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Study on engineering capability cultivation of postgraduate with university-enterprise joint projects

Wende Ke[1], Yan Wei[1], Chengzhi Hu[1], Yongsheng Ma[1], Dong Lu[1], Lei Kou[2], Yexu Huang[1,*]

[1]Department of Mechanical and Energy Engineering, Southern University of Science and Technology, Shenzhen 518055, Guangdong Province, China
[2]Institute of Oceanographic Instrumentation, Qilu University of Technology, Qingdao 266061, Shandong Province, China

ABSTRACT

The engineering capability of industry is very important for nation, especially in this fast developing stage of technology. Postgraduates are the candidates of engineering talents. We discussed the related works in current researches and policies of cultivation about postgraduates. Aimed at the problems in cultivating postgraduates' engineering ability in university & enterprise joint projects, the multi dimensional cooperation is proposed. First, the collaborative framework of cultivation is analyzed. Secondly, we proposed the directions that needs to be enhanced or weakened in cultivation procedures. Thirdly, three real cases were brought forth and analyzied while dealing with university-enterprise joint projects. The methods handled here are able to help those universities, mentors, postgraduates and enterprises altogether when improving postgraduate's engineering capability in university-enterprise joint projects.

Key words: engineering, joint project, postgraduate, enterprise

INTRODUCTION

Accompanied by the development and application of new rounds of computer science, robotics, artificial intelligence, biotechnology, *etc.*, the global industrial competition pattern is undergoing profound adjustments. Among them, the growth of engineering talents determine the direction of future socio-economic development. How to keep pace with the times and cultivate high-quality engineering innovation talents, especially leading talents, to cope with and lead the new industrial revolution is urgently needed.

Postgraduate engineering talents are key elements in enhancing national competitiveness. Combining postgraduate talent cultivation with enterprise research project is conducive to improving postgraduate talents' academic innovation and engineering practical abilities. This is an important attempt in the cultivation of postgraduate talents in higher education in China.[1,2] As of January 2024, China has cultivated more than 11 million postgraduates, with 3.65 million postgraduates enrolled in 2022. China Ministry of Education has proposed to cultivate the high-level innovative talents with a solid foundation, practical skills, and the capability to solve urgent technical problems for enterprises within three years.[3]

SOME RELATED RESEARCHES AND POLICIES

It is really a big challenge to make the engineering

***Corresponding Author:**
Yexu Huang, Department of Mechanical and Energy Engineering, Southern University of Science and Technology, 1088 Xueyuan Avenue, Shenzhen 518055, Guangdong Province, China. Email: huangyx3@sustech.edu.cn; https://orcid.org/0009-0002-7154-7049
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education and engineering practice closer.[4–6] Many foreign universities have carried out attempts and achieved this goal. For example, in 2017, the Massachusetts Institute of Technology (MIT) in the United States proposed the New Engineering Education Transformation (NEET) program, which couples engineering practice with leadership development, integrates various resources inside and outside the classroom, and forms a hierarchical and diversified engineering leadership education system to cultivate students' effective engineering leadership.[7] The University of California, Berkeley emphasizes the cultivation of practical experience and skills among postgraduates, actively promotes cooperation and exchanges with the industry, establishes multiple practical learning centers and innovation laboratories, and encourages postgraduates to autonomously choose research directions and topics to develop skills and capabilities in real engineering environments.[8] European countries promote engineering education mutual recognition programs through the European Network for Accreditation of Engineering Education (ENAEE), setting indicators such as knowledge and understanding, investigation analysis and judgment, engineering design and engineering practice, teamwork and communication, and lifelong learning abilities.[9] In Germany, the Accreditation Agency for Study Programs in Engineering, Informatics, Natural Sciences, and Mathematics (ASIIN e.V.) emphasizes in talent cultivation quality standards that students should possess engineering knowledge, technology, capabilities, interdisciplinary knowledge, and application capabilities, social responsibility and ethics, core qualifications, and socialization capabilities, including competitive foreign language qualifications in international environments.[10] The University of Edinburgh in the UK is committed to cultivating future engineers with professional knowledge and skills, teamwork, critical thinking, creativity and entrepreneurial spirit, resilience, adaptability, and flexibility.[11] In Japan, the engineering education professional accreditation agency emphasizes in the new version of accreditation standards the active learning mode with students as the main body, making the establishment of mechanisms to guide students' active learning a crucial indicator for accreditation, highlighting engineering design capabilities characterized by respecting needs and interdisciplinary crossing.[12] These universities have been involved in activities such as "joint cultivation" or "industry-academia-research cooperation" earlier and have accumulated a wealth of experience in coordination methods, technology transfer, knowledge sharing, *etc*.[13–16]

In accordance with its own development characteristics and the need for economic construction and high-level technical talent cultivation, China has promoted the development of joint university-enterprise graduate training. For example, in 1995, the "*Decision of the Central Committee of the Communist Party of China and the State Council on Accelerating Scientific and Technological Progress*" was promulgated, proposing matters related to joint training of postgraduates.[17] In 2004, the Ministry of Education issued the "*2003–2007 Education Revitalization Action Plan*"[18] mentioning the requirement to combine production labor and social practice in the process of graduate student cultivation to improve the quality. In 2010, the State Council issued the "*National Medium and Long-term Education Reform and Development Plan (2010–2020)*"[19] proposing to promote the "dual-supervisor system" for joint training of postgraduates by industry, academia, and research institutions. In the "*Opinions on Deepening the Integration of Industry and Education*" issued by the General Office of the State Council in 2018, it mentioned "promoting the reform of the combined cultivating model of professional master's degree postgraduates and enhancing the cultivation capacity of compound talents", thereby providing guidance.[20]

Currently, the postgraduate cultivation of university-enterprise joint project in China is flourishing, promoting the transformation of scientific research achievements in universities, the quality of cultivating high-end talents, and the accumulation of core competitive technologies for enterprises.[21,22] Many studies focused on the policies, strategies, methods and applications.[23–30] However, in the specific implementation process, inevitably, some problems and difficulties are encountered, such as the lack of sustainability in projects, unclear responsibilities of dual supervisors (from university and enterprise), frequent changes in research directions, excessive engineering orientation, occupying course class for project development, and arbitrary project progress arrangements. These issues make it difficult to ensure that postgraduates carry out specialized and in-depth research and technological breakthroughs in a specific academic field direction, which is not conducive to achieving the goal of cultivating high-level innovative talents. In fact, university-enterprise joint projects for cultivating postgraduates must fully consider the multidimensional synergistic relationship between the participants, simultaneously meeting the technical challenges of enterprise products while enhancing postgraduates' innovation capabilities and achieving the goal of higher education talent cultivation.

COLLABORATIVE FRAMEWORK AND FEATURES

As shown in Figure 1, the multidimensional collaborative framework of the university-enterprise joint

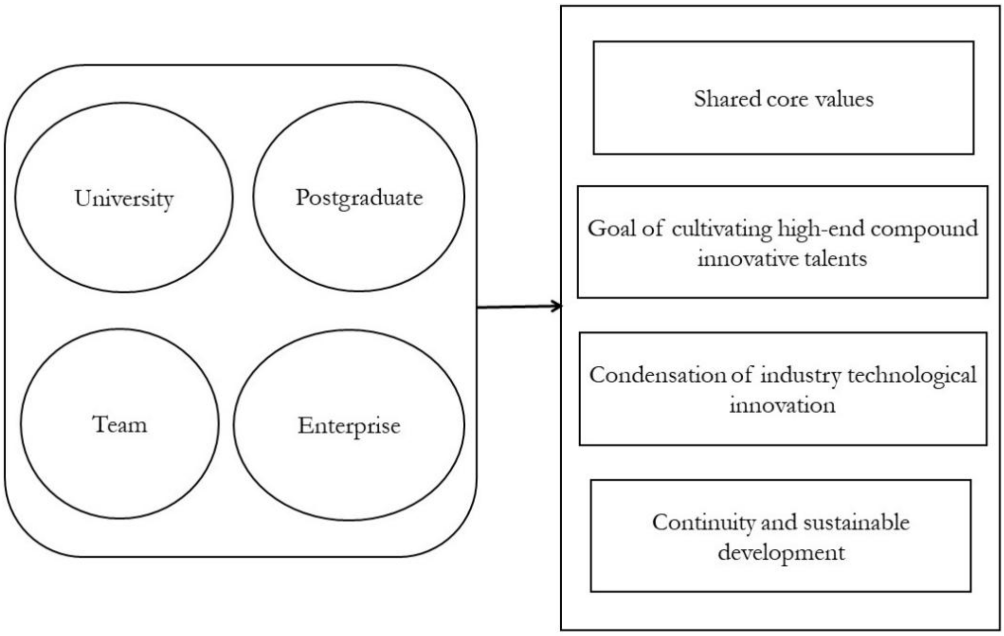

Figure 1. Multidimensional collaboration framework for cultivation mode.

cultivating model describes the relationships between universities, research teams, postgraduates, and enterprises, highlighting their close connections and shared development.

Reflecting shared core values

University-enterprise joint projects feature key technological breakthroughs and engineering innovation, involving multiple stakeholders such as universities, teams, postgraduates, and enterprises. These projects demonstrate mutual adjustment, long-term drive, and collaborative improvement, manifested through coordination, guidance, motivation, and evaluation, thereby enhancing project quality and talent development performance.

Specifically, enterprises develop new products based on market demands. By outsourcing key technological research topics to university research teams, they can achieve breakthroughs in core key technologies, leading to the industrial transfer of technology and the production of market-oriented products with higher cost-effectiveness and competitiveness. University research teams, in turn, gain insights into industry market demands during this process and actively participate in driving the iterative upgrading of industry key technologies.

Postgraduates, as the main participants, utilize this platform and opportunity to conduct research, enhance scientific literacy and key technological innovation capabilities, and achieve the public welfare goal of talent cultivation at universities.

Embodying the goal of cultivating high-end compound innovative talents

Cultivating high-end compound talents with the capability to meet economic and social demands and possess "high, refined, and cutting-edge" innovative capabilities requires engagement in innovative university enterprise joint research and development (R&D) projects. These projects primarily stem from the product R&D needs of high-tech enterprises, reflecting genuine market demands. Therefore, analyzing the key technologies involved in these products and identifying key breakthroughs may give the products advantages in terms of cost, quality, and utility.

For mentor teams of universities, identifying appropriate entry points from these key technologies, extracting scientific problems, defining meaningful research scopes and objectives, and conducting research can enhance the research capabilities of project participants. Postgraduates, under the guidance of mentors, identify research directions, actively participate in key technology R&D (research and development), cultivate a research spirit, learn research methods, master research tools, and gradually achieve advanced high-tech innovations.

Emphasizing the condensation of industry technological innovation

Typically, when postgraduates join a research group, they have limited understanding of industry technological developments, a narrow professional perspective, and weak foresight, making it difficult for them to accurately capture industry forefront research progress, hot spots, and challenging issues. Under the guidance of mentors, participating in university-enterprise joint R&D projects allows postgraduates to gradually experience and understand the real problems and scenarios faced by enterprise products, comprehend market demands and technical tough points, and thereby understand the current status and trends of industry development. This process enables postgraduates to perceive the industry's current situation from a broader professional perspective, aiding in self-positioning and establishing research directions, which are crucial for laying the foundation for their subsequent professional research and career. Once postgraduates have determined their specialized research areas, they can persistently conduct in-depth research from similar associated projects, enhancing their professional skills and industry insights, thereby reflecting better research outcomes.

Emphasizing continuity and sustainable development

University-enterprise joint projects seek to achieve a balance point of win-win cooperation between the economic interests and value demands of the enterprises and the talent cultivation public welfare value demands of the universities, ensuring fair distribution of benefits. By constructing a coherent and continuous collaborative mechanism among enterprises, universities, and postgraduates, integrating resources from all parties and optimizing them, a long-term harmonious and enduring cooperative relationship is formed. In this stable relationship, with the joint support of the university and the enterprise, postgraduates refine academic questions from engineering problems, propose feasible solutions, promote technological advancements in the industry, and establish a solid foundation for their subsequent career directions.

From the perspectives of master/doctoral supervisors and enterprises, they are also more inclined to choose postgraduates with relevant practical engineering R&D experience and key technological capabilities for cultivating or as key talent reserves, thus continuing the stable cooperation relationship.

STRATEGIES TO ENHANCE POSTGRADUATE'S ENGINEERING & INNOVATIVE CAPABILITIES

In university-enterprise joint projects, the engineering and innovative abilities of postgraduates serve as a more comprehensive component, encompassing aspects such as academic theories and methodologies, engineering technology and processes, market awareness, and competitiveness. As shown in Table 1, the directions that require enhancing or weakening are needed to consider carefully.

Openness for both academic and engineering

The openness of university-enterprise joint research projects reflects their characteristics of cross-regional, cross-industry, and cross-departmental collaboration, meeting the requirements of interdisciplinary complementarity and coordination. All participants can share resources and industry reputation, collaboratively advancing research innovation. Postgraduates act as the link between universities and enterprises, sharing resources from both sides and integrating high-end academic exploration of "scientific innovation" with the practical attempts of "engineering application". Mutual feedback promotes the cultivation of "high, refined, and cutting-edge" innovation capabilities.

During the first year of enrollment, postgraduates typically focus on studying professional courses at the university to strengthen their academic foundation. Therefore, it is not recommended for them to engage in project research and development too early. However, they can gain an understanding of existing project backgrounds and requirements, attend lectures from research teams and enterprise projects, and expand their learning in a targeted manner based on relevant courses. In the second and third years, when they start project learning and research, postgraduates can conduct continuous in-depth research on specific key issues. In terms of engineering, this involves multiple iterations of product characteristics. This dual-focus strategy of balancing academic and practical aspects should continue until their graduation.

Fast entry into projects

Typically, considering cost control and market demands, enterprises iterate their products quickly, leading to good economic benefits and a virtuous cycle from R&D to sales. The R&D cycle of individual university-enterprise cooperation projects is not long, usually not exceeding one year and even within 2 to 3 months. For university teams, maintaining a good cooperative relationship and continuously initiating new collaborative projects with enterprises are prerequisites for students' ongoing research. When the research cycle of a single project is short, it is essential to consider how postgraduates can quickly and keenly grasp the research content, determine feasible methods, master appropriate tools, and meet project goals within the specified timeframe. This process requires the postgraduate's mentor to survey the project and communicate fully with the enterprise and master's students before objectively determining a reasonable research schedule. There is usually a clear progression of technical achievements among milestones, reflecting a reasonable project arrangement.

Table 1: The features that need to be enhanced or weakened

Features	To be enhanced	To be weakened
Engineering capability	Directly participate in actual scientific research projects of enterprises	As limited by the needs of the enterprise May not meet the academic interests
Frontier research	Closely related to the current industry development trends and technological frontiers	The high research difficulty asks for high demand for the abilities and knowledge
Industry applications	The research results can be directly applied to the products or services of enterprises	Limit the depth and breadth of research and have not a wide spread impact in academic field
University enterprise joint	Enterprises provide practical platforms and resource, universities provide talent and intellectual support	Possible communication difficulties, inconsistent goals, and other issues may arise
Career development	Improve the employment competitiveness and career development space	Hard to make choices between corporate project and academic issue
Market demand	Understand market demand and industry trends Help to cultivate market awareness	Hard to keep a certain academic research under the frequent changing market
Solving issue	Be helpful to cultivate innovative thinking and problem-solving abilities	Affect the academic research and course learning

Some strategies may works based on the above analysis.

During project execution, participating postgraduates may encounter some challenges, such as unfamiliarity with research content, tools, and methods, especially for students new to project development with limited experience, leading to project delays or stagnation. Therefore, mentors, experienced senior postgraduates, engineers from enterprises, *etc.*, should provide sufficient guidance and assistance. They should extract key research points from project characteristics, assign suitable and challenging sub-problems to students, and provide timely and accurate help when they face research difficulties.

Resource utilization

University research teams typically have laboratories, equipment, and other resources that facilitate research activities for postgraduates. However, joint projects with enterprises may have specific product feature requirements, necessitating the provision of various resources and conditions by the enterprise. With rich project management experience and a high level of marketization, enterprises often possess unique engineering methods and market sales channels in their product domains, offering abundant software and hardware resources such as market research results, customer demands, design, processing, testing, and manufacturing facilities. These resources are suitable for technology transfer during project development. Research teams that leverage these resources, especially by building upon existing achievements through secondary development, can significantly reduce research cycles and improve research outcomes.

When seeking resource utilization, enterprises typically proactively provide research tools and their usage methods, previous product modeling and simulation results, control methods, and test parameters. For minor innovation requirements, postgraduates only need to optimize existing methods step by step based on the previous product development route to achieve better results through comparison. For major innovation requirements that involve exploring new research paths, postgraduates play a key role in tackling certain critical technical challenges while also coordinating and advancing efforts collaboratively. Seizing and implementing these opportunities can enhance postgraduates' project management capabilities.

Learning from senior engineers

Engineers in enterprises often have rich experience in product development in frontline research and engineering fields. They have participated in or led relevant product developments that have achieved good market benefits. They possess a deep understanding and experience in market demands, product characteristics, and key technologies involved. They provide direct guidance and assistance to postgraduates familiarizing themselves with industries and projects. Therefore, seeking technical research and development methods and skills, learning industry knowledge, product problem identification, and solution approaches from senior engineers helps postgraduates broaden their industry perspectives, enhance technical skills, quickly identify feasible research methods, and shorten project cycles. Especially at the beginning of a project when postgraduates have limited understanding of relevant technologies, guidance from senior engineers enables them to enter substantive research and development stages more swiftly.

In task allocation and management, due to overall workload constraints, senior engineers can only complete a portion of the work. The sub-problems undertaken by postgraduates may either be independent or partially overlap with the business content of senior engineers. When working independently, the interconnection between tasks may be minimal, suitable for postgraduates with some project development experience. When overlapping occurs, communication with senior engineers is facilitated, making it suitable for postgraduates entering projects for the first time. In either case, leveraging joint projects as a platform for assistance, conducting continuous and coherent in-depth research after clarifying research directions, can lead to genuine self-growth in theoretical and technical innovation for postgraduates.

Ensure the coherence of research direction

The joint research and development projects between universities and enterprises should primarily focus on cultivating postgraduates. Especially when research teams undertake multiple projects, the research content should be coherent or closely related. This is crucial for developing the continuous research capabilities of postgraduates in specific fields. Therefore, before undertaking joint projects with enterprises, master/doctoral mentors need to fully understand the postgraduates' training objectives, training duration, and existing research foundation. The primary goal should always be to cultivate postgraduates when taking on projects, selecting appropriate research directions, and tasks. If mentors fail to provide sustained and coherent guidance and research opportunities for students in a specific direction and repeatedly engage them in unrelated projects, it hinders the students from identifying their specific research direction and goals. Constantly switching research content across unrelated projects makes it challenging for students to engage in sustained and in-depth research in specific areas, which is not conducive to graduate student training.

Balance project development and course teaching relationships

As a mentor in class, course teaching should serve teaching objectives and talent development. Students have their own course learning tasks and come from different research groups with their research topics. Therefore, it is not suitable to organize students to conduct joint project during course teaching. However, introducing projects appropriately into courses has some significance. In some courses related to projects, limited integration of R&D projects as case studies into the teaching syllabus, such as market and enterprise needs, product characteristics, key technologies, and solutions, can be beneficial. After integrating these contents into teaching cases, students will have a clearer and practical understanding of the knowledge points. Introducing some already solved key technologies into course projects as students' R&D goals encourages them to integrate course knowledge with actual projects, actively learn and research, enhance their understanding of knowledge, and improve practical innovation capabilities, thereby achieving good teaching results.

Deeply understand enterprise demands

Enterprises, driven by market benefits, generally expect to achieve product key technology breakthroughs and results transformation at an appropriate cost and quickly. Their benefits lie in short product R&D cycles, relatively lower costs, enhanced functionalities, and ease of use, among others, with significant engineering characteristics. However, postgraduates usually have weaker engineering capabilities and may not meet enterprise demands at first. Therefore, mentors should deeply communicate with enterprises about project goals and determine the key technology development direction. They should also consider the postgraduates' professional foundation to ensure they work on improving their own capabilities. The convergence of these two lines reflects the consistency between project development and talent cultivation. It is important to note that postgraduates' R&D tasks focus on key technology breakthroughs rather than the entire new product realization process.

Communicate to resolve contradictions in the R&D process

Various contradictions may arise during the R&D process, such as failure to meet development task deadlines, difficulty achieving technical indicators, poor teamwork collaboration, personnel changes midway, ineffective cost control, long production cycles, minor quality improvements, *etc.* The root causes of these issues should be thoroughly investigated and addressed through effective communication. For instance, whether R&D task arrangements are reasonable, whether task volumes match postgraduate's capabilities, whether technical indicator settings are appropriate, whether research team members have varying research levels or unreasonable allocations, whether enterprise project managers have coordinated task progress and member arrangements effectively, and so on. It is crucial to define specific key technology breakthroughs that postgraduates should focus on, encourage them to periodically report progress, and seek help and support from their research groups, other groups, and experienced engineers from enterprises when necessary.

CASE ANALYSIS

Case one: coherent project (last for about or above 1–2 years)

Our research group has successively undertaken two joint projects with Leju (Shenzhen) Robot Technology Co., Ltd., each lasting for one year. On their Roban robot platform, we conducted research on humanoid robot kinematics and motion posture optimization to improve the robot's balance and smoothness during stair ascent and descent. The project team consisted of project managers, senior engineers, and postgraduates.

Initially, master's mentors and senior engineers guided the postgraduates in learning about humanoid robot kinematics, dynamics, and related modeling and simulation methods. Subsequently, the students independently conducted research and testing according to project progress requirements after consulting research literature.

These two projects involved four postgraduates in developing key technologies for humanoid robots, and the research content was consistent and coherent with the students' research directions. The students utilized and improved dynamic multi-objective optimization, neural networks, and reinforcement learning methods to optimize robot movements. Due to thorough preparation, complementary team capabilities, and organized communication within the project team, we achieved and optimized humanoid robot motion trajectories. The research outcomes included scientific publications, granted patents, improved Roban robot motion performance, leading to further support for postgraduate innovation projects and awards in competitions such as the China Robotics and Artificial Intelligence Competition. These achievements met the requirements of our corporate partners and successfully facilitated the graduation of the students.

Case two: course teaching example (last for about one semester)

Taking the professional course "Sensor and Driver Technology" for an example, this course targets both undergraduates and postgraduates, focusing on the basic principles and application methods of sensor and driver. In class, we appropriately introduced what we have achieved in the joint R&D project with China Shenzhen Zifu Medical Technology Co., Ltd., on the next-generation capsule endoscope robot. In order not to occupy teaching contents, we only used some few works as cases in class, to explain its principles and methods. We carefully combine it with teaching contents as the supporting materials. Surprisingly, four undergraduates and three postgraduates in class were willing to join in our team to develop this project further outside class. At the end of semester, we found that their course scores were not as high as those students only in class but they still passed the examinations. On the other side, their new prototypes showed excellent performance in real-time video data transmission, magnetic control effects, micro-motor driving, and even surpassed enterprise expectations in certain aspects (such as accuracy in positioning and micro-motor propeller control). Under the enterprise's fast and strong transfer, these prototypes were merged into new generation capsule endoscope robots. Therefore, it is crucial to balance classroom teaching, exams, and joint projects effectively.

Case three: short-term joint project (last for about 2–4 months)

Our research group collaborated with China Shenzhen Yijia Medical Technology Co., Ltd., on a project for traditional Chinese medicine ear and tongue area recognition and positioning. Three postgraduates specializing in image processing participated in the project, with research content aligned with their research directions at a broad level but differing at a detailed level. Students used and improved the active appearance model (AAM), the active shape model (ASM), and deep learning algorithms for contour partitioning and key point detection in ear and tongue images. To ensure clear division of work and specialization, students mainly worked on key technology development for ear and tongue recognition and partitioning based on ear and tongue image datasets, while company engineers developed ear and tongue partitioning application software using the improved algorithms in the Java programming language. Due to the short project period, students faced significant research pressure and had very frequent early-stage communications, which stabilized in the middle and later stages with reduced communication. The final algorithm met the company's requirements, although the actual project completion time extended to four months, exceeding the initial estimation. We regret that there have been no similar research projects later, which has affected the sustained research for postgraduates. From these projects, we have summarized as the following, and Table 2 shows the feedback from graduate students.

Mentors play a leading role in the entire cultivation process and also bear the greatest responsibility. some short-term projects involve a small number of postgraduates (such as 2–3 people). After these projects are completed, if there are no similar new research projects to continue, it will have a significant impact on the establishment of postgraduate's research directions and the cultivation of engineering abilities. Therefore, mentors need to follow a long-term and relatively fixed research direction and goals when selecting cooperative enterprises. For mentors who have not yet established too many connections with the enterprise, they will face great pressure, but they must adapt to this situation and bear the greatest responsibility.

The research direction of postgraduates and the research content of projects should be ideally coherent. If there are multiple short-term projects (*e.g.*, within 2–4 months) with little mutual relevance, participating students may struggle to determine their research direction effectively, hindering sustained and in-depth research in that area. This conflicts with the goals of graduate student talent development programs and should be noted by mentors. a suitable suggestion is that mentors should reduce the

Table 2: Feedback from postgraduates

Feedback	Advantage	Disadvantage
Improvement of practical ability	Participate in actual projects combining theory with practice accumulate practical experience	The pressure of checking research progress is high More time and effort are needed to learn new tools
Research subsidies	The subsidy amount is considerable Reduce economic pressure	There may be delays in subsidy distribution
Employment opportunities	The opportunity to directly work for joint training units More possibilities for career development	Employment opportunities are influenced by projects and enterprises
Experience	Contact and learn more knowledge Enrich life experience	Need to adapt to new living and working environments
Views on the future	More confident Being able to face greater challenges	Compared to senior engineers, there is a psychological gap

number of such research projects they undertake.

Providing assistance and being appropriately tolerant towards students, especially at the beginning of projects, is crucial. Mentors and senior engineers from the industry should collaborate to explain project characteristics and technical objectives to students, helping them to quickly engage in project development. In terms of scheduling, mentors should communicate with the enterprises to provide students with sufficient learning time and allow to experience the trial and error. Environmental support should be matched and complementary, with mentors providing on-campus support and enterprises providing off-campus support, enabling students to continuously focus solely on their research work.

When postgraduates participate in projects, they are not responsible for completing an entire engineering project but should focus on tackling key technologies extracted from the projects. They should delve deeply into a specific technical area which may be more academic and not engineering, while the commercialization of their technology should be handled by industry engineers. Overemphasizing the engineering process can distract students from in-depth academic research and may conflict with the responsibilities of industry engineers. During the project research process, some scientific questions will be extracted. Analyzing and conducting in-depth research on these issues can effectively enhance the academic ability of graduate students. Therefore, traditional academic activities, such as lectures, progress reports, *etc.*, can focus on these scientific issues and their solutions.

Course teachings must meet the requirement of professional curriculum arrangements, always with talent cultivation as the only goal. In class, organizing students to engage excessively in joint research and development projects with enterprise should be avoided, because it occupies the presetting learning contents. So projects in class shall be considered and planned very carefully if it is illustrated in class. Only a very small number of existing methods and conclusions need to be extracted from the project for students to verify.

CONCLUSION

We discuss the directions that needs to be enhanced or weakened in university-enterprise joint projects. Under the comprehensive coordination of mentors and industry partners, joint research projects can provide excellent research opportunities and platforms for postgraduates. The coordination with careful consideration helps to enhance students understand product characteristics and real industry needs, stimulates their research interests, keeps them abreast of disciplinary research progress, enables sustained and in-depth research in specific fields, upgrades existing methods and technologies through new methods and technologies, enhances their research innovation capabilities, and accumulates achievements. Simultaneously, it provides enterprises with more competitive new features for marketable products, achieving a win-win situation in university-enterprise collaboration.

DECLARATIONS

Author contributions

Ke WD: developed the concept for the manuscript, reviewed the literature, formulated research questions, collected the data, conducted analyses and interpreted the data. Wei Y developed formal analysis, investigation, visualization. Hu CZ and Ma YS organized resources, data curation and supervision. Lu D and Kou L developed original draft writing, review and editing. Huang YX developed conceptualization, methodology, validation and project administration, and funding acquisition. All authors have read and approved the final version.

Ethics approval

Not applicable.

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Conflict of interest

The author has no conflicts of interest to declare.

Data availability statement

No additional data.

REFERENCES

1. Wang LZ, Wang XP, Yuan WJ, Xie CC. [On Optimizing the Cocultivation of Postgraduates between Universities and Research institutes]. *Acad Degrees Grad Educ.* 2021(12):1–9.
2. Yu JX, Lin CY, Li ZM. [The Educational Value of Industry-Funded Research Projects in Universities]. *Acad Degrees Grad Educ.* 2022(3):51–56
3. [China has trained more than 11 million graduate students]. Uploaded January 4, 2024. Accessed 2024-7-8. http://www.moe.gov.cn/jyb_xwfb/s5147/202401/t20240104_1097971.html
4. Buckley J, Trevelyan J, Winberg C. Perspectives on engineering education from the world of practice. *Eur J Eng Educ.* 2022;47(1):1–7.
5. Lowe D, Goldfinch T, Kadi A, Willey K, Wilkinson T. Engineering graduates professional formation: the connection between activity types and professional competencies. *Eur J Eng Educ.* 2022;47(1):8–29.
6. Naukkarinen J, Bairoh S. Gender differences in professional identities and development of engineering skills among early career engineers in Finland. *Eur J Eng Educ.* 2022;47(1):85–101.
7. MIT. Capabilities of Effective Engineering Leaders. Accessed June 12, 2024. https://gelp.mit.edu/capabilitiesofeffectiveengineeringleaders
8. UC Berkeley Academic Program Review. *Guide for the review of existing instructional programs (Revised 2020).* Berkeley; 2022.
9. About ENAEE. ENAEE. 2014-11-19. Accessed July 8, 2024. https://www.enaee.eu/about-enaee/
10. *Criteria for the Accreditation of Degree Programmes-ASllN Quality Seal Engineering, Informatics, Architecture, Natural Sciences, Mathematics, individually and in combination with other Subject Areas.* ASIIN e.V.; .2015.
11. We engineer better futures. Uploaded April 14, 2023. Accessed July 8, 2024. https://media.ed.ac.uk/media/We+engineer+better+futures/1_nvkcza0w/39062631
12. Zhang ZX, Cai SF, Li LL. [Burden Reduction,Improvement of Quality and Efficiency:The Reformation Direction of Professional Accreditation of Engineering Education in Japan]. *Res High Educ Engin.* 2020(06):162–167.
13. Ancona DG, Caldwell DF. Bridging the boundary: external activity and performance in organizational teams. *Adm Sci Q.* 1992;37(4):634.
14. Santoro M, Chakrabarti A. Building industry–university research centers: some strategic considerations. *Int J Manag Rev.* 1999;1:225–244.
15. Carayannis EG, Alexander J, Ioannidis A. Leveraging knowledge, learning, and innovation in forming strategic government–university–industry (GUI) R&D partnerships in the US, Germany, and France. *Technovation.* 2000;20:477–488.
16. Barnes T, Pashby I, Gibbons A. Effective university-industry interaction: a multi-case evaluation of collaborative R&D projects. *Eur Manag J.* 2002(3):272–285.
17. Ministry of Science and Technology of the People's Republic of China. [Decision of the Central Committee of the Communist Party of China and The State Council on Accelerating scientific and Technological Progress]. Uploaded May 06, 1996. Accessed July 8, 2024. https://www.most.gov.cn/ztzl/jqzzcx/zzcxcxzzo/zzcxcxzz/zzcxgncxzz/200512/t20051230_27321.html
18. [Notice of The State Council approving the Transfer of the 2003–2007 Education Revitalization Action Plan of the Ministry of Education]. gov.cn. Uploaded March 3, 2024. Accessed July 8, 2024. https://www.gov.cn/gongbao/content/2004/content_62725.htm
19. [National Medium and Long-term Education Reform and Development Plan (2010–2020)]. Ministry of Education of the People's Republic of China. Uploaded July 29, 2010. Accessed July 8, 2024. http://www.moe.gov.cn/srcsite/A01/s7048/201007/t20100729_171904.html
20. *Several opinions of The General Office of the State Council on deepening the integration of Industry and education.* Uploaded December 19, 2017. Accessed July 8, 2024. https://www.gov.cn/zhengce/content/2017-12/19/content_5248564.htm
21. Li JL, Wan M, Pei X, Zhang SL. [On History,Characteristics and Tendency of Policy Reform and Implementation in Joint Postgraduate Cultivation in China]. *J Grad Educ.* 2016(6):8–12.
22. Zhao DX, Wang M, Lu HB. [Multi-agent Cooperative Training Mode for Engineering Professional Degree Postgraduates]. *Acad Degrees Grad Educ.* 2021(12):9–19.
23. Wu S, Zhang BS, Wang CH, *et al.* [Exploring the Practice Path of Collaborative Training of High end Pharmaceutical Talents between Schools and Enterprises from the Perspective of Chengdu Chongqing Linkage]. *Univ Educ.* 2024;(8):113-116+120
24. Huang XY, Liang XL. [How to Deeply Cooperate with Schools and Enterprises to Cultivate Engineering Master's Students: Exploration and Practice of Guangdong Province Graduate Joint Training Base (Foshan)]. *Acad Degree Grad Educ.* 2023;(8):1-6.
25. Zhang J, Li H, Ma XB. [The Model and Operating Mechanism of Joint Training of Translation Master's Students by Schools and Enterprises]. *Degree Grad Educ.* 2023;(8):7-12.
26. Liang CJ, Xiong SW, Fan T. [Reform and Practice of Industry Education Integration Graduate Training Model Based on Enterprise Demand Orientation]. *Degree Grad Educ.* 2023;(5):7-13.
27. Wang JS, Zhang W. [Exploration and Practice of Industry Education Integration Training for High level Professional Talents Facing Major National Needs]. *Degree Grad Educ.* 2022;(8):1-5.
28. Meng QH. [Discussion on the Cultivation Mode of Professional Master Degree Postgraduate of Vehicle Engineering under the Background of New Engineering: Taking the Vehicle Engineering Major of Hangzhou Dianzi University as an Example]. *China Mod Educ Equip.* 2022;(11):94-96.
29. Wang QJ, Xu XR, Yuan Z. [Collaborative Mechanism of Professional Degree Graduate Training Model—Based on Collaborative Innovation Perspective]. *Value Eng.* 2016;35(35):247-249.
30. Ma YH, Liu RZ, Yu MM. [Integrating Education with Enterprises to Cultivate Engineering Postgraduates]. *Degree Grad Educ.* 2021;(7):12-18.