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Article

Task–Evidence Coordination for Internal Quality Assurance in Engineering Professional Master's Education: A PDCA-Based Single-Case Study

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Abstract: Professional master's education in engineering encompasses coursework, research training, and engineering practice, across which quality objectives, supervisory responsibilities, and evidence of student learning may become disconnected. Using professional master's education in mechanical engineering at Xijing University, China, as an explanatory single case, this study employs directed content analysis and descriptive statistics to examine coursework, university–industry collaborative supervision, research training, and master's thesis management through an analytical sequence of objectives, tasks, responsibilities, evidence, and feedback. Four interrelated coordination gaps are identified: insufficient alignment between competency requirements and assessment evidence, inadequate coordination of university–industry supervisory responsibilities, fragmentation of information across training stages, and discontinuities in corrective action and follow-up verification. Drawing on Total Quality Management and the Plan–Do–Check–Act (PDCA) cycle, the study develops a framework comprising three interconnected subsystems: quality objectives and standards, organizational responsibilities, and process monitoring, evaluation, and feedback. It further proposes a task–evidence coordination mechanism that uses identifiable training tasks as reference points and comparable verification across training cycles as a criterion for assessing improvement. Evidence from curriculum development, industry-based practice facilities, and linkages among research projects, disciplinary competitions, and master's theses indicates that practical foundations for implementing the proposed mechanism are in place. However, the available data are insufficient to establish its independent effects on educational quality. The study offers a task-level analytical framework and an operational approach to internal quality assurance in professional master's education in engineering.

Keywords: Professional master's education in engineering; Internal quality assurance; PDCA cycle; Training tasks; Process evidence; Single-case study

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1. Introduction

Professional master's education in engineering places considerable emphasis on authentic engineering problems as a context for learning, with the aim of developing students' integrated competencies in technical solution design, experimental validation, and engineering applications. In 2023, China's Ministry of Education issued a policy on the differentiated development of academic and professional degree education, emphasizing practice-oriented training and differentiated quality assessment for professional degree programs [1]. The Degree Law of the People's Republic of China, which came into effect in 2025, further clarified institutional responsibilities for ensuring the quality of degree education [2]. Against this backdrop, quality assessment should consider not only outcomes such as course performance and master's theses but also the development of students' competencies through research projects, academic supervision, and industry-based practical training.

Research on internal quality assurance in higher education has gradually expanded beyond summative evaluation to encompass multi-stakeholder governance, evidence-based assessment, and the development of a quality culture. Studies focusing on professional degree education in China have examined collaborative quality governance, accountability for thesis quality, and value-added assessment [3-6]. Krooi et al. proposed the 3P model, emphasizing the context-sensitive alignment of the purposes, people, and processes involved in internal quality assurance [7]. Samuel and Farrer explored the application of the Plan–Do–Check–Act (PDCA) cycle to curriculum design and continuous review in higher education, highlighting the importance of evidence-informed decision-making and the implementation of improvement actions [8]. Although these studies provide valuable organizational and process-oriented perspectives on internal quality assurance, further investigation is needed to understand how different quality assurance elements can be integrated within individual training tasks that span coursework, industry-based projects, and master's thesis research, and how traceable relationships can be established between quality assessment and subsequent improvement.

Accordingly, this study addresses three research questions: (1) What coordination gaps exist among quality objectives, supervisory responsibilities, process evidence, and feedback mechanisms in professional master's education in mechanical engineering? (2) How can a PDCA-based operational mechanism be developed by treating individual training tasks as the primary unit of analysis within a university–industry collaborative training context? (3) Which components of the proposed mechanism are supported by evidence from existing educational practices, and which claims regarding its effectiveness require further empirical validation? By addressing these questions, this study aims to develop an operational framework for task-level internal quality assurance and examine the conditions for its application in the context of actual educational and training practices.

2. Theoretical Framework and Research Methods

2.1. Applicability of Total Quality Management and the PDCA Cycle

Total Quality Management (TQM) views quality as the outcome of interactions among organizational objectives, stakeholders, and implementation processes. Its central principle is to embed quality requirements into ongoing organizational activities rather than treating quality assurance as a separate, end-stage evaluation. In professional master's education in engineering, expected competencies encompass the identification of engineering problems, solution design, experimental investigation, technological application, and professional ethics. Quality management organized solely around individual courses or master's theses may overlook the continuity of training tasks across different stages of education. Accordingly, this study adopts the training task as its unit of analysis, defined as an educational activity with identifiable objectives, assigned responsibilities, an implementation process, and evaluation criteria. This approach enables an examination of how broader quality requirements are translated into observable evidence of competency development.

The Plan–Do–Check–Act (PDCA) cycle comprises four interconnected stages: planning, implementation, evaluation, and corrective action. Professional master's education involves interrelated activities, including coursework, research projects, industry-based practical training, and master's thesis research. These activities can generate task specifications, successive design versions, experimental records, and supervisory feedback associated with the same engineering task. The relevance of PDCA therefore extends beyond the sequential arrangement of its four stages. More importantly, it provides a means of linking objective setting, process evaluation, accountability, and subsequent verification through a common task identifier.

Previous research on internal quality assurance has emphasized the need for alignment among organizational purposes, participating stakeholders, and implementation processes [7]. Research on student participation further suggests that

students' involvement should extend beyond one-off satisfaction surveys to include meaningful participation in discussions and improvement activities [9]. In view of the characteristics of professional master's education in engineering, this study identifies four observable requirements for internal quality assurance: whether competency standards are linked to specific training tasks, whether supervisory responsibilities are clearly identifiable, whether evidence from successive training stages can be connected, and whether identified quality problems lead to subsequent actions whose outcomes can be verified.

2.2. Case Selection and Scope of the Study

This study focuses on professional master's education in mechanical engineering at Xijing University, located in Xi'an, Shaanxi Province, China. Since introducing graduate education in mechanical engineering in 2012, the university has progressively developed interconnected educational activities involving advanced manufacturing courses, graduate student innovation funding, university–industry dual-supervisor arrangements, engineering practice bases, and master's thesis research. The coexistence of university-based coursework and industry-oriented engineering tasks provides a context for examining relationships among stakeholders, training stages, and different forms of quality evidence.

An explanatory single-case study design was adopted, with coursework, university–industry joint supervision, professional practice, research training, and master's thesis management treated as embedded units of analysis. Case selection was informed by the practical nature of the engineering tasks, the continuity of educational activities across training stages, and the traceability of existing records. The purpose of the study is to explain how different elements of internal quality assurance can be connected and to identify the conditions under which the proposed mechanism may operate. It does not seek to make statistical generalizations about other higher education institutions.

2.3. Data Analysis and Evidence Assessment

The study draws on three categories of documentary materials. The first comprises the 2023 master's training program in mechanical engineering, course syllabi, and materials relating to the Advanced Manufacturing Technology course, which were examined to identify relationships between competency objectives and teaching activities. The second includes records of university–industry collaborative training, engineering practice bases, graduate student innovation funding, disciplinary competitions, and master's theses, which were used to identify connections among training tasks across different educational stages. The third consists of student development portfolios, institutional policies on collaborative supervision, and multi-year statistics on educational development and achievements, which were examined to assess organizational conditions and patterns of reported outcomes. Materials were included when they provided identifiable information about a training stage, task content, or associated responsibilities. Records containing only aggregate figures, without links to individual training tasks, were used exclusively for descriptive statistical analysis and not to infer changes in student competencies.

The analysis employed a theory-informed directed content analysis. First, a common set of analytical categories was established: quality objectives, training tasks, responsible stakeholders, process evidence, and evaluation and feedback. Second, the available documentary evidence was organized according to coursework, university–industry practice, research training, and master's thesis management. Third, where research projects, competition entries, and master's theses concerned the same research topic, their connections were cross-checked by comparing project titles, technical content, and research outcomes. Finally, the scope of each finding was assessed according to the type and strength of the available evidence. This procedure emphasizes traceable relationships among documentary records and does not assume that the existence of institutional arrangements necessarily demonstrates successful quality improvement.

Evidence was assessed at three levels. Enabling evidence, such as training programs, teaching resources, engineering practice bases, and institutional policies, indicates whether the conditions needed to support quality assurance are in place. Process-linkage evidence, consisting of related records documenting the same task across research projects, competitions, and master's thesis research, indicates continuity among educational activities. Effectiveness evidence requires an identifiable quality problem, corresponding corrective actions, and follow-up evaluation results that are comparable with the initial assessment. These three levels of evidence are analytically distinct and cannot be treated as interchangeable. Because the available materials primarily support the first two levels, this study does not make causal claims regarding gains in course-related competencies, the effectiveness of academic supervision, or the independent effects of the PDCA mechanism.

3. Case Context and Quality Assurance Challenges

3.1. Insufficient Alignment between Training Objectives and Evidence of Engineering Competencies

In earlier curriculum development efforts, the alignment among knowledge modules, engineering tasks, and assessment criteria was not sufficiently established. Although courses related to advanced manufacturing may provide comprehensive coverage of relevant technical knowledge, course content and conventional assessments alone are insufficient to determine whether graduate students can select appropriate manufacturing processes, justify technical solutions, and conduct experimental validation under specific engineering conditions.

A central challenge for course-level quality assurance is therefore to translate expected engineering competencies into achievable learning tasks and establish explicit quality criteria for evaluating technical designs, experimental reports, and engineering analyses.

3.2. Insufficient Coordination of University–Industry Supervisory Responsibilities and Practice Assessment

University-based supervisors primarily emphasize research methods, academic standards, and master's thesis quality, whereas industry supervisors are more familiar with corporate research and development conditions and the practical applicability of engineering technologies. Although these perspectives are complementary, the absence of jointly agreed task specifications, milestone-based assessment criteria, and supervisory feedback procedures may lead to inconsistent expectations, difficulties in tracking supervisory involvement, and divergent assessments of students' contributions to engineering projects.

Quality assurance in dual-supervisor arrangements must therefore extend beyond the formal appointment of supervisors. It requires clearly defined supervisory responsibilities, assessment milestones, and accountability for addressing identified problems, all organized around engineering tasks jointly agreed upon by university and industry supervisors.

3.3. Fragmented Process Evidence and Weak Continuity in Quality Feedback

Graduate student innovation funding programs, disciplinary competitions, industry-based practical training, and master's thesis research generate different forms of documentation, including project proposals, technical outputs, practice records, and thesis manuscripts. Because these activities are administered by different organizational units and serve distinct assessment purposes, the resulting evidence may remain fragmented across individual training stages. Such fragmentation makes it difficult to reconstruct the continuous process through which research problems are identified, technical solutions are refined, engineering designs are validated, and research findings are communicated.

When information from different training stages cannot be systematically connected, deficiencies identified during coursework, such as weaknesses in manufacturing process analysis, may not be incorporated into subsequent practice assessments. This discontinuity limits the ability of quality assurance mechanisms to track recurring problems and verify whether corrective actions have been effective.

3.4. Limited Integration of Multi-Stakeholder Assessment and Student Feedback

The quality of engineering practice encompasses the authenticity of training tasks, technical constraints, students' actual contributions, and professional ethics. Assessments conducted solely within the university are unlikely to capture all these dimensions. Feedback from industry supervisors, graduate students, and alumni should therefore be considered alongside task-specific quality evidence and incorporated into problem diagnosis and improvement decisions.

Taken together, the quality assurance challenges identified in the case can be grouped into four interconnected areas: translating competency standards into assessable tasks, coordinating university–industry supervisory responsibilities, maintaining continuity in process evidence, and integrating quality feedback into corrective action and subsequent verification.

4. Internal Quality Assurance Framework and the PDCA Operational Mechanism

4.1. Three Interconnected Subsystems of Internal Quality Assurance

To address the challenges identified above, this study proposes an internal quality assurance framework comprising three mutually supporting subsystems.

The first is the quality objectives and standards subsystem, which translates educational requirements through a sequence of training objectives–core competencies–training tasks–quality evidence. This subsystem operationalizes expected competencies, including engineering problem analysis, technical solution design, experimental validation, and professional conduct, as observable and assessable learning performances.

The second is the organizational responsibilities subsystem, which defines the roles of the university, its academic schools, university-based supervisors, industry supervisors, and graduate students in task formulation, implementation, quality assessment, and improvement activities.

The third is the process monitoring, evaluation, and feedback subsystem, which collects quality information at key stages of coursework, research training, engineering practice, and master's thesis development. It links successive training cycles through the identification of quality deviations, analysis of underlying causes, implementation of corrective actions, and verification of improvement outcomes.

These three subsystems address three fundamental questions: What standards should be used to assess quality? Who is responsible for achieving and evaluating quality? What evidence should inform continuous improvement? Their common point of reference is not an abstract administrative process but an identifiable training task. For each task, its objectives, responsible stakeholders, stage-specific evidence, and feedback arrangements should be connected within a coherent information chain. The overall framework is illustrated in Figure 1.

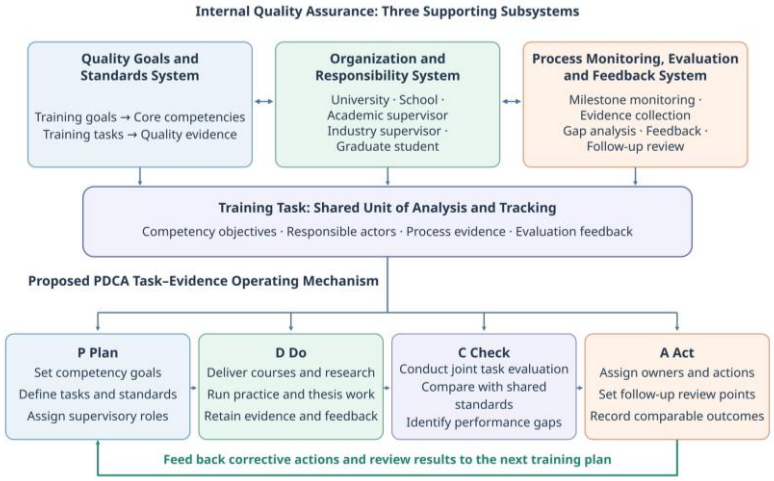

Figure 1. PDCA-Based Internal Quality Assurance Framework for Professional Master's Education in Engineering

4.2. Alignment of Training Tasks and Evidence Across the Four PDCA Stages

In the Plan (P) stage, competency objectives, milestone-based quality standards, and the division of supervisory responsibilities between university and industry partners are established according to program requirements and the characteristics of engineering tasks.

In the Do (D) stage, training activities are implemented through coursework, research projects, industry-based practical training, and master's thesis research. Relevant evidence, including technical designs, research records, and supervisory feedback, is documented throughout implementation.

In the Check (C) stage, participating stakeholders assess students' actual contributions, learning performance, and deviations from expected outcomes against the quality criteria established for each training task.

In the Act (A) stage, identified quality problems are assigned to responsible stakeholders, corrective actions and verification milestones are established, and the outcomes are reviewed in subsequent training cycles involving identical or comparable tasks.

A defining feature of the PDCA mechanism is its traceability across training cycles. For each quality problem requiring improvement, the evidence chain should include, at a minimum, a task identifier, the criteria used to identify the deviation, the stakeholder responsible for corrective action, records of implemented measures, and comparable follow-up evaluation results. The revision of institutional policies or the documentation of administrative meetings alone does not constitute sufficient evidence that an improvement has been effective.

Table 1 summarizes the relationships among quality assurance activities, process evidence, and stakeholder responsibilities across the four PDCA stages.

Table 1. Quality Assurance Activities, Process Evidence, and Responsibilities Across the Four PDCA Stages

Stage	Quality assurance activities	Main forms of process evidence	Responsibilities and feedback
Plan (P)	Define competency objectives, establish quality standards, and allocate training tasks and responsibilities	Training programs, course objectives, project task specifications, and supervisory assignments	The university coordinates quality standards; academic schools organize task planning and supervisory assignments

Do (D)	Implement coursework, research activities, engineering practice, and master's thesis training	Student work, experimental records, practice logs, and supervisory feedback	Course instructors, university and industry supervisors, and graduate students jointly implement training activities
Check (C)	Assess actual performance against established objectives and identify quality deviations	Milestone assessments, quality of student work, and feedback from university supervisors, industry supervisors, and students	Academic schools coordinate multi-stakeholder assessment and identify individual and recurring quality problems
Act (A)	Implement corrective actions and conduct follow-up verification	Corrective action records, follow-up assessments using comparable criteria, and revisions to quality standards	Responsible stakeholders implement corrective actions; academic schools verify outcomes; the university coordinates institutional-level issues

4.3. Multi-Stakeholder Coordination and the Use of Quality Information

The university is responsible for coordinating quality standards and allocating institutional resources, while academic schools oversee quality monitoring at key training milestones and the verification of corrective actions. University-based supervisors focus primarily on research methodology and academic standards, whereas industry supervisors participate in the design, implementation, and assessment of authentic engineering tasks. Graduate students contribute to quality assurance through process documentation, periodic reflection, and feedback on their learning and practical training experiences.

The effectiveness of multi-stakeholder coordination depends on whether the participating parties can produce complementary and mutually informative assessments of the same training task. Student feedback, in particular, should be incorporated into traceable improvement actions rather than remaining an isolated source of evaluation data [9].

Quality information should be collected according to the principle of minimum necessary data collection, using individual training tasks as the primary reference. Individual learning and supervision records should support personalized guidance and student development, while appropriately aggregated and anonymized information can inform school-level analyses of recurring problems in courses, practice bases, and supervisory arrangements.

Access to information involving confidential corporate technologies, intellectual property, or students' personal data should be restricted according to clearly defined responsibilities and legitimate operational needs. Such arrangements can support evidence-informed quality assurance while minimizing unnecessary administrative reporting and duplication of records.

5. Case Implementation and Research Findings

5.1. Alignment between Training Objectives and Evidence in Curriculum Reform

The Advanced Manufacturing Technology course was organized in accordance with the 2023 master's training program in mechanical engineering. Its content was structured into four modules comprising 22 chapters: advanced manufacturing processes and materials, manufacturing automation, modern production management, and advanced manufacturing systems. Engineering cases involving additive manufacturing, precision machining, and domestically developed industrial software were incorporated into the curriculum. Course development resulted in 14 teaching plans and associated instructional materials, an introductory laboratory guide for 3D printing, and cloud-based

learning resources. The course also incorporated bilingual instruction and curriculum-integrated ideological and political education. Collectively, these developments established instructional resources through which course objectives could be linked to engineering training tasks.

The selection of additive manufacturing processes illustrates how competency objectives could be translated into task-specific assessment criteria. Identifying material and equipment requirements, justifying process selection, analyzing technical constraints, and evaluating safety and ethical considerations could serve as distinct assessment dimensions. Students' learning performance could then be examined through laboratory reports, technical proposals, and records of successive revisions. This represents a proposed operational approach to assessment based on the existing course content rather than an assessment procedure whose effectiveness has already been demonstrated. The available course materials provide evidence of instructional design and implementation readiness, but they are insufficient to establish changes in students' engineering competencies.

5.2. Allocation of Responsibilities in University–Industry Collaborative Training

Xijing University has explored a collaborative supervisory arrangement involving university-based academic supervisors, industry supervisors, and project leaders. Within this arrangement, academic supervisors are responsible primarily for research direction and academic standards, industry supervisors focus on the implementation of engineering technologies, and project leaders coordinate task schedules and milestone deliverables. A professional practice base jointly established by the university and Xi'an Feifanshi Robotics Technology Co., Ltd. provides a setting in which graduate students can engage in training activities associated with authentic research and development tasks.

Within this training context, project task specifications could be used to document technical objectives, the scope of students' responsibilities, and the respective roles of university and industry supervisors. Practice logs, milestone deliverables, and joint assessments could provide evidence of students' participation and technical contributions. The case confirms the existence of an industry-based practice platform and an organizational arrangement for collaborative supervision. However, the available records do not provide sufficient evidence to determine changes in the actual supervisory involvement of industry mentors or the effectiveness of annual corrective-action reviews.

5.3. Task Continuity Across Research Projects, Disciplinary Competitions, and Master's Theses

Historical training records reveal identifiable connections among research training, disciplinary competitions, and master's thesis research. Of the 67 master's theses in mechanical engineering completed between 2015 and 2020, 48 (71.6%) were associated with projects supported by graduate student innovation funding. Among these, 23 theses were also associated with award-winning outcomes in disciplinary competitions, representing 34.3% of the total 67 theses. These descriptive figures indicate the extent to which earlier research training activities were connected to subsequent research outputs. They do not constitute a before-and-after comparison of the effects of PDCA implementation.

A research project involving a low-melting-point alloy (LMA) abrasive polishing machine provides a specific example of task continuity across different training activities. The graduate innovation project entitled Design and Implementation of an Electromagnetic Polishing Machine Using Liquid LMA Abrasives, its associated competition entry, and the master's thesis entitled Design and Implementation of a Contactless Permanent-Magnet-Driven LMA Abrasive Polishing Machine addressed a common technical theme. The thesis further examined the design of the apparatus, simulation analysis, and prototype development. The correspondence among the project topic, competition output, and thesis content provides evidence that the research task maintained continuity across these training activities.

From an internal quality assurance perspective, this example illustrates how project initiation records, engineering outputs, and master's theses can function as interconnected

evidence points within a longer training process. Nevertheless, the limitations of the available evidence must also be recognized. The existing materials do not fully document the reasons for successive design revisions, the actual influence of supervisory feedback, or comparable assessment results before and after corrective actions. Accordingly, evidence of continuity in research tasks must be distinguished from evidence that PDCA-based improvement has been successfully implemented and verified.

5.4. Outcome-Oriented Training and Process Management through Student Development Portfolios

As part of its distinctive training practices, the university has incorporated research or engineering projects, academic papers, patents or other innovative outputs, and professional competency development into staged training tasks. It has also explored the use of student development portfolios, project progress tracking, and presentations of research outcomes. From a quality assurance perspective, these arrangements can establish a chronological record organized around individual training tasks, allowing research progress, revisions made in response to identified problems, and supervisory feedback to be linked over time.

Given differences in project duration, research complexity, and the forms of expected outputs, requirements concerning particular achievements should not be treated as uniform thresholds for degree conferral. Instead, assessment should emphasize students' actual contributions, the quality of technical solutions, and their potential value in engineering applications. Table 2 therefore distinguishes verifiable case facts from the conclusions they can support and the additional evidence required to evaluate effectiveness.

Table 2. Evidence Assessment Matrix for Professional Master's Training Practices in Engineering at Xijing University

Unit of analysis	Verifiable case evidence	Conclusions supported by the evidence	Key evidence required to evaluate effectiveness
Coursework	The Advanced Manufacturing Technology course comprises four modules and 22 chapters, supported by 14 teaching plans, a laboratory guide, and cloud-based learning resources.	Engineering cases and course-based training tasks have established instructional resources and implementation conditions.	Consistent assessment of student work, evidence of course learning outcome attainment, and records of successive revisions.
University–industry practice	A collaborative practice base and an arrangement defining the roles of academic supervisors, industry supervisors, and project leaders.	An industry-based engineering environment and a multi-stakeholder supervision arrangement are in place.	Records of supervision by both parties, assessments of students' technical contributions, and subsequent verification results.
Research–competition–thesis linkage	Of 67 historical master's theses, 48 were associated with innovation funding; an LMA-related project, competition entry, and thesis addressed a common technical theme.	Some research tasks demonstrate continuity across funded projects, competitions, and master's thesis research.	Successive task versions, supervisory assessments, evidence of competency development, and follow-up verification records.

Process management	Student development portfolios, project tracking arrangements, and seven supporting institutional policies.	Institutional arrangements provide a basis for tracking training tasks and assigning quality-related responsibilities.	Linked records identifying quality problems, responsible stakeholders, implementation outcomes, and verification across training cycles.

5.5. Overall Characteristics of Institutional Development and Training Outcomes

Xijing University has established seven supporting institutional policies and arrangements concerning training programs, professional practice, and master's thesis management, including student development portfolios and collaborative assessment under the dual-supervisor system. The university has also continued to develop courses, teaching cases, and digital learning resources. These initiatives provide institutional and material support for task organization, the allocation of responsibilities, and process documentation. However, the consistency with which these arrangements are implemented requires further examination of routine supervision and quality monitoring records.

The related educational practices have also generated cumulative achievements in research innovation, technology transfer, academic publications, and disciplinary competitions (Table 3). Because some indicators cover different periods and student populations, they are used here solely to describe the scale of educational activities and the accumulation of training resources. They are not interpreted as changes in competency within a single student cohort or as effects attributable to PDCA implementation.

Table 3. Cumulative Institutional Development Indicators and Educational Outputs Associated with Training Reforms at Xijing University

Area of development	Cumulative indicators and outputs	Nature of the data and scope of interpretation
Student coverage	More than 210 graduate students were covered by the related training reforms.	Indicates the scope of educational activities across multiple years; does not represent a sample for effectiveness evaluation.
Curriculum development	More than 10 courses underwent reform; 16 teaching development projects were undertaken.	Reflects the scale of course and instructional development activities.
Teaching resources	More than 70 teaching cases, 24 sets of bilingual video-based course materials, and three instructional manuals.	Reflects the accumulation of teaching cases and digital learning resources.
Research innovation	More than 150 granted patents and 27 technology transfer or commercialization outcomes.	Represents cumulative outputs involving different periods and populations; does not establish a net improvement effect.
Academic publications and competitions	82 academic papers and 76 competition awards at the provincial level or above.	The outputs differ in type and statistical coverage and are not used to calculate growth rates.

Note: The indicators cover different periods and populations. All figures are presented as descriptive statistics and do not constitute a comparable before-and-after assessment of the training reforms.

6. Discussion

6.1. From Stage-Based Management to Task-Level Quality Governance

The 3P model conceptualizes internal quality assurance in higher education through the alignment of purposes, people, and processes [7]. Building on this perspective, the present study operationalizes these dimensions through a task-level quality governance approach in professional master's education in engineering. Specific training tasks serve as the means through which competency objectives are translated into educational activities; university-based supervisors, industry supervisors, and graduate students assume responsibilities associated with these tasks; and design records, experimental reports, and assessment feedback constitute process evidence. This task-oriented operationalization extends the systemic perspective of the 3P model to identifiable units of assessment spanning coursework, industry-based projects, and master's thesis research.

Compared with quality management approaches organized around separate training stages or final educational outcomes, task-level governance has two distinguishing characteristics. First, the progression of a common technical problem across coursework, engineering projects, and master's thesis research can be traced over time, making it possible to identify redundant training activities or discontinuities in assessment. Second, multi-stakeholder assessment can be organized around shared engineering constraints and students' actual contributions, while student feedback can inform task revisions and subsequent verification [9]. However, realizing these potential advantages depends on maintaining consistent task identifiers and assessment criteria across different training stages.

A distinction should therefore be made between the structural completeness and operational effectiveness of an internal quality assurance system. Structural completeness refers to the presence of the necessary objectives, organizational arrangements, and procedural components. Operational effectiveness, by contrast, requires evidence-based judgments concerning specific quality problems, clearly assigned responsibilities, and documented outcomes of corrective actions in subsequent training cycles. The contribution of this study is not to propose a new theory that replaces the 3P model, but to explain how its underlying principles can be operationalized at the task level within university–industry collaborative engineering education.

6.2. Conditions for Assessing the Effectiveness of Internal Quality Assurance

Previous research has incorporated PDCA-based continuous improvement into curriculum design, review, and quality assessment in higher education [8]. Unlike quality assurance conducted within a single course cycle, however, the development of competencies in professional master's education in engineering extends across coursework, industry-based projects, and master's thesis research, with quality-related information distributed among multiple organizational stakeholders. To address this complexity, the present study proposes a cross-stage information chain comprising task identifiers, quality standards, responsible stakeholders, process evidence, corrective actions, and verification results. This approach translates PDCA from a general representation of an improvement cycle into a traceable and assessable set of task-level management relationships. Research on work-integrated learning similarly emphasizes the importance of aligning assessment objectives, learning contexts, and evaluation methods [10].

Assessing effectiveness requires a further distinction among three levels of evidence. Resources and institutional arrangements provide enabling evidence that the conditions for implementing the proposed mechanism are in place. Connected records documenting successive stages of the same training task provide process-linkage evidence that educational activities have been organized in a continuous manner. Effectiveness evidence, however, requires identifiable quality problems, documented corrective actions, and follow-up assessment results obtained using identical or comparable criteria. Only under these conditions can it be determined whether a particular improvement action was associated with positive changes. Even where differences between initial and subsequent assessments are observed, other influences related to teaching practices and student

cohorts must be accounted for before independent causal effects can be attributed to PDCA implementation.

6.3. Implementation Conditions and Scope of Applicability

The sustainability of the proposed mechanism is influenced by differences among engineering projects, the availability of industry supervisors, and restrictions on access to educational and technical information. In practice, each training task could be assigned a concise identifier, with its competency objectives, principal responsible stakeholder, identified quality problems, corrective actions, completion deadlines, and verification evidence documented in a common record. Academic schools could then use these records to identify recurring problems across training activities while avoiding duplicate reporting requirements in coursework, professional practice, and master's thesis management. Corporate technical information and personal data should be shared only to the extent necessary for legitimate quality assurance purposes. Sustained organizational support and the development of a quality culture are also important for preventing continuous improvement initiatives from becoming fragmented or isolated activities [11].

The explanatory scope of this study is limited to professional master's education in mechanical engineering at a single application-oriented university in China. The available case evidence consists primarily of institutional arrangements, teaching resources, and records demonstrating connections among training tasks. It does not include longitudinal competency assessments, systematic feedback from industry supervisors and students, or comprehensive corrective-action and verification records covering complete training cycles. Future research could therefore undertake longitudinal task-level tracking within the same student cohorts and examine the applicability of the proposed framework through comparative studies involving different professional degree programs and higher education institutions.

7. Conclusions

First, internal quality assurance in professional master's education in engineering can be organized around individual training tasks that connect competency objectives, organizational responsibilities, and quality evidence within three mutually supporting subsystems. This task-oriented approach provides observable units through which the requirements of differentiated professional degree education can be operationalized.

Second, the practical value of the PDCA mechanism lies in establishing traceable relationships among training tasks, assessment criteria, responsible stakeholders, corrective actions, and subsequent verification for the same identified quality problem. Claims of continuous improvement must be supported by follow-up evidence obtained using identical or comparable assessment criteria.

Third, the curriculum reforms, university–industry collaborative training arrangements, and research project–competition–master's thesis linkages at Xijing University provide an educational context for examining the proposed mechanism. The task–evidence coordination approach developed in this study offers a means of organizing quality assessment throughout the training process. Nevertheless, the extent to which this approach improves educational quality remains to be established through longitudinal empirical evidence.

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