TEACHING REFORM AND PRACTICE OF SINGLE-CHIP MICROCOMPUTER COURSE BASED ON CDIO MODEL

Jianshu Cao

School of Engineers, Beijing Institute of Petrochemical Technology, Beijing,102617, China

ABSTRACT

In engineering education, it is critically important for theory teaching to be combined with practice. In order to achieve the teaching goals of a single-chip microcomputer (SCM) principles and interface technology course, the CDIO engineering education concept is introduced to solve practical engineering problems. On the basis of the CDIO engineering education outline, a task-driven teaching model with "Teaching, Learning & Doing" at its core is constructed. Basic knowledge and ability used in designing SCM application systems are covered in each real instance, and the practical ability of students is cultivated through the experimental course, individual projects and team cooperation projects. In team learning, each group consisting of 3–4 members is required to design a mechanical system or piece of equipment whose main control unit is an SCM. The design process should be divided into different parts, including market analysis and research, overall scheme demonstration and design, mechanical structure design, SCM control system design, system assembly and debugging, and technical and economic analysis. Finally, students will write technical reports to explain their projects and conduct on-the-spot system demonstrations during their defenses. The achievement of every group or group member is evaluated by peer assessment and teacher evaluation. Through the project study based on the CDIO model, students will understand that the development and application of microcomputer systems is an iterative and continuous improvement process. In order to obtain a high-quality product, every step in the process should be improved. When the course learning is finished, the performance of the students is generally evaluated by assignments, discussions, quizzes, experiments, individual reports, group work and the final exam. The above teaching practice is a significant enhancement demonstrated in the students' ability to develop SCM application systems, along with notable improvements in their engineering practice and innovation skills.

KEYWORDS

CDIO concept; single-chip microcomputer; project-driven; active learning; learning assessment. Standards: 1, 5, 6, 7, 8, 11

INTRODUCTION

The characteristics and superiority of the single-chip microcomputer (SCM) determine its universal application. Due to its intellectual potential, strong interface driving capability and low power consumption, the SCM has been widely used in industrial, information and household appliance fields, with the application techniques changing rapidly. In recent years, SCM-applied technical talents have been in great demand. As SCM technologies are updated in China and abroad, all colleges and universities are accelerating the development of SCM courses and research on teaching reform. To satisfy the needo cultivate high-level applied talents, enhancing course construction and reform is a focus of teaching reform, and *SCM Fundamentals and Interfacing Technology* is an important professional skills course for machinery major students. The current teaching model, which focuses on theoretical teaching supplemented by experimental teaching, has a large number of deficiencies in cultivating students to solve engineering problems. In the traditional SCM teaching method, teachers give lessons in the classroom according to the arranged chapter order of the textbooks. However, the examples cited in these textbooks are often too simple to meet real application needs. Even if a student has completed all the contents specified in the teaching plan, they may still be unable to systematically and thoroughly master the design and debugging of SCM application systems. Furthermore, the teaching order of most SCM courses basically involve the basic concepts, hardware structure, instruction system, assembly language, interrupt system, timer counter, serial port, memory extension, A/D and D/A interfaces, man-machine interface and application system design. As these knowledge points are learned independently, the students still cannot understand the complete SCM development process or the countless relations between each segment when the course is finished, and may even lack an understanding of the concepts of programmer and simulator. Therefore, it seems crucial to integrate the teaching content, arrange the teaching order and reasonably combine the contents of each segment, which is also key to solving the existing issues in the traditional teaching model. Nonetheless, this course has various new concepts with abstract content and precise logic, so it is difficult to be taught vividly in such a way that the students remain engaged. It is impossible to display the vivid features and strong control functions of SCM products through lectures alone. Therefore, the teaching of this course also challenges teachers in their theoretical knowledge, practical ability and teaching methods.

Over an extended period of teaching practice, based on the CDIO engineering education model（Bernhard, J., & Baillie, C. 2016）, the author trained the students to acquire engineering application ability as the principal line; reconstructed the content of the course in accordance with the project module and used practical examples to organize unit teaching; and explained the basic knowledge and capabilities required for SCM application system design in the process of completing each example. These measures broke the constraints of the knowledge system, diverged from previous approaches and constructed a new teaching content system. Course experiments, individual projects, teamwork projects and other forms were also adopted to train the students to gain practical engineering capabilities.

TEACHING OBJECTIVES OF COURSE AND IMPLEMENTATION MODEL

SCM Fundamentals and Interfacing Technology is an elementary course in professional skills for machinery majors. It not only requires the students to master the necessary professional knowledge and basic skills, but also trains them to consider independently and solve complicated engineering issues. Besides, the course aims to lead the students to understand the basic concepts of SCM hardware, software and interfacing design, then design an application system according to real needs, allowing them to be trained to gain actual operational ability. The specific teaching targets of this course include.

Teaching Target 1

The students should master the relevant knowledge of SCM systems; understand the basic concepts, composition system and operating principle of SCM and extended chips; master the structure, principle, applications and related knowledge of SCM application systems; master programming methods using the assembly language; and write an SCM application program in the C language.

Teaching Target 2

The students should gain the capability to basically design an SCM application system and preliminarily solve complex engineering issues; complete the scheme design, circuit design, program design and system integration and debugging of SCM application systems; use computer-assisted digital circuit design and analysis software; and consider environmental protection, technical economy and other factors, thereby gaining the preliminary capability to solve complex engineering issues.

Teaching Target 3

The students should acquire and apply the criterion, specifications, handbook, atlas and related technical data; master the usage of key reference search tools and Internet search engines; utilize Internet and literature search tools to collect technical information on SCM-related issues and generate a literature summary report; gain knowledge of the development of new technology and concepts in SCM systems, and their future development directions; and be stimulated to pursue further study and research in this field so as to prepare for the subsequent course.

Teaching Target 4

The students should gain teamwork and technical communication capabilities; organize projects with team members and design an SCM application system; cooperate as a group to complete a mechanical system or piece of equipment with SCM as its main control unit; conduct market analysis and survey, overall scheme demonstration and design, mechanical structure design, SCM control system design, system assembly and debugging, technical economical analysis and other processes; and write a technical report and reporting draft, and perform project reporting and on-site system demonstration and response.

Teaching Target 5

The students should master the basic experimental methods for developing SCM, gain experimental research capabilities and obtain effective conclusions; through experimental operation and project learning, the students should aqcuire experimental study capability, master experimental research methods, gain experience in software programming and circuit design and debugging, summarize the content learned in a timely manner and finally obtain an effective experimental conclusion; and master the usage and experimental test methods of typical microprocessors, grasp how to debug the hardware circuits and software of microcomputer application systems, and obtain basic experimental skills in microcomputer application systems.

To achieve the above teaching targets, the following teaching methods and approaches are adopted: course teaching, assignments, discussions, quizzes, experimental research, group project and final exam. The details are shown in Table 1:

Table 1. Course teaching target realization matrix

Teaching Target	Approach
Target 1	• Classroom teaching: Highlight the focal points with clear thinking, pay attention to interaction between teacher and student, master the studying condition of the students and track each student in their learning process; • Discussion: Take the "Memory Extension" chapter as the content of the discussion sessions and train the students to conduct pre-class self-study, submit self-study reports, hold group discussions and communication, and master the teaching content; • Classroom tests: After teaching each technology point, spend 5–10 minutes on a quiz in order to evaluate and understand how much the students have mastered; • After-school assignments: Issue assignments after each class to enable the students to consolidate what they have learned, then correct all assignments and provide prompt feedback; • Final exam: At the end of the semester, check to what extent the students have mastered SCM-related knowledge and gained application capabilities through an exam comprising basic concepts (40%) and comprehensive application (60%).
Target 2	• Large assignment: Through the post-class large assignment "SCM Development and Application Summary", require each student to consult a wide range of literature, write a literature review and produce a PowerPoint presentation; • Experimental research: Complete eight credit hours and the preparation, experimental scheme design, experimental operation and writing of experimental reports for seven experiments; • Project teaching: Establish project groups consisting of 3–4 students. Students shall research the literature and technical data to complete the hardware design and software programming. Each group should complete one practical example of an SCM application system and write a project report.
Target 3	• Large assignment: Through the post-class large assignment "SCM Development and Application Summary", require each student to consult a wide range of literature and write a survey. Each group shall produce a PowerPoint presentation; • Project teaching: Establish project groups consisting of 3–4 students. Students shall research the literature and technical data to complete the hardware design and software programming. Each group should complete one practical example of an SCM application system and write a project report.
Target 4	• Project teaching: Establish project groups consisting of 3–4 students. Students shall research the literature and technical data to complete the hardware design and software programming. Each group should complete one practical example of an SCM application system, write a project report and reporting draft, and perform project reporting and on-site system demonstration and response.

	Training in communications, lecture reporting and writing ability plays an important role in the entire project plan, which aims to train the students to use words and drawings accurately and proficiently according to the specifications in writing the technical reports, reporting drafts and statements.
Target 5	• Experimental research: Complete eight credit hours and the preparation, experimental scheme design, experimental operation and writing of experimental reports for seven experiments; • Project teaching: Establish project groups consisting of 3–4 students. Students shall research the literature and technical data to complete the hardware design and software programming. Each group should complete one practical example of an SCM application system and write a project report.

COURSE TEACHING MODEL BASED ON CDIO ENGINEERING EDUCATION CONCEPT

On basis of the CDIO engineering education concept（Cleginaldo Pereira de Carvalho 2016), the author introduced the state-of-the-art technologies of the discipline, followed education and teaching laws, and took training the students to solve engineering issues as the core. The *SCM Fundamentals and Interfacing Technologies* course adopts modular construction based on the work process so as to build a "Teaching, Learning & Doing" integrated task-driven teaching model that "takes the project tasks as the principle line and ensures that the course is teacher-dominant and student-oriented". Finally, a feasible approach for improving the students' practical ability was determined.

REFORM AND PRACTICE OF SCM TEACHING BASED ON CDIO ENGINEERING MODEL

Build a course modular teaching model determined by the typical work process of SCM application systems

The author took training the students to gain engineering application ability as the principal line（Graham, R，2018）, reconstructed the course content in accordance with the project module, used practical examples to organize unit teaching and explained the basic knowledge and capabilities required for SCM application system design in the process of completing each example. These measures broke the constraints of the knowledge system, diverged from previous approaches organized and arranged according to the order of knowledge points, and rationally and scientifically constructed a teaching content system dependent on the need to explain the project knowledge points.

For example, in the process of learning the module "SCM Instruction System and Assembly Language Programming", the students should accurately and properly use SCM instructions to interpret and write the program, rather than being able to recite the 111 SCM instructions. The teachers should further analyze and thoroughly explain several typical practical examples, then enable the students to firmly master the basic programming idea, approach and issues to be noted in the actual operating process.

According to the knowledge points in the work process of SCM application systems, it begins with deciding on a modular project (or task), then undergoes scheme demonstration, simulation verification, drawing and debugging (Fig. 1), and ends with the completion of the final product.

Intensify practical teaching and reinforce training in engineering application and innovation capabilities

As far as the practical teaching content and system reform are concerned, the practical teaching system was reconstructed according to the three major modules: experiment, design practice, and after-class technological activities. In light of the students' cognitive rules and the new training model and teaching content system, such practical projects as basic experiments, comprehensive experiments, virtual simulation experiments, large assignments, project design and after-class technological activities were established, forming an integrated practical system, as shown in Fig. 2.

Establish the practice site and resources based on the CDIO teaching model

Great efforts were made to construct high-level course teaching resources covering basic theory and application, texts and multimedia, and network courseware for use during and after class（Malmqvist, J., Wedel, M.K., Lundqvist, U., et al，2019）. The three-dimensional high-level SCM course teaching resources were built with textbooks as the main body and supplemented by multimedia teaching courseware. An open SCM experimental system with proprietary intellectual property rights was also researched and produced. A practical teaching site equipped with 30 sets of new SCM development systems and 6 sets of SCM comprehensive experimental development systems under a network environment was constructed, as shown in Fig. 3.

Write and publish a Proteus-based modular featured textbook and establish a virtual open experimental system

The featured textbook introduces the basic knowledge of SCM and utilizes a series of modular practical example analyses and hands-on practices to enable the students to solve practical engineering problems by hand to a certain extent. At the same time, all circuits and code are brought into open, allowing the learners to study, research and carry out hands-on practice. In the textbook, Proteus, the latest development technology of the disciple, and the globally popular SCM development software Keil uVision4 are used as the development platform for building a virtual experimental system.

Develop an "open-type SCM experimental system" with proprietary intellectual property rights

New to China, the serial port programmable SCM STC89C52 was adopted by virtue of its convenient serial port programming, which greatly simplifies the development and time costs of SCM. The students can not only conduct replication experiments, but also build and test experimental circuits themselves in the design of new experiments, as shown in Fig. 4.

Build a course learning website on SCM Fundamentals and Interfacing Technologies

This course learning website includes the course overview (involving the course introduction, teaching programme, teaching plan, etc., giving the students a preliminary understanding of the course and its teaching process), network teaching plan, teaching videos, experimental guide, exercises, tests and other modules. This makes it possible to extend teaching and learning out of the classroom, intensify, expand and extend classroom teaching, and provide a platform for students' autonomous learning.

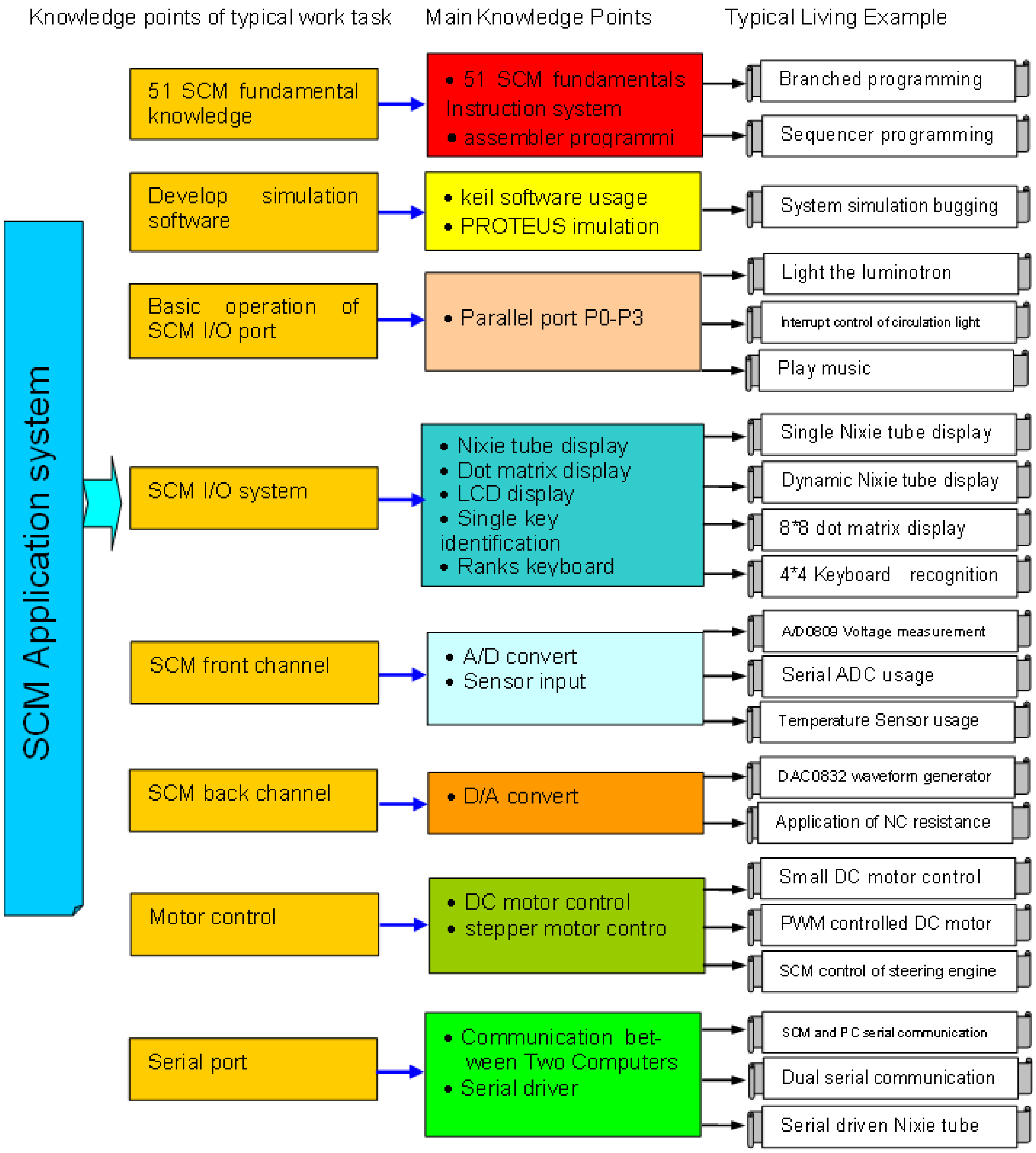

Figure 1. Course project modular

Adopt a teaching model in which the course is "teacher-dominant and student-oriented", and build a new "Teaching, Learning & Doing" integrated teaching approach

During the teaching of this course, the teachers flexibly applied various kinds of teaching methods. When giving lectures, "project task" was taken as a principal line, and an approach was adopted which integrated teachers' giving lectures with students' explaining, individual questioning with group discussion, and classroom teaching with post-class communication, taking the advanced model of international CDIO engineering education as a reference（Li, X., Xing, Y. and Wang, H，2021）. Through classroom lectures, symposia, short theses, comprehensive experiments and project training, heuristic and participative teaching was implemented, which promoted the students to harmoniously develop their knowledge, ability and quality, and trained their innovative spirit, practical ability, self-study ability, communication ability, teamwork spirit and social adaption ability.

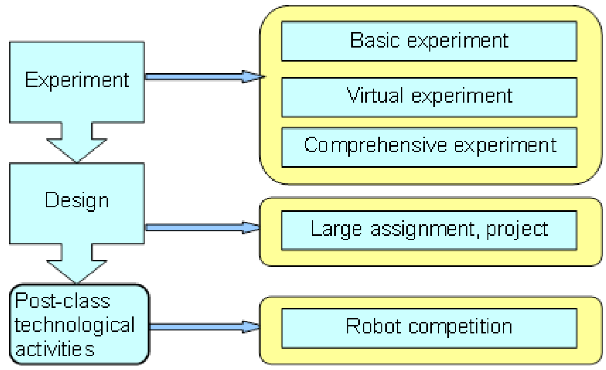

Figure 2. Practical teaching system for SCM securities

Figure 3. SCM course learning and practice site based on CDIO teaching model

Figure 4. Open-type SCM experimental system

The student-oriented concept was used to build the “Teaching, Learning & Doing” integrated task-driven teaching model. This model can be divided into three hierarchies, aiming to enable the students to proficiently master the project modular knowledge of typical work tasks based on the SCM application system. Hierarchy I refers to multimedia theoretical teaching and work task setup, and focuses on the teachers “Teaching” combined with the students explaining and discussing, as shown in Fig. 5. Hierarchy II refers to experimental teaching integrated with computer simulation training and hands-on practice to complete work tasks, and focuses on students “Learning”, as shown in Fig. 6. Hierarchy III refers to designing and producing, which means integrating project tasks and post-class technological activities to complete a mechanical system or piece of equipment with SCM as the main control unit. After conducting market analysis and survey, overall scheme demonstration and design, mechanical structure design, SCM control system design, system assembly and debugging, technical economical analysis and other processes, the students write technical reports and reporting drafts, and perform project reporting and on-site system demonstration and response. Via project learning based on the CDIO model, the students should understand that the development of SCM application systems is an iterative and constantly improved process. After ceaseless improvement in multiple links, a high-quality physical product will be completed as the final product. In this hierarchy, it places emphasis on the students "Doing" in order to give full play to their subjective initiative and train their innovative and practical abilities.

Figure 5. Group discussion and explanation of students

Figure 6. The Students conduct system assembly and debugging

Establish a formative evaluation approach that considers the students' learning process

After the course study is finished, in order to assess how well each student has mastered and applied each knowledge point, they shall be evaluated overall on the extent to which they have achieved the current course teaching targets through regular assignments, discussions, quizzes, experiments, individual reports, group reports, the final exam and other links. In the evaluation and examination of capability target achievements, the results of the final exam account for 50% and usual performance accounts for 50% (including with how much initiative the student participates in symposia, to what extent they focus on quizzes, how sensitive they are to new knowledge, how well they understand and apply new knowledge, what is their learning attitude reflected in post-class assignments and how deeply they consider and solve problems. Large assignments and symposia: 10%; experimental results: 10%; project learning: 30%). The detailed assessment and evaluation methods are shown in Table 2:

Table 2. Course teaching target evaluation matrix

Composition of results	Assessment/evaluation links	Grade	Assessment/evaluation rules
Usual results 50%	Usual assignments (including large assignments and classroom tests)	10	Mainly check how well a student revises, understands and masters the knowledge points of each class, calculate the average credit of all assignments and record as 10% of total grade.
	Experimental research	10	Each time, give an independent score according to the experimental scoring criterion and dependent upon the reviewing conditions, scheme design, experimental operation and quality of the

			experimental report of each experiment for each student, then average the credits of all experiments and record as 10% of total grade.
	Project learning	30	Comprehensively evaluate the various abilities of each student according to the project learning scoring criterion and dependent upon the group project design report, system completion and debugging level, technical report and response conditions, and through the teachers' evaluation and group members' mutual assessment, then record as 30% of total grade.
Final exam 50%	Final exam	50	The final exam shall be arranged according to the course teaching targets and grade hours. It shall mainly include 51 SCM fundamentals, numerical system conversion, instruction system and programming, memory expansion, timer/counter, interrupted application, parallel port application, man-machine interface, AD switch, DA switch and so on. The types of questions are divided between basic concepts (40%) and comprehensive application (60%).

In project learning evaluation, the results of each group and group member are determined by mutual evaluation between members and the evaluation of the teacher, and according to the system completion and debugging level, group cooperation and communication conditions, technical reports, response conditions and other learning results. Training in communications, lecture reporting and writing ability plays an important role in the entire project plan, which aims to train the students to use words and drawings accurately and proficiently according to the specifications in writing the technical reports, reporting drafts and statements.

Build a continuous course improvement mechanism which emphasizes feedback

In the course teaching process, according to student feedback and the analysis of students' learning achievements, students are required to an write an examination paper analysis, course summary and teaching reflections, and identify what could have been improved in the teaching of the course so as to make further improvements in the next teaching link.

CONCLUSION

This topic is based on the work process of the SCM course modular teaching model. The practical system has been wholly practiced in machinery majors since 2010 and possesses a certain effect and high actual significance and promotional value.

Based on the CDIO engineering education concept, the teaching method of the course "takes the project tasks as the principle line and ensures that the course is teacher-dominant and student-oriented" and adopts the "Teaching, Learning & Doing" integrated task-driven teaching model to create a relaxed practical teaching environment.

The model introduced herein diverges from the evaluation method of the traditional teaching model and builds diversified evaluation methods based on mastering disciplinary knowledge.

The results of the above teaching practices verify that the students are significantly cultivated in developing SCM application systems, as well as in their practical and innovative engineering capabilities.

REFERENCES

Bernhard, J., & Baillie, C. (2016), Standards for Quality of Research in Engineering Education, *International Journal of Engineering Education*, 32(6), 2,378–2,394.

Cleginaldo Pereira de Carvalho (2016), Project Based Learning: An Approach to One Robotic Cell Design, *Proceedings of the 12th International CDIO Conference*, Turku, Finland, June 12th–16th, 2016.

Graham, R. (2018), The Global State of the Art in Engineering Education, *Massachusetts Institute of Technology (MIT) Report*, Cambridge.

Malmqvist, J., Wedel, M.K., Lundqvist, U., et al. (2019), Towards CDIO Standards 3.0, *Proceedings of the 15th International CDIO Conference*, Aarhus, June 25th–27th, 2019, 1–24.

Li, X., Xing, Y. and Wang, H. (2021), Teaching Reform of "Linux Management and Application" Based on CDIO, *Proceedings of the 17th International CDIO Conference*, Bangkok, June 21st–23rd, 2021, 1–7.

BIOGRAPHICAL INFORMATION

Jianshu Cao is a Professor and Dean of the School of Engineers at the Beijing Institute of Petrochemical Technology. His current research interests include pipeline inspection technology and higher engineering education research.

Corresponding author

Prof. Jianshu Cao
Beijing Institute of Petrochemical Technology
No. 19 Qingyuan North Road, Daxing District,Beijing,102617, China
86-010-81292270
jianshu@bipt.edu.cn