process, operation and motion, i.e. from macro to micro and from the overall process to individual motion. During the teaching, the students complete the project from the bottom level to the top in a step-by-step manner. First, the project tasks of the third level are completed. Then, the design and optimisation of the production system, working-time and on-site management standards are completed, based on the experience and lessons acquired from the third-level tasks. Finally, the first level comprehensive project is completed.

EVALUATION METHOD FOR THE FUNDAMENTAL IE COURSE, WITH WHOLE PROCESS MONITORING AND MULTI-SUBJECT EVALUATION

Traditionally, the evaluation method of fundamental IE teaching is outcome-oriented, with the teacher undertaking the evaluation. The evaluation measures the mastery of theoretical knowledge and the score is generally determined by a closed book examination. With the project classroom teaching, the student's learning is team-oriented throughout the whole process, from project selection to implementation and evaluation. Traditional results-oriented evaluation methods should incorporate process-oriented evaluation. The evaluators should not only include the teachers, but also other project team members, and the students themselves, by self-evaluation. The evaluation is not only of the mastery of knowledge, but also of team co-operation, project participation and the project results.

The evaluation is divided into two stages: the first is based on the overall project team performance and the final score is determined by the teacher; the second is based on the individual performance of team members, and the contribution of each member. The content and evaluation is shown in Table 1.

Table 1: Whole process and multi-subject evaluation of the IE course.

Evaluation			
Object	Goal	Indicators	Methods
Whole team	Division and co-operation of project mission, practice, analysis and solution of project problems by the whole team.	Project implementation planning, progress control, on-site data quality, depth of problem analysis, correct solutions chosen, rationality and validity of project results, understanding of logic connections among different projects, oral responses	Final score S_{tm} is ascertained on the basis of Team *t*'s performance on project *m* by teachers
Student individual	Perceiving, learning and individual contribution to the project	Ranking the team member contributions by teacher, group leader and other members, to ascertain each member's contribution	Order relation analysis [10] to ascertain the contribution degree r_i of member *i*

If the score of team *t* on project *m* is S_{tm}, and the relative contribution of team member *i* is w_i, after considering the evaluation weights of different subjects, the final contribution is r_i for team member *i*. Suppose the average contribution of the team member is *mr*, then, the final score of the team member is calculated by the formula: $S_i = S_{tm} \times (1 + mr - r_i)$. The weight of different subjects can be determined by the analytic hierarchy process (AHP). The comprehensive evaluation method of fundamental IE can not only assess the learning achievement of each student fairly and objectively, but also encourage students to participate in team learning.

CONCLUSIONS

Learning to practice is one of the aims of education. It is necessary to develop a new teaching method to improve students' ability to deal with efficiency requirements and the cost problems of production systems in an increasingly complex manufacturing environment.

In this article, a project classroom teaching method for a fundamental IE course was presented by systematically introducing real-life engineering problems to the process of classroom teaching based on PBGS. This can avoid the weakness of teacher *teaching* as the main vehicle for learning, which isolates knowledge. This new method of teaching provides a platform for students' team learning and comprehensive systemic applications. The whole process monitoring and multi-subject evaluation ensures quality and effectiveness of classroom teaching.

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