Engineering Education Review

RESEARCH

Research on the Evaluation Index System of New Engineering Education Talent Cultivation Based on the Maturity Model

Jianxiang Xu[1], Haixia Qie[2], Jinhu Tao[3,*]

[1]Tianjin Light Industry Vocational Technical College, Tianjin 300350, China
[2]School of Education, Tianjin University, Tianjin 300350, China
[3]International Centre for Engineering Education under the auspices of UNESCO; School of Education, Tsinghua University, Beijing 100084, China

ABSTRACT

Constructing a talent cultivation evaluation system that adapts to the new engineering education is a reflection of responding to the new requirements of engineering education reform. Based on the maturity model and Conceive–Design–Implement–Operate (CDIO) framework, the research utilizes the Delphi method based on the Analytic Hierarchy Process to construct a talent cultivation maturity model and evaluation index system corresponding to the university training cycle. First, the influencing factors of the maturity of talent cultivation in new engineering education include five aspects, namely knowledge structure, social adaptability structure, ability structure, moral structure, and thinking structure. Each aspect contains several secondary elements. Second, a new engineering education talent evaluation framework has been developed, which includes five factors and four stages. The core elements of each stage are different, for example, practical ability is most prominent in the ability structure of the initial stage, while professional knowledge is most prominent in the knowledge structure of the maturity stage. Third, as far as the maturity score of the five dimensions are concerned, each stage gives priority to different dimensions. For example, in the mature stage, social adaptability structure and thinking structure are the most noteworthy, with a score of 9 for both. These research provides a systematic foundation for updating cultivation concepts and advancing the comprehensive restructuring of training paradigms and methods, thereby effectively enhancing the essential connotation of new engineering talent cultivation.

Keywords: new engineering education, maturity model, evaluation index system

INTRODUCTION

Against the background of a new round of technological revolution and booming industrial transformation, countries around the world are in a critical period of economic restructuring and upgrading. The industrial development process is being accelerated by emerging technologies such as artificial intelligence, cloud computing, and big data, which are also reshaping the production logic, value system, and human lifestyle of industries around the world. In fact, technological iteration is also reshaping people's expectations and focus on the ability elements of engineering and technology talents, affecting people's judgments on the quality standards of engineering education and the ability structure of engineering talents.

New engineering education is a strategic response to

***Corresponding Author:**
Jinhu Tao, International Centre for Engineering Education under the auspices of UNESCO/ School of Education Tsinghua University, Beijing 100084, China.
Email: taojinhu@tsinghua.edu.cn; https://orcid.org/0000-0003-4316-0795
Received: 22 June 2026; Revised: 14 October 2026; Accepted: 18 October 2026
https://doi.org/10.67229/eer.26100009

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License, which allows others to copy and redistribute the material in any medium or format non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.

new challenges in engineering education, and a key reform issue to optimize the ability structure of engineering talents, improve the quality of engineering talent training, and cultivate professional talents suitable for future social development. To accelerate the development of the outstanding engineer system, the Ministry of Education of China developed the *Accreditation Criteria for Excellent Engineers Education* (Ministry of Education, 2025) in 2025. Guided by the cultivation of outstanding engineers, the policy continues to drive engineering education reform as a driving force, aiming to establish a distinctive Chinese system for training engineers. The National Science & Technology Council (2024) proposes pillars for Science, Technology, Engineering, and Mathematics (STEM) education in the next five years, including STEM Research and Innovation Capacity, STEM Workforce, STEM Teaching and Learning, STEM Engagement, STEM Environments. The UK Royal Academy of Engineering (2025) believes that the "*Engineers 2030*" strategy is both a task deployment and a warning, depicting the key image that engineers should possess in 2030 and beyond. Future engineering and technical personnel should not only possess excellent skills, but also have a sense of social responsibility, public trust, and business awareness. The Singapore Ministry of Education has proposed a "21st Century Competencies" that is also aimed at future engineers. Its core is Social Motivational Competencies such as self-awareness, self-management, and responsible decision making, followed by specific skills such as communication, collaboration, and information skills (Ministry of Education Singapore, 2026). The EU STEM Education Strategic Plan explicitly states that it is necessary to strategically and fully utilize its most important asset - human capital, play a strategic leading role, and enhance the quality and level of talent (European Commission, 2025).

Constructing a quality standard system that meets the requirements of engineering education and building an evaluation index system based on it is a key path to follow the concept of "returning to the essence of engineering education". But, consistent with the CDIO philosophy, we believe that technical competence is a type of instrumental ability that is often embedded in the various abilities of engineers, and the key to its development is still the construction of general abilities for engineering talents. Moreover, previous studies have not explored the key focus of ability structure in conjunction with the development stages of new engineering education talents, and have overly emphasized static characteristics. This study combines the CDIO engineering education model outline and the analysis of social and economic needs to explore the influencing factors of the maturity of new engineering education talent cultivation. Based on the capability maturity model and the periodic characteristics of school cultivation, a stepped engineering talent cultivation quality maturity model and evaluation index system are constructed. This provides theoretical support for comprehensively supervising, judging, and detecting the quality of engineering talents, weighing the contributions of universities in industrial technology, social economy, and other aspects, and further formulating and improving the Chinese standards and models for new engineering education professional construction and talent cultivation.

INFLUENCING FACTORS OF THE MATURITY OF NEW ENGINEERING EDUCATION TALENT CULTIVATION

When Lin Jian (2017) was exploring the construction of new engineering education, he proposed that the main goal of the construction was to cultivate a group of engineering and technological talents with the ability of innovation and entrepreneurship, cross-border integration and high quality, who are compound. *The Washington Accord* put forward 11 requirements for the graduation of engineering students, namely engineering knowledge, problem analysis, design/development of solutions, investigation, tool usage, the engineer and the world, ethics, individual and collaborative team work, communication, project management and finance, and lifelong learning. Many elements such as knowledge, skills, innovation, teamwork and morality provide more explicit phased goals for the process of talent cultivation.

The new round of industrial revolution requires new engineering education talents not only to be specialized, but more importantly to be trained in comprehensive perspectives in economy, science and technology, politics and other aspects, so as to predict and respond to the new trends of future world development. The requirements of society for the renewal, paradigm shift and reconstruction of the concept of engineering talent cultivation include a broad knowledge system, comprehensive professional quality, analysis and research of complex engineering problems, responsibility and ethics, communication and teamwork, leadership and lifelong learning and innovative development (Lin, 2020). Under the global perspective of engineering education, the CDIO engineering education model clearly divides the knowledge, skills and attitudes that modern engineers must possess, involving professional skills and ethics, interpersonal communication skills, mastery of skills and knowledge, and the conception, design, implementation and operation of systems (Tao & Shang, 2006). Drawing on the CDIO engineering education model and the demands of the economic society, the maturity of talent cultivation within new engineering education is shaped by several influencing factors: knowledge structure, social adaptability structure, ability structure, moral character structure, and thinking structure.

CDIO and maturity model complement each other. The study elucidated the five dimensions of talent cultivation maturity based on CDIO, and analyzed the highlighted elements of the five dimensions in different stages based on the maturity model.

Knowledge Structure

In the context of new engineering education, possessing a broad and extensive knowledge structure has become the foundation for engineering talents to cope with interdisciplinary integration development and gain advantages in the fierce competition of the information age. Therefore, new engineering education talents not only master professional knowledge in the field of disciplines, but also achieve interdisciplinary integration and innovation through learning relevant subject knowledge. Engineering knowledge closely related to professional disciplines is the foundation of engineering talents. Different knowledge nodes are interconnected to form a cross integrated knowledge network, and a personalized engineering knowledge system is constructed. Through continuous self-regulation, it adapts to technological development, knowledge updates, and exploration and innovation in emerging or unknown fields.

Social science knowledge and basic science knowledge play a fundamental role in the entire engineering knowledge system (Budiman & Irawan, 2023). The non logical thinking generated by the broad humanistic knowledge content complements the logical thinking formed by social science knowledge and basic science knowledge, which is conducive to broadening students' horizons, activating their thinking, and benefiting the ability of future engineering talents to adapt to society. In order to avoid cultivating "one-dimensional individuals" bound by their profession and causing the "spiritual emptiness" brought about by utilitarianism, general education follows the cultivation concept of "complete individuals", promotes students' understanding and mastery of interdisciplinary knowledge and basic skills, and cultivates humanistic literacy and comprehensive qualities that reflect value care. This is the comprehensive embodiment of value rationality education in the new engineering education reform (Kelly, 2008).

Competency Structure

Under the background of the new industrial revolution, the formation of a diversified ability structure, including scientific research ability, practical ability, innovation ability, transferable skills and management ability, is an important way for new engineering education talents to meet the future development needs of society. Unlike the ability to acquire information through learning, research ability is a creative process of actively exploring new situations and topics by quickly discovering and analyzing problems. Kuhn (1997) pointed out that between the two industrial revolutions, most researchers solved the "difficult problems" in their field according to the rules provided by peer-reviewed norms. In the latest engineering revolution, the research ability of engineering talents is reflected in solving the problem of matching between the new technology with the Internet as the core and social development according to the currently recognized norms of science.

To cultivate outstanding engineering talents in new engineering fields, it is necessary to follow the laws of engineering education, establish a correct view of engineering education, change the traditional thinking mode of "emphasizing knowledge over action", and return to engineering education practice (Song, 2026). In the process of practice, if one can ignore the chaotic flow of information and focus wholeheartedly on the research cause, they will eventually develop an ability - the ability to determine whether two things have the same basic elements and confirm their equivalence. This ability constitutes the fundamental source of transferable skills and innovation and creativity. Engineering talents with innovative and entrepreneurial abilities, as well as transferable skills, can better meet social needs, serve national strategic development, and enhance the international competitiveness of engineering education (Wang, 2025). Management ability, as the cornerstone of the high-level training objectives for leaders in new engineering education, relies on universities relying on linked project platforms to establish precise standards, and dynamically and timely calibrate the gap between actual level and efficiency standards based on project research progress and completion status (Song et al., 2023).

Moral Structure

Throughout each stage of the development of new engineering education, innovation exists, introducing uncertainties and additional choices. The reform of engineering education is gradually transitioning to the new engineering phase precisely through the process of making choices and determinations. Fostering virtue and nurturing talent is the fundamental task of education, and it is essential to guide the transitional phase of engineering education reform with "virtue." In the process of cultivating talent in new engineering education, efforts must focus on guiding the direction of talent development through moral elements such as personal cultivation, social morality, and professional ethics (Martin et al., 2021).

Personal cultivation refers to the refinement and nurturing of an individual's cognition, encompassing self-awareness, self-examination, and self-improvement, which influence an individual's behavior through intangible forces. As an individual's outlook on life and the world continuously evolve in response to their surround-

ing environment, scientific cognition, emotion, and willpower prompt the individual to constantly reflect on the gap between their actual level and their ideal state. In contrast to the focus on individual cultivation, Adam Smith, based on the most fundamental human emotion of "sympathy," regarded social morality as reflecting the conventions and norms driven by common social interests. In the field of engineering, this norm is concretized into engineering ethics, which adjusts the relationship between engineering technology and social interests, serving to regulate the conduct of engineers (Yan & Hong, 2008). Professional ethics, centered on balancing the interests of individuals, the industry, and society, primarily reflects the interest demands of specific professions and sectors.

While strengthening students' engineering ethics and morality, integrating professional ethics into daily teaching activities to cultivate engineering talents who possess national cultural identity, a sense of responsibility for national interests, and a commitment to sustainable development constitutes an accelerated pathway for realizing the modernization of industry. The reform of new engineering education has diversified the values inherent in engineering. The emergence of emerging technologies such as big data, artificial intelligence, and aerospace has increased the reliance of engineering talent on judgment concerning the value of engineering activities. Consequently, the operation and impact of engineering activities are highly dependent on the professional ethics of engineering talent.

Thinking Structure

Way of thinking determines scientific achievement. Newton's methodology, based on Euclid's axiomatic system and Ptolemy's exploration of the laws of celestial motion, extended the principles of mathematics to the field of natural science, and expanded from the laws of celestial motion to the exploration of the laws of the world. This approach was later summarized by later generations as mechanical thinking, which directly gave rise to industrial civilization. In an era represented by technologies such as big data and artificial intelligence, the deterministic assumptions of mechanical thinking hinder the development of engineering talents. In contrast, the formation of computational, critical, dialectical, and innovative thinking serves as the cornerstone for future engineering talents to transcend cause-and-effect relationships and establish correlational analysis for problem-solving. Computational thinking, within the realm of scientific thinking, is a form of thinking characterized by abstraction, programming, and automation, focusing on problem-solving. The research and application of artificial intelligence and big data, grounded in computational thinking, have expanded humanity's capacity to understand and solve problems. *The Washington Accord,* in its published *Graduate Attributes and Professional Competencies*, has added "computational thinking" (Li et al., 2025). Furthermore, China's newly issued *Engineering Education Accreditation Standards (2024)* has also incorporated "computational thinking" into the graduation requirements for engineering students.

In the cultivation of engineering talents, the core value of critical thinking and dialectical thinking lies in guiding students to grasp the inherent contradictions of things and the connections among their various aspects from a holistic perspective (Patchamuthu, 2020). This ability is particularly crucial in the era of information explosion—it enhances students' capacity to select, understand, and evaluate in the face of massive knowledge, deepens their insight into the essence and laws of development, thereby effectively resisting the intrusion of various negative ideologies, and strengthens the adaptability and leading capacity of the new generation of engineering talents in the new industrial era. Based on the essence of engineering activities as the creation of objects (Liu, 2012), coupled with new disciplinary connotations, new engineering technologies, and new societal demands, innovative thinking has become the key to cultivating engineering talents.

Social Adaptation Structure

Yuval Noah Harari (2017) believes that the educational revolution is a key force in changing the differentiation between the elite class and the proletariat brought about by the grim prospects of artificial intelligence. Eric Schmidt, Chairman of Google, points out that education systems worldwide are not equipping students with the skills to coordinate with increasingly intelligent machines or the abilities to adapt to a more intelligent future society. (Eric Schmidt, 2014, as cited in Wang, 2017) "The ability to skillfully leverage external tools" is the essence that distinguishes humans from other living beings. The role that machines and other tools play in human productive activities is undergoing a transformation. In primitive, slave, and feudal societies, humans had already begun using tools such as stone implements, bronze, and iron to compensate for the limitations of their senses, engaging in social production activities dominated by humans. With the advent of machines, they began to directly participate in productive activities, transforming the mode of production. Competition, once existing solely among humans, has expanded to encompass competition both among humans and between humans and machines, with machines becoming participants in the contest for productive value.

In the process of coping with a future highly intelligent society, how to avoid becoming a "useless class" jointly eliminated by natural selection and artificial selection has become a fundamental issue. Social adaptability skills—

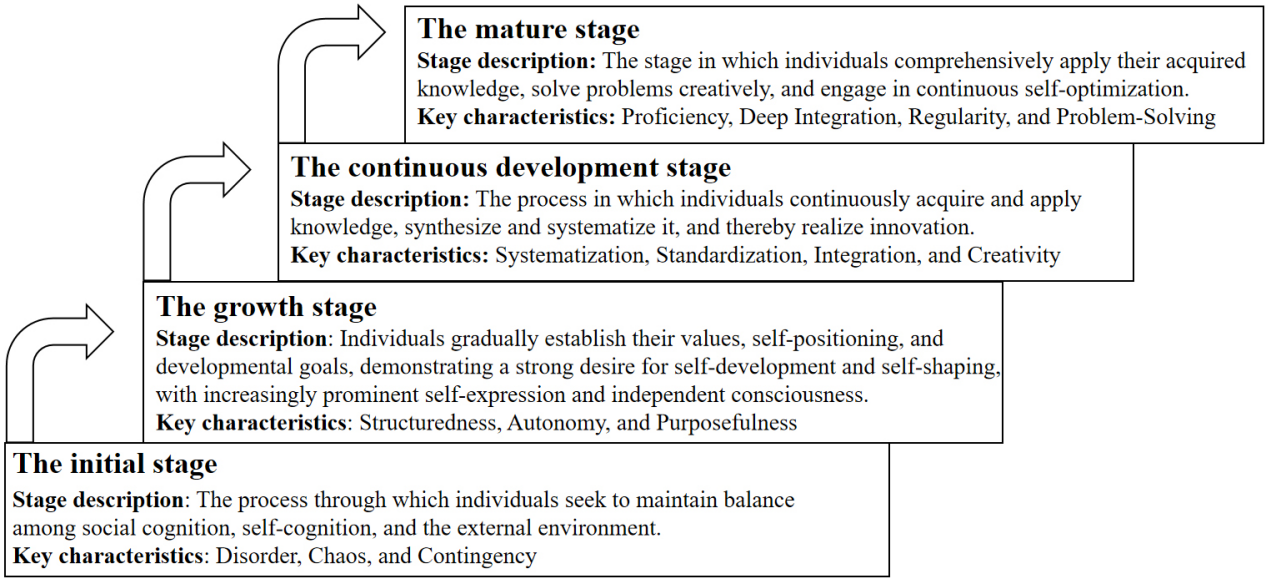


Figure 1. Maturity levels of talent cultivation

such as communication, cooperation, collective consciousness, teamwork, and lifelong learning—are increasingly becoming the most powerful weapons for individuals to resist technological alienation and grasp the transformations of the era. They also serve as the critical fulcrum for driving profound reform in engineering education.

CAPABILITY MATURITY MODEL FOR TALENT CULTIVATION IN NEW ENGINEERING EDUCATION

The Capability Maturity Model (CMM) (Akhlaghpour & Lapointe, 2018) first emerged in 1987 at Carnegie Mellon University. With strong support from the U.S. Department of Defense and other agencies, it has since evolved into various forms, including CMM 1.1, CMM 2.0, SW-CMM, and P-CMM. These models are divided into five maturity levels: Initial, Repeatable, Defined, Quantitatively Managed, and Optimizing.

Based on the classification criteria of the CMM and the periodicity of student cultivation, this study divides the maturity of talent cultivation in new engineering education into four stages—the initial stage, the growth stage, the continuous development stage, and the mature stage—corresponding to the four phases of the undergraduate cultivation cycle in colleges and universities. Each stage specifies the tasks to be accomplished or the contradictions to be resolved at that stage, namely the knowledge, abilities, and competencies that engineering talents need to acquire during that phase, as illustrated in Figure 1. The CMM model presents a progressive developmental trajectory and can serve as a model framework aligned with the stages of talent cultivation. The capability level at each grade serves as the foundation for engineering talents to reach the next higher level, and the process of continuously upgrading maturity corresponds to the gradual enhancement of engineering talents' capability levels.

Initial Stage

The initial stage of talent cultivation in new engineering education generally corresponds to the first year of the undergraduate cultivation cycle. According to Erikson's theory of psychosocial development, students at this stage are in a transitional period between the fifth stage, "Identity vs. Role Confusion," and the sixth stage, "Intimacy vs. Isolation," representing a critical period for exploration. First-year students, having just completed their secondary education, are accustomed to the passive learning methods and thinking patterns of high school. Their abilities to actively acquire information and engage in self-planning require improvement, making them prone to exhibiting disorder and confusion in the learning process, which results in the acquisition of learning outcomes being highly coincidental. During the initial stage, students face the tasks of quickly adapting to university learning and life, clarifying their self-role positioning, and pursuing self-development. This stage is critical for individuals to seek social cognition and self-cognition while maintaining balance with the external environment.

As the starting point of the maturity model, the initial stage lays the foundational role for the entire learning journey. Timely and correct guidance in helping students respond positively to the new environment can assist

them in maintaining enthusiasm for their professional studies. The focus of talent cultivation in the initial stage is primarily on the acquisition of foundational knowledge and abilities. The trend toward the integration of disciplines and specialties makes general education—such as humanities and social sciences—an indispensable foundational accumulation for engineering students at this stage.

Practical ability enables engineering talents to transform engineering activity planning into practical operations, reflecting the qualities and potential to address problems related to design, implementation, and adjustment. Personal cultivation, which primarily represents the active exercise of individual subjective initiative, runs through the entire process of talent cultivation in the development of new engineering education.

Growth Stage

The growth stage of talent cultivation in new engineering education corresponds to the second year of the undergraduate cultivation cycle. During this period, students' identity continues to deepen, and they begin to confront more substantive issues of self-positioning. Following the learning and development achieved in the initial stage, general knowledge and humanistic literacy have laid a broad foundation for the acquisition of professional knowledge. Through active participation in professional learning and organizational activities, students' individual values, self-positioning, and developmental goals are gradually established. They exhibit strong willingness for self-development and prominent self-awareness, demonstrating initiative in setting learning goals and absorbing effective information in a structured and systematic manner during the learning process.

Initiative and ideals serve as important tasks for college students to accomplish during the growth stage. This stage is crucial for students to enhance their thinking abilities, establish a clear self-positioning, and develop their professional roles (Yi & Zhang, 2015). The study of foundational scientific knowledge in the growth stage, combined with the conception, analysis, implementation, and evaluation of projects within the cultivation process, forms the scientific research ability of engineering students to explore the essence of things, laying a solid foundation for the study of professional courses in the continuous development stage.

The accumulation of knowledge and abilities remains a task for students to accomplish during the growth stage and serves as the supporting force for the development of their thinking. In response to the growth stage of talent cultivation, universities promote the positive transformation of the primary contradictions at this stage by offering courses in critical thinking and analysis, as well as organizing cooperative and extension activities.

Continuous Development Stage

The continuous development stage of talent cultivation in new engineering education corresponds to the third year of the undergraduate cultivation cycle. In terms of professional learning, students have gained an in-depth understanding of the scope and content of their chosen discipline, enabling them to integrate knowledge into their own practice and form a logical system and knowledge framework. In terms of developing abilities and thinking, students are able to assess their own developmental progress and reflect on their personal state. The learning process in the continuous development stage is characterized by systematization, standardization, creativity, and integration. It is a process in which individuals continuously acquire and apply knowledge, integrating and developing it to achieve innovation.

Building upon the learning level achieved in the growth stage, the continuous development stage requires mastering instrumental knowledge to cope with a rapidly changing world, and attempting to systematically manage acquired knowledge and abilities through dialectical thinking to enhance the identification and utilization of information. Universities should vigorously encourage students to actively participate in practical activities, use theoretical frameworks to contemplate real-world problems, and focus on the process of cultivating thinking. Furthermore, students should proactively construct a moral system that encompasses both social morality and personal cultivation, thereby achieving continuous development.

Mature Stage

The mature stage of talent cultivation in new engineering education corresponds to the final year of the undergraduate cultivation cycle. Following the cultivation in the initial stage, growth stage, and continuous development stage, students have completed the study of professional knowledge and professional skills. During the learning process, they demonstrate proficiency and deep integration of knowledge, enabling them to proactively identify problems in project training and conduct research, continuously optimizing their own knowledge system and skills.

The mature stage represents the highest level of the talent cultivation maturity model and also serves as the starting point for individuals entering society. Integrating the four-year learning journey and establishing social awareness become the primary psychological tasks. Engineering talents at the mature stage need to deepen their study of professional knowledge based on the foundation established in the continuous development stage, cultivate a mindset of "lifelong learning," achieve the ability to transfer knowledge and capabilities, and develop innovative thinking as well as innovation and

Table 1: Hierarchical Structure of Maturity Levels for Talent Cultivation in New Engineering Education

Stage	Evaluation Dimension				
	Knowledge Structure	**Ability Structure**	**Social Adaptability Structure**	**Moral Structure**	**Thinking Structure**
Initial Stage	General Knowledge	Practical Ability	Communication and Exchange	Personal CultivationSocial Morality	Computational Thinking
Growth Stage	Foundational Scientific Knowledge	Research Ability	Cooperative AbilityCollective Consciousness	Personal CultivationSocial Morality	Critical Thinking
Continuous Development Stage	Instrumental Knowledge	Management Ability	Team Collaboration	Personal CultivationSocial Morality	Dialectical Thinking
Mature Stage	Professional Knowledge	Transferable Skills Innovation and Entrepreneurship Ability	Lifelong Learning	Social MoralityProfessional Ethics	Innovative Thinking

Note: *Artificial intelligence capability is a horizontal capability that may be embedded in various capabilities, such as Instrumental knowledge of artificial intelligence, research capabilities based on artificial intelligence, etc.*

entrepreneurship abilities.

As the ultimate destination of talent cultivation, the mature stage fosters a multi-level competency structure encompassing knowledge, abilities, thinking, moral character, and social adaptability. This structure helps engineering talents meet the demands of the engineering activity chain required by the ever-changing technological era, supports their capacity for continuous self-development, and leads the economic development driven by future engineering industries. The structure of the maturity-based talent cultivation framework for new engineering education is shown in Table 1.

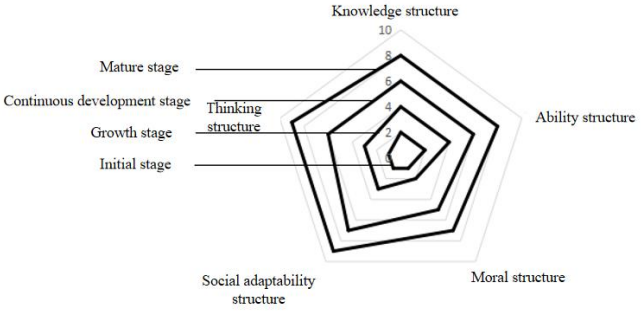


Figure 2. Hierarchical structure of talent cultivation maturity levels

DESIGN OF THE CAPABILITY MATURITY EVALUATION INDICATOR SYSTEM

Based on the descriptive analysis of the stages of talent development in higher education institutions, a capability maturity evaluation indicator system is constructed, consisting of five dimensions: knowledge structure, ability structure, moral structure, social adaptability structure, and thinking structure. The maturity level of the evaluation indicators across these five dimensions determines the overall maturity of talent cultivation in new engineering education. The hierarchical structure of these factors is illustrated in Figure 2.

Evaluating talents in new engineering education involves a complex indicator system that encompasses both qualitative and quantitative indicators. Given the comprehensive nature of the indicator system, the evaluation of talents can employ the Delphi method based on the Analytic Hierarchy Process (AHP) to calculate the weights of each indicator. When introducing the Delphi method, there are four operational steps involved. Firstly, the experts and research questions in the intended field were identified. Secondly, distribute the research materials to various experts and have them independently score. Thirdly, wait for consensus among experts to output a conclusion with consensus, otherwise it will be necessary to re-evaluate. Finally, organize all the results. When introducing the AHP method, there are three operational steps involved. Firstly, decompose the core objective into multiple hierarchical sub objectives; Secondly, synchronously compare the importance of ratings between different dimensions and form a judgment matrix based on scores ranging from 1 to 10; Finally, organize all the results to form weight index. Specifically, AHP integrates both quantitative and qualitative approaches by decomposing a complex objective into several hierarchical sub-objectives until data can be obtained. The highest-level objective is termed the goal layer, while the lowest-level objective is termed the indicator layer, with the intermediate levels potentially consisting of multiple tiers. By constructing this hierarchical structure, the importance of each pair of indicators is compared to determine the weights of different indicators (Guo et al., 2008). The Delphi method primarily involves soliciting opinions from relevant domain experts and scholars through anonymous scoring, and subsequently making decisions based on expert input. The evaluation team compiles relevant materials on talent cultivation and distributes them to each expert,

Table 2: Maturity Level Scoring Table for Talent Cultivation in New Engineering Education

Dimension	Maturity Level			
	Initial Stage	Growth Stage	Continuous Development Stage	Mature Stage
Knowledge Structure	2	4	6	8
Ability Structure	2	4	6	8
Moral Structure	1	2	5	7
Social Adaptability Structure	1	3	7	9
Thinking Structure	1	3	6	9

enabling them to score indicators that are ambiguous and cannot be directly quantified.

In the evaluation process, the elements influencing talents are categorized into three levels: first-level indicators, second-level indicators, and observation points. Knowledge, being the most readily quantifiable indicator, allows observation points for knowledge structure to be scored with reference to academic achievements or grade point average. Observation points for ability structure can be scored through project platforms by statistically analyzing platform data, or through the quantity and quality of professional certifications. Observation points for thinking structure can be measured and scored using thinking scales that have undergone reliability and validity testing. Observation points for social adaptability and moral structure employ a five-tier expert scoring method, with corresponding scores assigned as 1–2, 3–4, 5–6, 7–8, and 9–10.

Following discussions among relevant experts, each dimension is scored on a scale of 10 points. Talent cultivation enters the initial stage when it achieves 2 points in both the knowledge structure dimension and the ability structure dimension, and 1 point in the moral structure dimension, social adaptability structure dimension, and thinking structure dimension. Talent cultivation enters the growth stage when it achieves 4 points or more in both the knowledge structure dimension and the ability structure dimension, 2 points or more in the moral structure dimension, and 3 points or more in both the social adaptability structure dimension and the thinking structure dimension. Talent cultivation enters the continuous development stage when it achieves 6 points or more in both the knowledge structure dimension and the ability structure dimension, 5 points or more in the moral structure dimension, 7 points or more in the social adaptability structure dimension, and 6 points or more in the thinking structure dimension. Talent cultivation enters the mature stage when it achieves 8 points or more in both the knowledge structure dimension and the ability structure dimension, 7 points or more in the moral structure dimension, and 9 points or more in both the social adaptability structure dimension and the thinking structure dimension, as shown in Table 2.

As a progressively developing model, the maturity evaluation indicator system follows the sequence of students' psychological development and aligns with the principle of gradual progression in talent development. At each stage of talent cultivation, the dimensions of knowledge, ability, moral, social adaptability, and thinking undergo development to varying degrees and with different focal points. For instance, in the initial stage, the knowledge structure emphasizes the evaluation of general knowledge, while the ability structure focuses on the evaluation of practical ability.

Each evaluation dimension encompasses numerous second-level indicators. For instance, the knowledge structure includes second-level indicators such as general knowledge, foundational scientific knowledge, instrumental knowledge, and professional knowledge. The ability structure includes second-level indicators such as practical ability, research ability, management ability, transferable skills, and innovation and entrepreneurship ability. At different stages, each evaluation dimension emphasizes different second-level indicators. For each second-level indicator, several observation points are established. For example, general knowledge can be further divided into artificial intelligence knowledge, humanities knowledge, ethical knowledge, artistic knowledge, economic knowledge, and laws and regulations. Research ability can be further into artificial intelligence assisted technology, problem analysis, investigation capability, literature retrieval, project integration, and exploratory verification. The indicators are evolutionary in nature and can be dynamically adjusted in response to technological advancements and evolving societal needs.

CONCLUSION

High-quality and multi-level engineering talents have consistently served as the driving force supporting the rapid development of the new economy. Understanding and grasping the core competitiveness of engineering talents, and forming an evaluation index system for new engineering education and talent cultivation is of great significance. Based on the CDIO framework, maturity model, and expert interviews, this study draws the following conclusions.

First, five dimensions are included in the maturity of talent cultivation within New Engineering Education. They are respectively knowledge structure, social adaptability structure, ability structure, moral character structure, and thinking structure. Compared with CDIO or other theoretical models, this model emphasizes more on the social adaptability structure of new engineering education talents, the role of national identity in professional ethics, and the early cultivation of computational thinking.

Second, a new engineering education talent evaluation framework has been constructed, which includes five dimensions and four stages. This framework considers the dynamic characteristics of engineering talent development and reveals prominent elements of five-dimensional structures in different stages of development. For example, research ability is emphasized in the ability structure of the growth stage, and innovative thinking is emphasized in the thinking structure of the mature stage. Using the expected objectives at each stage as a reference, it measures the current developmental state of new engineering talents relative to these expected objectives, organically integrating maturity levels, talent cultivation stages, and the evaluation indicator system into a unified framework.

Third, in terms of maturity ratings across five dimensions, different dimensions are prioritized at each stage. In the Initial stage, knowledge structure and ability structure have the highest score (both 2 points). In the growth stage, knowledge structure and ability structure have the highest score (both 4 points). In the continuous development stage. ,social adaptability structure has the highest score (7 points). In the maturity stage, social adaptability structure and thinking structure have the highest rating (both 9 points). Furthermore, the evaluation of talent capabilities in new engineering education should be in line with the development laws of each stage, and different stages should have different emphasis on training.

The construction of the maturity model for talent cultivation in new engineering education fundamentally reflects the trend of continuous improvement and ongoing optimization in talent cultivation. On one hand, it enables a relatively accurate assessment of the capability level of engineering talents; on the other hand, it promotes the transformation of talent cultivation paradigms, improves cultivation objectives and competency structures, and repositions higher engineering education.

DECLARATIONS

About the Authors

Jianxiang Xu, Tianjin Light Industry Vocational Technical College, Master of education, Education Management and Evaluation. Email: 18602699459@163.com

Haixia Qie, Professor, School of Education, Tianjin University, Ph.D. in education. Research in Higher Engineering Education. Email: gjsqhx@tju.edu.cn

Jinhu Tao, Assistant Researcher, International Centre for Engineering Education under the auspices of UNESCO/ School of Education, Tsinghua University, Ph.D. in education. Research in Higher Engineering Education. Email: tjutjh@126.com

Acknowledgements

None.

Author Contributions

Jianxiang Xu: Data curation, Writing—Original draft preparation. Haixia Qie: Guiding, Reviewing and Editing. Jinhu Tao: Conceptualization, Methodology, Visualization, Supervision.

All authors have read and approved the final version.

Funding

This work was supported by the Youth Project of the Ministry of Education on National Education Sciences Planning, entitled "Research on the Digital Intelligence Competency Framework and Development Mechanisms for Undergraduate Engineering Students in the Context of Generative Artificial Intelligence" (EIA250447).

Ethics Approval and Consent to Participate

Not applicable.

Conflict of Interest

The author has no conflicts of interest to declare.

Data Availability Statement

All data have been included in this paper.

AI-Generated Content Declaration

None.

REFERENCES

Akhlaghpour, S., & Lapointe, L. (2018). From placebo to panacea: Studying the diffusion of IT management techniques with ambiguous efficiencies: The case of capability maturity model. *Journal of the Association for Information Systems, 19*(6), 441-502. https://doi.org/10.17705/1jais.00498

Budiman, B., Suwarma, I. R., Aba, A., & Irawan, H. (2023). A systematic review on interdisciplinary STEM: Integration of humanities, arts, and social scientific issues in science learning. *Jurnal Pendidikan MIPA, 24*(3), 571-583. https://doi.org/10.23960/jpmipa/v24i3.pp571-583

China Engineering Education Accreditation Association. (2024). *Engineering education accreditation standards* (2024 edition). https://jwc.jnu.edu.cn/_

upload/article/files/d6/ce/cb6f450f464da6f94a2ff1af8aa9/41cba82e-2699-4dae-858d-2c5d8ec8d721.pdf

European Commission. (2025, March 5). *A STEM education strategic plan: Skills for competitiveness and innovation* (COM(2025) 89 final). https://education.ec.europa.eu/sites/default/files/2025-03/STEM_Education_Strategic_Plan_COM_2025_89_1_EN_0.pdf

Guo, J. Y., Zhang, Z. B. & Sun, Q. Y. (2008). Research and application of the analytic hierarchy process. *China Safety Science Journal*, (5), 148-153.

Harari, Y. N. (2017). *Homo deus: A brief history of tomorrow*. Vintage.

Kelly, W. E. (2008). General education for civil engineers: Sustainable development. *Journal of Professional Issues in Engineering Education and Practice, 134*(1), 75-80. https://doi.org/10.1061/(ASCE)1052-3928(2008)134:1(75)

Kuhn, T. S. (1997). *The structure of scientific revolutions*. University of Chicago Press.

Li, C., Xu, R. H., Duan, L., Wang, Y., Chen, X., & Liu, Z. (2025). Engineering education should emphasize computational thinking: Insights from the Washington Accord graduate attributes framework. *Research in Higher Engineering Education,* (6), 26-32.

Liu, H. (2012). The origin of "excellence" in higher engineering education in France, the United States, Germany, and Russia. *University Education Science*, (2), 46-50.

Lin, J. (2017). The construction of China's new engineering disciplines for the future. *Tsinghua Journal of Education*, *38*(2), 26-35. https://tje.ioe.tsinghua.edu.cn/oa/DArticle.aspx?type=view&id=201702003.

Lin, J. (2020). Development of the general standards for training quality of new engineering talents. *Research in Higher Education of Engineering,* (3), 5-16.

Martin, D. A., Conlon, E., & Bowe, B. (2021). A multi-level review of engineering ethics education: Towards a socio-technical orientation of engineering education for ethics. *Science and Engineering Ethics, 27*(5), 60. https://doi.org/10.1007/s11948-021-00333-6

Ministry of Education of the People's Republic of China. (2025, November 24). *Notice of the Ministry of Education on issuing the educational industry standard Standards for Excellent Engineer Education Accreditation.* http://www.moe.gov.cn/srcsite/A22/s7065/202512/t20251209_1422841.html

Ministry of Education, Singapore. (2026, January 6). *21st century competencies.* https://www.moe.gov.sg/education-in-sg/21st-century-competencies

National Science and Technology Council. (2024, November). *Federal strategic plan for advancing STEM education and cultivating STEM talent.* https://bidenwhitehouse.archives.gov/wp-content/uploads/2024/11/2024fedSTEMplan.pdf

Patchamuthu, S. (2020). *The development of critical thinking skills in engineering foundation year: An exploratory study into theory and practice at UK universities* [Doctoral dissertation, University of Southampton].

Royal Academy of Engineering. (2025, November). *Engineers 2030: Final report.* https://nepc.raeng.org.uk/media/ttoie1vl/nepc-engineers-2030-final-report-4.pdf

Song, Q. (2026). The theoretical connotation, logical rationale, and practical pathways of the industry-education integration talent cultivation model in new engineering education. *Heilongjiang Education (Higher Education Research and Evaluation)*, (3), 47-51.

Song, Y., Chen, C. & Li, T. Y. (2023). Cultivation models and development pathways of undergraduate engineering leadership: A grounded analysis based on seven cases. *Research in Higher Engineering Education,* (4), 73-78.

Tao, Y. F., & Shang, C. H. (2006). Insights from the CDIO framework for innovation in higher engineering education. *China Higher Education Research*, (11), 81-83.

Wang, Q. (2025). Exploration and practice of the cultivation model for top-notch innovative talents in the context of new engineering education. *Journal of Higher Education, 11*(32), 38-41+45.

Wang, Z. B. (2017). *Educational revolution in the age of artificial intelligence.* Beijing United Publishing Company.

Yan, F. & Hong, X. W. (2008). On the cultivation of professional ethics awareness. *Journal of Tsinghua University (Philosophy and Social Sciences Edition),* (S1), 125-129.

Yi, M. & Zhang, J. S. (2015). A brief analysis of how to examine the stage characteristics of university student affairs. *Asia-Pacific Education*, (10), 242.