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INDUSTRIALIZED RESEARCH EXAMPLES FOR TEACHING INNOVATIVE IDEAS IN UNDERGRADUATE RESEARCH AND PRACTICE: THE EXAMPLE OF METAL-LOADED ZSM-5-CATALYZED MTA REACTION

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ABSTRACT
With the rapid development of industry in the new era, green, efficient energy utilization occupies an important position, thus posing new requirements for practical and innovative skills of undergraduate students. In this paper, we use metal-loaded ZSM-5 catalyzed MTA reaction as an industrial practice example to investigate the process and significance of students' design in practical innovation courses. The catalyst research example is used to create a training system for students' problem identification, practical process evaluation and other competency development processes, to explore the influence of subjective or objective aspects that may be encountered during the practical process, and to investigate the significance of industrialized practical experiments for students' competency development.

KEYWORDS: innovative skills, process evaluation; ZSM-5

1. INTRODUCTION
Steadfastly following the path of industrialization and making efforts to promote high-quality development of industrial economy are important development goals of today's society and are of great significance for improving the overall socio-economic level. Therefore, the cultivation of high-quality innovative professionals with strong practical ability to serve the modernization construction has become one of the important tasks of higher education personnel training (Liao et al., 2022). Purely theoretical teaching can no longer meet the expectations of today's era for the competence of undergraduates. It is particularly important to design practical courses that meet the level of students' abilities according to the needs of today's industrialized technology, to cultivate students' innovative abilities and to improve their research level.

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In this paper, a practical course on industrialized topics is designed to exemplify the development of practical and research skills of students. The selected example is an experimental investigation of metal-loaded ZSM-5 catalyzed methanol aromatization (MTA) reaction according to the need of the times for efficient utilization of coal and other resources (Yang et al., 2017b), and the best type of catalyst is selected by comparing the catalytic effect of different types of metal-loaded ZSM-5 molecular sieves on MTA reaction (Yang et al., 2017a). This experiment trains students in all aspects of their abilities such as practical skills, data analysis, presentation and research skills. The analysis of the teaching effect results made the significance of such practical courses for the development of students' practical and innovative abilities (Wang et al., 2023).

2. Industrialized Research Experimental Course Ideological and Educational Process Module

2.1 Development of problem identification skills

In the practice of undergraduate teaching, we often emphasize the improvement of undergraduate students' ability to analyze and solve problems, but neglect the cultivation of students' ability to discover scientific problems, which is a worrying phenomenon. In scientific research activities, students consciously discover some valuable scientific theoretical or practical problems and actively investigate them (Denniston et al., 2017). In essence, undergraduate research problem awareness refers to the mental activity about research problems, which consists of three parts: cognitive, exploratory and behavioural tendencies towards scientific research.

The following diagram shows the design of the training process for developing students with an international perspective and the ability to discover:

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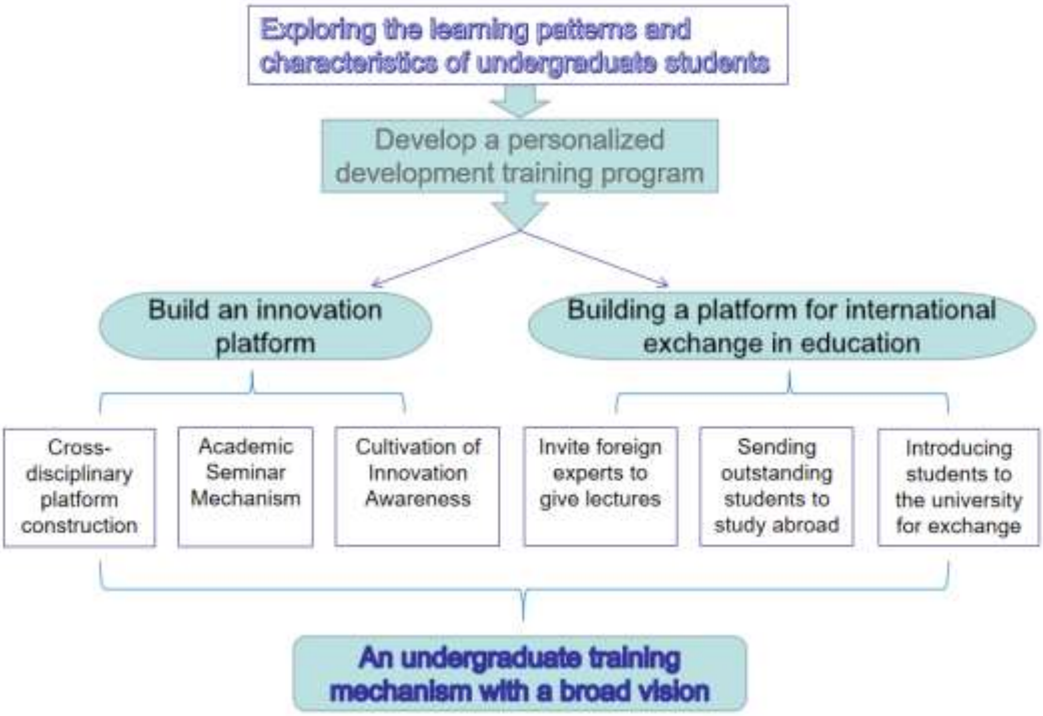

Figure 1. Design of discovery ability and international perspective cultivation

In the ZSM-5 catalyst preparation experiments, students can broadly propose the use of Cu, Fe, Ga and other metals to load the ZnZSM-5 molecular sieve by reviewing the literature and understanding the specific application scenarios of the industrial process. This process directly contributes to the students' knowledge of the research problem, the ability to explore (Salanova et al., 2012), and has this crucial role in the advancement of subsequent practical tasks.

2.2 Test the effect of practice through experimental process evaluation

The evaluation of the experimental process is very important for the evaluation of the results of the development of students' hands-on skills (Rababa, 2021). The evaluation of experimental investigation of metal loading ZSM-5 mainly contains attendance, lab report, students' self-assessment and mutual evaluation. Establishing an experimental process evaluation method that is both practical and meets the requirements of experimental teaching is one of the elements of the practical course design work (FERSTER, 1961). In the process of experimental teaching, the experimental process evaluation is included in the evaluation of innovation class, which can not only meet the requirements of student training, but also improve students' learning initiative and experimental hands-on ability.(Chang et al., 2016) However, effective evaluation of the experimental process is a relatively complex issue, which involves the evaluation of the whole experimental process, including all aspects of experimental

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preliminaries, experimental operation level, experimental attitude, experimental data and problem-solving ability(Shadle et al., 2012).

Based on an industrial example of metal loaded ZSM-5 catalyzed MTA reaction, a sketch of the practical process was designed as follows:

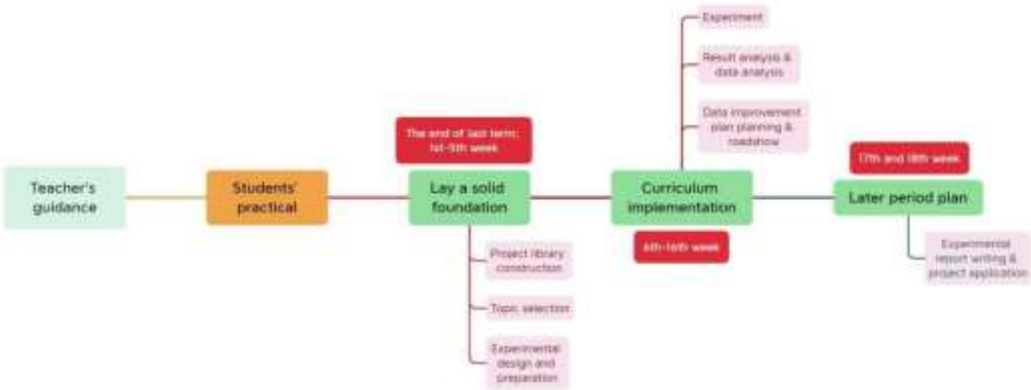

Figure 2. Practice design history diagram

In the process of ZSM-5 experiment, the products after various metal loads are tested and analyzed in time to finally determine whether they meet the standards. It can be seen that in the teaching practice, it is necessary to continuously try and improve in order to establish a set of effective evaluation mode, improve students' learning initiative and hands-on ability, and lay a good foundation for solving practical engineering problems in the future.

2.3 Reflection and growth at the end of the experiment

After each group of metal-loaded ZSM-5 molecular sieve experiments, the teacher should reflect and summarize the effect of the course in time, analyze the problems of instruments, experimental steps and students' motivation in the experiments (Fan et al., 2017), analyze the root causes of the problems and solutions (O'Connell and Kaur, 2019). First, whether the students can clearly and completely answer the questions raised by the teacher before the experiment; second, whether each student is actively involved in the experimental operation, for the students who are not highly motivated to ask the reasons; third, to screen the normal operation of experimental equipment, observe whether the students are operating in a standardized manner, whether to actively solve the various subjective and objective aspects of the problem(Ezeudu et al., 2019); fourth, after the experiment, whether the students on the experimental data to After the experiments, students analyze the experimental data in time and review them after questioning; fifth, whether there is a real improvement in students' learning ability and hands-on ability(Molenaar et al., 2011); sixth, whether the safety problems in the experiments are prevented and strictly supervised. Based on these issues, teachers should arrange suitable time in time to organize students to discuss and record the experimental results in class.

The following table reflects the time allocation and the summary of content allocation for each part of the practice process:

Table 1 Multi-dimensional evaluation system associated with the curriculum

Order number	Assessment contents	Assessment ability	Ratio(%)
1	Concluding report (experiment report)	Ability of write, analyze and summarize experimental reports	30
2	Experiment plan	Ability of consult, analyze and design experimental programs	20
3	Participation rate in spare time	Teamwork, cooperation and leadership	20
4	Students' mutual estimation	Team cooperation ability	10
5	Roadshow	PPT-making, language expression, project presentation, and resilience ability	10
6	Attendance and classroom performance	Attendance rate, experimental operation skills	10

After all the experiments are finished, teachers should reflect and summarize again with the pre-lab report, lab process evaluation, lab report and post-class discussion to optimize the teaching program design, so as to achieve the purpose of improving the teaching effect.

3. Influencing factors in the process of developing innovative ability

1. The level of students varies. With the increase of national education cost, undergraduate education is in the golden period of booming development, and the enrollment scale of engineering undergraduates is growing rapidly (Li, 2023), but from the enrollment situation, the quality of engineering undergraduates may have factors that are not conducive to the cultivation of their innovation ability.

2. Defects in professional theoretical knowledge education. In recent years, due to the increasing number of college graduates, the problem of shortage of education resources has gradually emerged. Compared with the undergraduates of public engineering colleges and universities which have been running for a long time, some colleges and universities which have not been running for a long time

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and are not highly qualified have a big gap in the mastery of professional knowledge due to the teachers' qualifications and school conditions (Ma et al., 2017).

3. The curriculum is not comprehensive enough. The study of undergraduate courses is a solid foundation for the cultivation of creative consciousness, creative spirit and creative ability. At present, most of the courses are limited to the teaching of basic subjects, and do not fully reflect the more cutting-edge knowledge. At the same time, in the process of selecting courses for undergraduates, due to the limitation of conditions, theory is emphasized rather than practice. Students' imagination and practical skills are as important as their knowledge, and education should cultivate students' individuality and creativity rather than excessive theoretical pile-ups. Undergraduates have fewer interdisciplinary courses, which involve narrower knowledge and lack the ability of comprehensive application of knowledge. The formation of innovative consciousness and the cultivation of innovative ability of undergraduates are often limited by these factors.

4. Lack of personalized guidance. Mentors do not have enough energy to guide and manage the daily study and research of undergraduates (Dai et al., 2019). It is not only related to the quality of undergraduate training, but also a key factor in the cultivation of undergraduate students' innovation consciousness and innovation ability. However, with the increasing number of undergraduates, the quantity and quality of supervisors' work cannot meet the needs of undergraduates' innovation cultivation. The lack of the most basic experimental conditions and financial guarantee makes undergraduates not get the opportunity to practice and innovate in the learning process.

4. The significance of industrialized research experiments for students' competence development

With the progress of science and technology in society, one can clearly see the significance of scientific experiments for the whole society. Quality education is focused on cultivating students' innovative spirit and practical ability, and undergraduate students can greatly improve their innovative and practical ability in the process of doing experiments. Industrialized practical experimental teaching reform is one of the important topics of current university teaching reform, which helps to cultivate students' ability to discover and think well, to work in a rigorous way, to improve constantly, to be pragmatic in quality, to be loyal, to have team spirit to coordinate with each other in division of labor, and to work hard on labor concepts.

Industrial research experiments can develop students' safety awareness. In the process of guiding students' experiments, instructors need to emphasize the issues related to chemical experimental safety and describe the relevant handling measures to effectively reduce experimental safety problems. As the experimental course continues to advance, the safety awareness training mode of "from teacher-initiated narrative to teacher-inspired student narrative to student-initiated narrative" is used to eventually train students to establish a conscious awareness of experimental safety and to develop conscious experimental safety habits, and to plant experimental safety awareness deep in their hearts.

Industrialized research experiments allow students to experience what it means to learn. Before students do the experiment, they will prepare themselves to understand what instruments, experimental procedures, and theoretical knowledge will be used in the experiment. During the preparation process, students will further consolidate their theoretical knowledge and appreciate the meaning of learning. During the experiment, students will also ask questions, which will also stimulate students' thinking skills and allow them to seek answers in the experiment, so that they can experience the effectiveness of learning.

Industrialized research experiments can speed up learning and improve learning efficiency. Scientific research shows that people can remember about 15% of the knowledge they acquire from verbal forms, while using visual and auditory senses simultaneously can receive about 65% of the knowledge. Experimental teaching makes students' various senses stimulated by letting them use their hands, eyes and brains, which prolongs students' intentional attention time and prompts the brain to synthesize and analyze the information transmitted by each sense, thus improving the thinking density of classroom teaching. Therefore, teaching science knowledge through experiments can make students' learning take the shortcut, take the straight path (Pretz and McCollum, 2014), and get more knowledge in less time, thus speeding up learning and improving learning efficiency.

Industrialized research experiments can stimulate students' interest. We often say that interest is the best teacher, as long as students have an interest in the experiment, then students will have motivation, the ability to accept knowledge will be greatly improved. Experiments can fully mobilize students' interest in learning, and students can intuitively feel the knowledge of books materialized. In the process of preparing experiments, students can also develop the ability to consult the literature, which is of great significance for undergraduate students to further their studies (Ma et al., 2017). This is of great significance for undergraduates to further their studies. Students' learning can be changed from "passive" to "active", and from "I want to learn" to "I want to learn".

Industrialized research experiments are the best opportunity and way to develop students' hands-on skills. Mentors create the conditions for each student to have enough hands-on time and opportunities, and encourage students to do it. Make them go from being afraid to not afraid, from not knowing to knowing. The mentor should also make a summary, point out the problems in the operation of the students and correct them, which have a positive effect on the standardization of student laboratory operations. At the same time, instructors should also encourage students to form their own experimental groups, independent choice of experimental topics of interest, so as to better train students' hands-on ability and innovation.

5. CONCLUDING REMARKS

Experimental teaching of industrialization research responds to the industrialization needs of the times and is an important part of training innovative talents and carrying out quality education, as well as one of the forms of teaching combining theoretical systems, basic knowledge, experience, ideas, methods and technologies, effectively cultivating students' basic qualities and innovative abilities. The cultivation of students' innovative ability depends on scientific practical activities, and the innovation process cannot be separated from practice; innovation without practice is also an empty dream. It can be said that experimental teaching is an important part of innovation education. More industrialized research experiments are needed by the society, and it is also a good strategy to cultivate wise talents.

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