

Seamless Transition from Graduation to Employment: The Training Pathway for IoT On-site Functional Engineers

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Abstract: As Internet of Things (IoT) technology permeates and is deployed at scale across numerous industries, there is an urgent industrial demand for engineering talent capable of ensuring that IoT systems achieve their intended functions and operate stably within complex on-site environments. However, existing talent training systems often lag behind the rapid evolution of technology and the changing nature of job roles, resulting in a structural mismatch between the competencies of graduates and the actual needs of the market. This paper focuses on the critical role of the IoT On-site Functional Engineer and aims to explore effective training pathways for this profession. The study first systematically analyzes the evolving definition of this role within the context of industrial upgrading, its specialized sub-directions, and the spectrum of interdisciplinary competencies required by the market. Subsequently, it constructs a core competency model oriented toward the goal of "Seamless Transition from Graduation to Employment," encompassing the three dimensions of technical implementation, scenario application, and professional practice, while elucidating their interrelationships. Finally, it proposes a comprehensive training model and implementation pathway. This model is underpinned by deep industry-education integration as an institutional guarantee, involves restructuring the curriculum system through project-based and work-process-oriented approaches, establishes a continuous, closed-loop practical teaching framework, and implements a dynamic evaluation and continuous improvement system. This provides a systematic reference for the targeted cultivation of applied IoT engineering and technical talent.

Keywords: IoT On-site Functional Engineer; Seamless Transition from Graduation to Employment; competency model; training model; industry-education integration

Introduction

The integrated innovation and cross-domain application of Internet of Things (IoT) technology are driving profound transformations in social production and service models, with their implementation effectiveness highly dependent on functional realization and reliable operation and maintenance after on-site deployment. The IoT On-site Functional Engineer, serving as a critical interface connecting technical solutions with the delivery of business value, is seeing their core role become increasingly prominent. However, this position is characterized by a high degree of on-site presence, comprehensiveness, and non-standardization, imposing unique demands on practitioners' interdisciplinary knowledge, practical skills, and professional competence. Traditional talent cultivation models, which emphasize theoretical compartmentalization and laboratory verification, struggle to meet the competency requirements of this emerging role. Therefore, conducting targeted research on scientific training pathways for IoT On-site Functional Engineers, and resolving the structural contradiction between the supply side of talent cultivation and the demand side of industry, is of practical necessity and urgency for supporting the healthy development of the IoT industry, enhancing the efficacy of technology application, and promoting high-quality graduate employment. This study aims to provide a theoretical basis and practical framework for reforming and optimizing the talent cultivation system in related disciplines through systematic analysis of job requirements, construction of a competency model, and design of innovative training pathways.

1. Analysis of the Professional Connotation and Job Requirements for IoT On-site Functional Engineers

1.1 Professional Definition and Core Characteristics of the IoT On-site Functional Engineer

The IoT On-site Functional Engineer is a professional technical role dedicated to realizing specific functions and ensuring reliable system operation of IoT systems within their final deployment and application environments. Their workspace extends beyond standard laboratory settings into specific physical spaces such as industrial production lines, smart buildings, agricultural sites, or urban infrastructure. Their core mission is to ensure synergy and functional fulfillment among sensing-layer devices, network transmission, and platform applications^[1]. The essence of this role lies in transforming design solutions into stably operating physical systems and resolving various technical and non-technical issues that arise during the transition from the laboratory to complex on-site environments.

The core characteristics of this profession are reflected in its highly comprehensive and on-site nature. Engineers must possess interdisciplinary knowledge integration capabilities, mastering sensor technology, embedded systems, network communication, and industry-specific application logic. Compared to purely research and development or operational roles, their work exhibits a strong non-standardized nature, requiring them to address heterogeneous equipment, variable environmental interference, and non-ideal deployment conditions on-site. Their problem-solving ability relies not only on theoretical knowledge but more crucially on rapid comprehension of on-site situations, experiential judgment, and practical skills, making them a critical interface connecting technical solutions with actual business value.

1.2 Evolution and Specialization of Job Responsibilities in the Context of Industrial Upgrading

As IoT technology progresses from proof-of-concept to large-scale deployment and deepens its integration with technologies such as artificial intelligence and edge computing, the scope of responsibilities for the IoT On-site Functional Engineer continues to expand and evolve. Initially, duties primarily focused on equipment installation, connectivity, and basic parameter configuration. At the current stage, responsibilities have advanced to encompass on-site system integration verification, end-to-end business data flow management, deployment and optimization of edge intelligence algorithms and functions, as well as support for adaptive secondary development tailored to specific scenarios. Engineers must ensure that the entire IoT solution not only achieves "connectivity" but also executes predefined intelligent functions stably and efficiently within real-world environments.

The deepening of responsibilities naturally drives the specialization of roles. Within large-scale or technologically complex vertical industries, more targeted specialized branches of this role have gradually emerged. For instance, the Industrial IoT On-site Functional Engineer, who focuses on industrial automation and production line integration, centers their work on industrial control protocols, time-series data, and system high availability. Conversely, engineers involved in complex smart city projects must excel at managing large-scale heterogeneous network access, public data platform interfaces, and cross-departmental coordination. These specialized directions require engineers to not only master a universal skill set but also develop deep expertise in the specific business processes, technical standards, and compliance requirements of their chosen industry.

1.3 The Spectrum of Competency Requirements for IoT On-site Functional Engineers in the Market and Industry

Market demands for IoT On-site Functional Engineers present a multidimensional spectrum of competencies, encompassing both technical hard skills and professional soft skills. The foundational technical capabilities include a profound understanding of IoT architecture, proficiency with mainstream sensors and actuators, wired and wireless communication protocols, edge gateway configuration, and cloud platform integration. With the widespread adoption of edge computing, skills in data preprocessing at the edge, deploying lightweight models, and managing containerized applications have become increasingly crucial. Concurrently, essential technical tools include basic programming and scripting abilities for automated testing and fault diagnosis, as well as the capacity to read and comprehend hardware schematics and software interface documentation.

Beyond purely technical expertise, companies place greater emphasis on an engineer's on-site

problem analysis and resolution capabilities. This includes the logical thinking required to systematically diagnose complex issues, the judgment to make technical decisions under conditions of incomplete information, and the adaptability to respond to unexpected situations. Communication and coordination skills are crucial, as engineers must clearly explain technical problems to clients, collaborate efficiently with backend R&D teams to pinpoint defects, and produce rigorous on-site reports and technical documentation. Furthermore, a fundamental awareness of project quality, timelines, and costs, along with the intrinsic motivation for continuously learning about emerging IoT technologies and industry knowledge, collectively shape the comprehensive spectrum of competencies that meets market expectations^[2].

2. Construction of the Core Competency Model for Achieving "Seamless Transition from Graduation to Employment"

2.1 Principles for Constructing the Competency Model Under the "Seamless Transition from Graduation to Employment" Objective

The primary principle for constructing a competency model serving the objective of "Seamless Transition from Graduation to Employment" is forward-looking vision and dynamic adaptability. The model must be designed based on the trends of IoT technology iteration and its convergence with industrial applications. It should not only reflect the current technical stack requirements of the position but also anticipate the potential impact of emerging technologies, such as edge intelligence and digital twins, on on-site workflows. Competency indicators should possess a degree of flexibility and scalability, enabling dynamic adjustment alongside technological evolution and shifting industry demands. This ensures that cultivated talent possesses the foundational literacy for continuous learning and adaptation to technological change, preventing a rapid disconnect between educational outcomes and market needs.

Another key principle is deep industry-education coupling and verifiability. The design of the competency model must originate from precise analysis of tasks and challenges in real work scenarios, ensuring that each core competency element corresponds to specific job responsibilities or problem contexts. The descriptions of competencies within the model should be specific, observable, and measurable, facilitating their translation into course teaching objectives, practical training project tasks, or assessment criteria. This requires that the model construction process fully incorporates insights and evaluations from industry technical experts, guaranteeing that the competency items are not only theoretically sound but also possess a strong practical orientation. This approach makes the pathway between the training process and employment outcomes clear and controllable.

2.2 The Three-Dimensional Core Competency Framework for IoT On-site Functional Engineers

The core competencies of an IoT On-site Functional Engineer can be systematically categorized into three interrelated dimensions: technical implementation capability, scenario application capability, and professional practice capability. Technical implementation capability constitutes the foundational dimension, encompassing operational skills related to the deployment, configuration, debugging, and troubleshooting of hardware and software associated with the IoT perception layer, network layer, and platform layer. This dimension ensures that engineers can accurately materialize technical solutions into operational physical systems, serving as the fundamental technical guarantee for fulfilling job responsibilities^[3].

Scenario application capability constitutes the core dimension, referring to the ability to integrate general technical skills with specific industry contexts, business processes, and concrete problems. This includes understanding the business logic and constraints of vertical industries, diagnosing and optimizing functions based on on-site data and phenomena, and even participating in necessary on-site adaptive development. Professional practice capability serves as the supporting dimension, encompassing communication and coordination, documentation, adherence to safety standards, project management awareness, and professional ethics required in project environments. These three dimensions are not simply parallel. Technical implementation provides the tools for scenario application, while scenario application gives value and direction to technical implementation. Professional practice capability, in turn, provides the behavioral framework and environmental safeguards for the effective execution of the former two within complex real-world settings.

2.3 Hierarchical Breakdown and Intrinsic Relationships of Core Competency Elements

Conducting a hierarchical breakdown of the three-dimensional competency framework can further clarify the progressive pathway for competency development. Within the technical implementation dimension, this can be decomposed into three levels of increasing depth: fundamental tool usage, system integration and debugging, and complex fault diagnosis. Scenario application capability demonstrates a progression from understanding standard solutions, to analyzing specific scenario requirements and performing configuration optimization, and further to participating in the design and implementation of customized functions. Professional practice capability encompasses an evolutionary hierarchy from basic communication and documentation discipline, to cross-team collaboration and client relationship management, and advancing to possessing a certain project perspective with awareness of quality and cost.

There exists a close intrinsic connection and a mutually reinforcing relationship among the various competency elements. For example, in-depth technical fault diagnosis capability contributes to more precisely identifying bottlenecks in scenario applications; conversely, a profound understanding of business scenarios can guide the priority and strategy of technical debugging. Standardized documentation skills are not only a requirement of professional practice but the process itself can deepen the understanding of both technical systems and business logic, thereby fostering the development of scenario application capability. This interconnectedness indicates that the training process cannot focus on isolated skills in isolation. Instead, it should employ comprehensive tasks that simulate real projects, enabling learners to synchronously construct and integrate competencies across multiple dimensions while solving complex problems, thereby forming an organic holistic competency structure.

3. Innovation in Training Models and Implementation Pathways for Employment Competence

3.1 Design of a Collaborative Education Mechanism through Deep Industry-Education Integration

The key to constructing a collaborative education mechanism for training IoT On-site Functional Engineers lies in establishing an institutionalized, normalized model for resource sharing and co-management of the process. This goes beyond simple internship base cooperation or sporadic enterprise lectures, requiring strategic alignment between the collaborating parties from the top-level design stage of talent cultivation. It is advisable to explore building a "dual-subject" education platform. By co-establishing industrial colleges or specialized program tracks, the enterprise's technology roadmap, engineering case library, professional certification systems, and experienced engineer teams can be systematically and modularly integrated into the entire talent cultivation process. The operation of such platforms relies on clearly defined rights and responsibilities, along with mutually beneficial rule design, to ensure a balance between educational principles and industry needs within the teaching process^[4].

The deep integration of the mechanism is reflected in the level of dynamic feedback and collaborative evolution. Partner enterprises not only provide static resources but must also deeply participate in the iterative improvement of teaching activities. For example, enterprise technical experts and institutional faculty can jointly form course teams responsible for the annual updating and case development of specific technical modules. The actual project requirements of enterprises, after undergoing teaching-oriented adaptation, can be transformed into student graduation project topics or comprehensive practical training projects. Simultaneously, the institution's research facilities and fundamental research capabilities can be opened to partner enterprises, providing them with early-stage technical validation support. This forms a virtuous cycle ecosystem of "talent cultivation – technology application – knowledge feedback," enabling the training system to remain acutely responsive to technological changes and market fluctuations.

3.2 Restructuring the Curriculum System with a Project-based and Work-process-oriented Approach

To achieve the shift from knowledge acquisition to competency development, the curriculum system must be deconstructed and reorganized according to the logic of completing authentic work tasks. Project-based teaching serves as the core vehicle, and its design should follow the law of professional growth, forming a graded sequence from "basic skill projects" and "specialized technical projects" to "comprehensive system projects." Each project simulates the complete work process of an

IoT engineering endeavor—from requirements analysis and solution design to deployment, implementation, and finally acceptance and operation-maintenance—thereby dissolving discrete disciplinary knowledge (such as microcontroller principles, wireless networks, and database technology) within the context of solving specific project problems. The student's learning path progresses from implementing single functional points, to integrating multiple subsystems, and ultimately to completing a small-scale IoT solution that closely mirrors real-world practice.

The work-process-oriented approach necessitates a detailed analysis of the typical work tasks of an IoT on-site engineer, based on which learning domains are designed. The organization of course content is no longer centered around disciplinary boundaries but instead revolves around practical work segments such as "equipment selection and installation," "network setup and debugging," "data integration and cloud migration," and "functional testing and fault troubleshooting." Within each learning domain, theoretical knowledge adheres to the principle of being "necessary and sufficient," serving to support the understanding and optimization of practical operations. This restructuring encourages students to develop systematic thinking guided by workflow processes, enabling them to comprehend the position and interrelationships of various technologies within the overall engineering context. Consequently, it cultivates their ability to integrate and apply technical knowledge to solve problems in complex, non-standardized on-site environments.

3.3 A Practical Teaching System Spanning the Entire Training Process with Quality Assurance

Establishing a tiered practical teaching system, which is equally emphasized and organically integrated with theoretical instruction, is crucial. This system should be designed according to the principles of cognitive and skill development, comprising four progressively advancing stages: cognitive practice, specialized skill training, comprehensive system training, and on-the-job enterprise internship. Initially, students gain familiarity with IoT components through demonstrations and hands-on operations. Subsequently, they engage in modular training of core skills—such as communication configuration, edge computing programming, and cloud platform integration—within controlled environments. This is followed by exercises in cross-technology domain comprehensive system integration and fault diagnosis utilizing highly simulated training platforms or real enterprise project data. Finally, capability transformation is completed by entering an authentic professional environment through an on-the-job internship.

To ensure the quality of practical teaching, it is necessary to establish standardized process management and a multi-dimensional evaluation mechanism. This requires developing detailed practical training syllabi, safety operation procedures, quantitative project acceptance criteria, and standardized process documentation. Introducing project management tools and quality management methods commonly used in enterprises, students are required to strictly adhere to engineering workflows. The evaluation system should integrate both process assessment and final assessment. The former focuses on the rationality of solution design, the standardization of operations, teamwork, and the problem-solving process, while the latter emphasizes the degree of functional realization, stability, and documentation quality of the final system^[5]. Establishing a regular inspection and defense system involving mentors from both the educational institution and the enterprise enables dynamic supervision and feedback on practical sessions. This ensures that practical teaching transcends mere formality and genuinely enhances students' professional competence.

3.4 Dynamic Evaluation of Training Outcomes and a Closed Loop for Continuous Improvement

The evaluation of training effectiveness must shift from a traditional academic performance orientation to a comprehensive assessment centered on the achievement of employment competence and long-term career development potential. This requires establishing a hybrid evaluation system encompassing both internal assessments and external feedback. Internal evaluation includes course assessments, project reviews, and skill certification pass rates, among others. External feedback involves collecting satisfaction data from internship providers and employing enterprises through stable channels, conducting follow-up surveys on graduate employment quality (such as job relevance, starting salary levels, and promotion speed), and gathering evaluation information from third-party industry certification bodies. Together, these data constitute the key performance indicator set for evaluating training effectiveness.

A continuous improvement mechanism based on evaluation data is crucial for sustaining the vitality of the training model. A dedicated teaching quality assurance unit should be established. This unit is

responsible for periodically (e.g., annually) analyzing all relevant evaluation data to identify weaknesses within the training process and emerging trends. The analysis results must be formally fed back to the Program Development Steering Committee, serving as the decision-making basis for initiating revisions to the training plan, updates to course content, enhancements to practical projects, or implementing faculty development programs. The resulting closed-loop management cycle of "monitoring-evaluation-feedback-adjustment" ensures that the talent cultivation system becomes an adaptive system capable of self-diagnosis and self-correction. This, in turn, continuously secures the achievement of the "Seamless Transition from Graduation to Employment" objective within a rapidly evolving industry landscape.

Conclusion

This research systematically investigates the cultivation of IoT On-site Functional Engineers, covering the analysis of job requirements, the construction of competency models, and the design of training approaches. The study clarifies the core essence and dynamic competency demands of this profession within the context of technological convergence and industrial upgrading. It establishes a forward-looking and verifiable three-dimensional core competency model. Based on this foundation, an integrated training implementation pathway is proposed. This pathway is built upon deep industry-education collaboration, centers on project-based and work-process-oriented methodologies, is structured around a progressive practical training system, and is reinforced by a dynamic evaluation and improvement loop. This approach emphasizes real-time alignment between educational provision and industry needs. It focuses on fostering the integrated development of knowledge, skills, and professional competence within authentic or highly simulated engineering contexts. The ultimate goal is to systematically shorten the transition period from academic learning to professional workplace readiness.

Looking ahead, the continuous evolution of IoT technology and the increasing complexity of on-site engineering scenarios require the training system to possess dynamic adaptability. Future efforts need to further focus on how to more agilely integrate rapidly iterating emerging technologies, such as edge intelligence and digital twins, into the curriculum and practical training. Additionally, it is essential to establish a more open and sustainable industry-education integration ecosystem. This will enable the continuous improvement of talent cultivation quality and the stable, long-term achievement of the "Seamless Transition from Graduation to Employment" objective.

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