sustainability

MDPI

Article

Investigating the Gaps between Engineering Graduates and Quantity Surveyors of Construction Enterprises

Ping Zhang *, Shuai-Ge Ma, Ying Sun and Yue-Nan Zhao

School of Materials and Architectural Engineering, Guizhou Normal University, Guiyang 550025, China; 222200191851@gznu.edu.cn (S.-G.M.); 21020191678@gznu.edu.cn (Y.S.); 21020191684@gznu.edu.cn (Y.-N.Z.)

* Correspondence: pingzhang@gznu.edu.cn

Abstract: Meeting the future workforce demands of the construction industry is defined as one of the main paths for sustainable engineering education. Quantity surveyors play a crucial role in driving the digital transformation of the construction industry. There is a pressing need to cultivate a significant number of engineering graduates who meet market demands to bolster the workforce of quantity surveyors for accomplishing this core mission. In this context, this study examined the main gaps existing between engineering graduates and quantity surveyors in terms of personal competencies needed to successfully value projects. Through the participation of 262 individuals (165 quantity surveyors and 97 engineering graduates), using a literature review, personal interviews, and a questionnaire survey, it was possible to assess five competencies (sustainable competency, budget competency, site management competency, engineering ethics, and settlement competency), and determine significant differences between both groups. All personal competencies' mean scores are higher for quantity surveyors than for engineering graduates. Four competencies are found to differ significantly between quantity surveyors and engineering graduates: sustainable competency, budget competency, site management competency, and settlement competency. As the conclusion derived from this study, it is recommended to introduce market-oriented mechanisms and establish a dynamic engineering talent model driven by market demand through collaborative development involving school–enterprise partnerships and the integration of expertise and creativity, aiming to foster the development of social practice competency. Particular emphasis should be placed on strengthening budget competency, site management competency, and settlement competency. The findings guide the education, training, and practice of quantity surveying to deal with emerging challenges in the dynamic market demand in China and beyond.

Keywords: competencies; skills; quantity surveyors; engineering graduates; gaps; construction enterprises

Citation: Zhang, P.; Ma, S.-G.; Sun, Y.; Zhao, Y.-N. Investigating the Gaps between Engineering Graduates and Quantity Surveyors of Construction Enterprises. *Sustainability* **2024**, *16*, 2984. https://doi.org/10.3390/su16072984

Academic Editor: Firoz Alam

Received: 2 February 2024
Revised: 28 March 2024
Accepted: 1 April 2024
Published: 3 April 2024

1. Introduction

Quantity surveyors play a crucial role as construction cost professionals, measuring and estimating the resources and costs required for construction projects while ensuring adherence to budget constraints [1,2]. Traditionally, their focus has been on cost management during the construction phase. Still, their diverse skills now enable them to contribute significantly to financial and contractual management at various project stages [3,4]. The economic downturn has underscored their importance, especially given the low profit margins in construction projects. In the UK, for instance, the top 100 contractors reported a pre-tax profit of approximately 1.5% in 2017. This emphasizes the challenges faced by small- and medium-scale (SME) organizations within the construction supply chain, operating at potentially even lower profit margins. Given the critical need to extract value and profitability from capital investments, the expertise and core competencies of professionals like quantity surveyors, who specialize in costing, become paramount [5]. Quantity surveyors, equipped with knowledge in cost management and building methodology, significantly contribute to securing the success of construction projects. Their competency to aid clients in accomplishing sustainable goals positions them as essential assets to the construction industry [6].

It is commonly acknowledged that during the construction phase of a project, one of the primary responsibilities of a quantity surveyor is to ensure effective cost management and control [1]. Renowned for their expertise in measurement, quantification, and preparation of bills of quantities, the Royal Institution of Chartered Surveyors (RICS) defines quantity surveyors as professionals with skills in procurement, financial control, and contractual management. This encompasses "managing expenses and overseeing costs on behalf of others" [7]. The core competencies of quantity surveyors encompass estimating construction expenses, quantification, preparing diverse contract documents (such as bidding documents and cost planning documents), contract management, and formulating final accounts [8]. While scholars identify "cost management" as the primary expertise of quantity surveyors, followed by "estimation and financial control", the evolving demands of the construction industry require these professionals to improve their skills [9]. In response, contemporary quantity surveyors are extending their services to encompass roles in project management [10]. Considering the intricate, segmented, and ever-changing nature of the construction industry, where numerous parties are frequently engaged in adversarial relationships, conflicts become nearly unavoidable [11]. Quantity surveyors are anticipated to have a significant impact in proactively preventing conflicts, adeptly managing disputes, and facilitating resolutions through established dispute resolution procedures [12,13]. Additionally, the future demands an increased focus on computer literacy and information technology (IT) skills [2,14]. It is vital for quantity surveyors to rapidly embrace advanced digital technologies like Building Information Modeling (BIM) to boost productivity and maximize financial gains [15,16]. The evolving landscape also necessitates quantity surveyors to obtain additional expertise on green building practices and cutting-edge technical approaches to safeguard their standing in the construction industry. As the industry witnesses the rise of smart buildings/cities and the exploitation of big data (BD), artificial intelligence (AI), and machine learning (ML), quantity surveyors are compelled to adapt to shifting industrial and owner needs. Developing emerging competencies becomes essential to advance construction quality and facilitate continual professional development in the competitive landscape of the modern construction industry [17–19].

The field of quantity surveying consistently deals with challenges and opportunities in evolving environments [20]. These opportunities often go untapped, primarily due to insufficient relevant skills and competencies. To fully harness these prospects, it is imperative to address the deficiency in skills [5]. In response to these challenges and the escalating complexity of civil engineering projects, quantity surveyors must be appropriately competent and committed to continuously developing their competencies. Wao (2016) [18] emphasizes the areas where quantity surveyors may be involved in the future, particularly in areas such as IT and sustainable construction, spanning the next 10–15 years. In recent years, the importance of BIM has witnessed a considerable surge. However, a significant obstacle to its widespread integration in the construction industry persists in the form of a shortage of knowledge and skills [21]. The remedy lies in training existing quantity surveyors and engineering graduates, ensuring that they possess the necessary knowledge, skills, and proficiency in BIM that align with their respective disciplines [22,23]. The Australian Institute of Quantity Surveyors (AIQS) (2004) has recognized the significance of educational and training efforts. These initiatives, concentrated on improving skills and knowledge, as well as fostering continuous professional development, are deemed crucial for the advancement of the quantity surveying profession [24]. These skills can be acquired through higher education or individual growth. For construction industry practitioners, specific fundamental skills and knowledge are expected, ideally accepted at universities, colleges, or higher education establishments [25]. In foreign countries, especially in developed nations, professional competency standards are formulated by industry associations to guide universities in establishing relevant course systems and conducting professional certification. Obtaining certification from industry associations becomes a key factor for engineering graduates to transition into professionals in the field successfully [26]. The ultimate goal of engineering graduates' training is to meet the industry market's needs fundamentally. However, Perera and Pearson (2011) highlight that the current education system falls short of meeting the demands of the industry, resulting in a misalignment between the competencies of quantity surveying graduates and industrial requirements [27]. Examining the competencies of quantity surveying graduates in Sri Lanka, Yogeshwaran et al. (2018) found that a significant portion of these competencies does not meet industry standards [3]. This discrepancy is frequently denoted as "skill and competency gaps", recognized as a crucial factor leading to graduate unemployment and employer discontent within the construction industry. It is essential to examine the primary disparities in personal competencies required for project success between engineering graduates and quantity surveyors. These recognized gaps will form the foundation for educational endeavors, training initiatives, and continuous professional development for quantity surveyors. The goal is to elevate the quality of services and secure the resilience of cost management firms in fiercely competitive markets.

A guiding direction for the standard system of competencies of quantity surveyors has been provided by the China Cost Engineering Association (CCEA). Building upon this guidance, a literature review was conducted to summarize the relevant research results domestically and internationally, which is conducive to forming a more precise competency framework for Chinese quantity surveyors. Subsequently, a questionnaire was employed to assess the competency framework of quantity surveyors, examining the current abilities of senior quantity surveyors and engineering graduates separately. The goal was to analyze the primary gaps existing between engineering graduates and quantity surveyors concerning the personal competencies crucial for achieving success in a project-oriented environment. This research aids in identifying the essential personal competencies needed by quantity surveyors in China and understanding the actual training and learning requirements of engineering students to better prepare them for entering their professional career after graduation.

2. Literature Review

2.1. The Competencies of Quantity Surveyors

Competency involves the effective application of a cohesive set of interlinked expertise, abilities, competencies, and individual qualities essential for accomplishing "critical work functions", which ultimately results enhanced employee effectiveness [28]. Babalola (2009) regarded a competent quantity surveyor as an individual expected to encompass a variety of skills, knowledge, and comprehension. Furthermore, this professional should utilize these skills and knowledge in diverse contexts [20]. The distinctive competency of quantity surveyors lies in their expertise in measurement and valuation [15], involving forecasting, analyzing, planning, controlling and accounting [29]. Quantity surveyors contribute to cost-effectiveness through project construction process management. They aim to control the project cost, mitigate risks, and enhance the project's value, ensuring clients' economic benefits. Because of the global problem of project cost overruns, governments and enterprises have increasingly recognized the need for more effective cost reduction in construction projects. This has led to a growing awareness of the importance and value of engaging expert quantity surveyors [30].

The increasing recognition of the pivotal role of quantity surveyors in organizations in the past few decades has prompted the development of international competency frameworks. The competencies expected of quantity surveyors have been outlined and detailed, providing a comprehensive overview of the functional components of each unit, which includes performance standards, range indicators, and evidence guidelines, as specified by the RICS, the Pacific Association of Quantity Surveyors (PAQS), the Association for Advancement of Cost Engineering (AACE), etc. [20]. The performance standards specify the outcomes required to demonstrate satisfactory performance for each competency element. Range indicators define the scope to which performance standards are applicable, while evidence guidelines offer tangible outcomes that demonstrate satisfactory competencies [20,31]. These criteria for competency guide both individuals and organizations in defining, assessing, and developing quantity surveying competencies, with their application expanding internationally. In general, the competency framework in different regional industry associations generally shows that the practical ability of quantity surveyors should contain three levels: basic abilities, core abilities, and professional abilities. And there are different specific requirements according to different occupational scopes and service objects [32].

The field of quantity surveying has continuously been recognized as vibrant, and its ever-changing nature shapes the abilities and proficiencies needed to address evolving requirements promptly. This dynamism is evident in the diverse skills and competencies of quantity surveyors emphasized by the RICS at various junctures [33]. In the early years, the quantity surveyor was preeminent for its expertise in measuring, quantifying, and compiling bills of quantities. Expanding upon the RICS definition, the quantity surveyor processes skills in procurement, financial, and contractual controls, covering comprehensive aspects of cost control and expenditure monitoring on behalf of clients or third parties [17,18,34]. This underscores the distinctly recognized “technical” role of quantity surveyors during that period. In fact, throughout history, this “technical” role has been the most widely acknowledged aspect of the quantity surveyors’ responsibilities [14,15,33]. Deviating from its traditional “technical” role, RICS has subsequently promoted the various roles of the quantity surveyor as “the building economist”, “cost engineer”, “procurement consultant”, and “cost consultant”. These roles have bestowed a fresh “managerial” image upon them [33]. The role of quantity surveyors has broadened beyond the measurement and estimation of costs in construction projects, which now encompasses emerging responsibilities such as risk management, quality control, dispute resolution, and payment management [7]. Despite the continued importance of technical competencies, future quantity surveyor services within an ever-changing environment are expected to require enhanced competencies in management-oriented skills [28]. In addition, conflict avoidance, business planning, sustainability consultancy, accounting principles, ethics and professional practice, and client care are considered the core competencies of a proficient quantity surveyor [9,35]. Shafie et al. (2014) [8] and Cunningham (2014) [15] asserted that incorporating and applying soft skills is crucial for quantity surveyors to foster their competencies in terms of collaboration, analytical thinking, and decision-making proficiency.

The construction industry is adopting high-tech digital tools like BIM to enhance efficiency and optimize earnings [36]. Quantity surveyors need to quickly embrace these advanced technologies to ensure the longevity of their professional careers [37]. From a cost management standpoint, many scholars have recognized BIM as a valuable tool for supporting the generation of estimates. BIM facilitates the precise and automated extraction of quantities, empowering quantity surveyors to collaborate seamlessly with various disciplines and visualize the envisioned development [38–42]. In 2016, Kamaruzzaman et al. underscored the BIM adoption of quantity surveyors in cost estimation. The competency was classified into three primary dimensions: visualization of data (e.g., preparation of bill of quantities, whole life cycle costing, contractual documentation), stable database (e.g., estimating, quantity takeoff), and coordination of data (e.g., storing, sharing, and accessing information) [42–44]. Meanwhile, competency is also required for quantity surveyors to cite BIM to strengthen team communication and enhance interoperability in the construction phase [38].

Quantity surveying is defined as a client-driven profession, wherein quantity surveying professionals address client requirements and must continually upgrade their skills to meet the ever-changing requirements of project owners [18]. Since the 21st century, quantity surveyors have expanded their roles to encompass broader responsibilities across every phase of the building life cycle, which includes involvement from project inception and design to obtaining consent, procurement, construction, commissioning of the completed building, and retrofitting or upgrading during the service stage [1]. Consequently, several new roles have emerged within the quantity surveying profession, placing heightened importance on satisfying customers' requirements. Quantity surveyors now engage in procurement, planning for design costs, comprehensive life cycle costing, value optimization, and risk assessment and control. As buildings shift their focus towards engineering services, there is an increased focus on measuring the cost and value of such services. Additionally, evolved roles encompass project and construction management, facilities management, managing contractual conflicts and legal disputes, and performing insurance valuation [14,33]. Different roles and responsibilities require quantity surveyors to address the requirements of their clients effectively. The work content of quantity surveyors will show a relatively fixed range due to the different occupation scope, service object, and project stage. For instance, authors such as Elhag (2005) [45], Crafford and Smallwood (2007) [46], and Ashworth (2013) [14], while restricting the responsibilities of quantity surveyors employed in construction enterprises during the construction phase, the role of the consultancy quantity surveyor has been expanded to cover the entire building life cycle. This includes responsibilities expanding beyond the phase of capital development: BIM spans into the subsequent stages of operation, maintenance, upgrades, and eventual disposal. Nevertheless, the range of services can be tailored to any stage of project development or the building life cycle, as determined by the client or employer [1]. Cunningham (2014) argues that there is no place for complacency, and the quantity surveyor must take proactive measures to meet client expectations in an increasingly competitive and interconnected global landscape [15].

The evident shift in climate patterns and ongoing depletion of natural resources have notably affected our constructed surroundings. As a result, industries worldwide are increasingly embracing sustainable developments and products [47]. As project sponsors or owners aim to minimize energy usage and optimize the utilization of eco-friendly materials, formulating a precise cost estimate and plan has become more complex [9]. To effectively provide cost advisory services for sustainable projects to customers and other professionals in the field, quantity surveyors need to enhance their competencies and knowledge continually. Understanding green products and materials has been identified as a critical advantage for quantity surveyors to sustain their professionalism in the field [47]. The evolving services related to green buildings also encompass the development of sustainability strategies, the assessment of life cycle costs (constructional elements and construction materials), selecting "Green Contractors", constructing cost databases of green projects, providing advice for engineering projects, and assessing the sustainability of property [9,47].

As the times undergo change and development, science and technology continually update and iterate. The needs of owners/customers evolve, leading to a continuous transformation of the role of quantity surveyors and an expansion of capability requirements. And it requires that quantity surveyors need to consistently participate in lifelong learning to stay updated on the rapid progress in technology and knowledge, significantly influencing their present and future service offerings [1,20]. Frei et al. (2013) [48] support this idea, suggesting that quantity surveyors should continually analyze the external business environment to identify future directions that are important to the business. They promote the development of strategies to realign their positions, viewing changes as chances rather than risks [1,48].

After conducting an extensive meta-analysis of the literature, Tables 1 and 2 provide a compilation of the most widely mentioned fundamental, core, and developing competencies expected of a quantity surveying professional.

Table 1. The competency indicators of quantity surveyors (institutions).

Resources	Dimensions	Competency Indicators
RICS (2018) [2]	Mandatory competencies	Communication and negotiation; health and safety; data management, etc.
	Core competencies	Commercial management; control and reporting, etc.
	Optional competencies	Commercial management; conflict avoidance; programming and planning, etc.
AIQS (2020) [35]	Basic skills	Quantification/measurement; communication skills; personal and interpersonal skills, etc.
	Project cost management competencies	Strategic planning; construction change management; financial audit; resource analysis, etc.
	Support competencies	Computer services; business management; life cycle cost analyses, etc.
	Asset financial management competencies	Special assessments; audits; technical due diligence; compliance issues
AACE [49]	Basic knowledge and skills	Computer operation; expansion capability, etc.
	Cost estimation and control	Basic knowledge of cost; risk analysis/contingency, etc.
	Project management	Resource/productivity management; contracts and contract management, etc.
	Economic analysis	Value analysis; value prediction, etc.
PAQS [50]	Basic skills	Quantification/measurement; communication skills; business and management skills, etc.
	Core competencies	Cost management; procurement; contract administration; feasibility studies
	Specialist competencies	Special assessment; business management; life cycle cost analysis, etc.
SISV [51]	Mandatory	Contract administration and management; professional and business ethics, etc.
	Elective	Building information modelling application; data collection and analysis; life cycle costing and analysis, etc.
	Optional	Business negotiation; continuous improvement management; critical thinking; technology application, etc.
CCEA [52]	Basic skills	Prepare and review project proposal and bill of quantities; optimization scheme; deal with project economic disputes; economic and social development planning, etc.
	Developing skills	Information technology; full life cycle management; engineering ethics

Table 2. The competency indicators of quantity surveyors (experts).

Resources	Dimensions	Competency Indicators
Mbachu (2015) [1]	-	Negotiation skills; communication skills; teamwork; interpersonal skills; data management; client relationship management; conflict management; attention to details; measurement/quantification; self-confidence; can-do attitude, etc.
Yogeshwaran (2018) [3]	New emerging competencies	Risk management; quality management and financial project appraisal
Seidu (2020) [5]	-	Quantitative and analytical skills; communication skills; artificial intelligence (AI) skills; collaboration and integration
Shafiei (2008) [8]	-	Quantification/measurement; analysis; interpersonal skills; communication; management; appraisal/evaluation; leadership, etc.
Ashworth (2013) [14]	Basic skill	Management; documentation; analysis; appraisal; quantification; synthesis and communication
Cunningham (2014) [15]	-	Financial management; contract administration; project management; professional and interpersonal skills

Table 2. *Cont.*

Resources	Dimensions	Competency Indicators
Dada (2012) [20]	Core competency	Feasibility/viability studies; development economics; cost planning and control; estimating; construction procurement system; contract documentation, etc.
	Optional competency	Economic management of urban infrastructure
	Special competency	Facility and risk management
Yap (2022) [28]	Basic/core competency	Business management; contract documentation; personal/interpersonal skills, etc.
	Evolving skills	Life cycle cost analysis; strategic planning; information technology; quality assurance; financial auditing; capital allowances, etc.
Antwi-Afari (2018) [36]	-	Technological skills; innovative and entrepreneurial skills; social image and talent management skills
Saka (2020) [43]	Knowledge of BIM	Construction design and contracting procedures; merits and demerits of BIM for design/construction/operation processes; information management, etc.
	Skills of BIM	Basic BIM operating skills and other advanced skills
Musa (2010) [53]	Future role	Computer literacy and information technology skills
Fung (2014) [54]	BIM capabilities	Cost appraisal capacity; cost estimation capacity; cost planning capacity; information management capacity; cost checking capacity
Ashworth (2018) [55]	Pre-contract role of the quantity surveyor	Preliminary cost advice; procurement advice
	Post-contract role of the quantity surveyor	Project cost accounting; work progress payments and claim management; preparation of loss adjustment; cost audit
Sun (2018) [56]	-	Professional skills; communication skills; continuous learning, etc.
Xu (2016) [57]	Professional competency	Application of cost software; professional knowledge of cost engineer; engineering practical experience; computer knowledge, etc.
	Comprehensive management	Comprehensive analysis ability; rapid response ability; communication ability; coordination ability; observation ability
	Individual quality	Cultural knowledge; health; ethics; ability to withstand pressure; innovative thinking
	Performance	Cost management; contract management; scheme comparison; investment estimation; design budget; construction drawing budget; tender price and bid quotation
Guo (2011) [58]	-	Engineering settlement; engineering settlement audit; professional ethics; risk and legal awareness; internal management
Zhang (2022) [59]	Professional knowledge skills and abilities	Professional knowledge; application ability; self-study ability; tendering service ability, etc.
	Comprehensive management abilities	Judgment ability; emergency ability; coordination and communication ability; organizational and management ability, etc.
	Individual inner abilities	Ethical qualities; physical health; adequate cultural literacy; learning ability, etc.

2.2. Challenges for Quantity Surveyors

The shifts in the market, construction industry, and client demands have presented challenges but broad prospects for development in the quantity surveying profession. Therefore, quantity surveyors have initiated the exploration of new potential roles. Beyond their traditional responsibilities, there is an anticipation for quantity surveyors to undertake evolving roles in the profession, placing heightened importance on addressing clients' requirements. The ongoing evolution of roles within the industry has made it difficult for quantity surveyors to sustain competitiveness in the construction labor market [33].

The historical acknowledgment of the quantity surveyor's role has predominantly centered on its technical aspect. Because of this inherent nature, there has been a belief that the tasks executed by a quantity surveyor could be easily substituted by either an individual or a machine proficient in basic arithmetic calculations. This perspective has prompted construction industry experts to continually advocate for enhancing technological expertise within the quantity surveying profession [18,33,60]. Per Ashworth et al. (2013) [14], the evolution of quantity surveyor services in the future is expected to be shaped by various factors. These factors encompass customer orientation, the novel utilization of information and communication technology (ICT), and the emphasis on sustainability goals. The profession consistently encounters challenges and opportunities in emerging markets, necessitating acquiring relevant skills and competencies [14,61]. For example, the main challenge facing the industry in South Africa is taking on roles beyond the conventional scope of quantity surveyor services and tackling the deficiency of pertinent expertise in the emerging generation of professionals. These challenges are closely linked to technical shortcomings, including a lack of knowledge, essential skills, and competencies required for future careers [28].

With the construction industry facing increasingly sophisticated customer requirements beyond traditional competencies, quantity surveyors are urged to update their competencies. This involves assuming new roles and shouldering additional responsibilities, including the adoption of advanced ICT such as BIM, BD, and AI. These technologies enable more precise and automated cost estimation and planning from the inception of a construction project [9,37]. The significance of digital technology has increasingly manifested in recent years [5,62]. The construction industry is actively adopting advanced digital technologies to improve productivity, maximize profits [9,16,63], enhance the work performance of quantity surveyors, and optimize project performance [41,43]. For example, BIM allows for the digital creation of precise virtual building models, ensuring their use throughout the entire life cycle and contributing to a safer and more productive environment [64]. Moreover, BIM simplifies the accessibility and sharing of building data for diverse functions, such as model creation and design, quantity takeoff and cost estimation, energy analysis and data management, and standardization [43]. Furthermore, BD allows the assessment of tenders against historical data through the application of algorithms. These algorithms can compare and contrast extensive sets of construction data and documentation. By fully leveraging past project cost data, BD facilitates the initiation of data mining examinations, establishing a foundation for the tender analysis of both new and existing construction projects [5,65]. BD technologies can aid in assimilating crucial and extensive cost data required by stakeholders to produce precise cost projections and social effects, ultimately resulting in increased value [5]. Thirdly, ML, being a subset of AI, presents a practical solution to address inaccuracies in cost estimation and time delays, aiming to minimize or prevent such occurrences. Clients expect a favorable project return, while construction enterprises aim for profit maximization. This approach is feasible due to the construction industry's ability to generate substantial data through the involvement of various parties in the construction process, which can be collaboratively employed for ML [5]. However, a significant challenge highlighted in the literature is the insufficient competencies in information technology. Hence, there is an urgent requirement for quantity surveyors to be well-informed and proficient to thrive in the contemporary construction industry [43,66]. And the results suggest that quantity surveyors do not necessarily have to be specialists in digital technology to play a part in the future. The primary focus should be on developing expertise and specific functionalities within their domain to a competent level [43]. Therefore, future quantity surveying professionals would have to acquire some skills and capabilities, such as evolutionary algorithms, artificial neural networks, knowledge discovery, regression modeling, data integration and fusion, etc. [5,65]. Furthermore, related studies also state that the quantity surveying profession encounters notable challenges in meeting the demands of green building. "Suitability analysis" was identified as the highest-priority competency for quantity surveyors to ensure the longevity of their business in the construction industry [9].

Evolving customer demands are increasingly focused on the comprehensive capabilities of quantity surveyors. Mbachu (2015) [1] observed that quantity surveyors' businesses should maintain a broad and diversified portfolio of service offerings. This strategy helps them evade the impact of fluctuations in the business environment, where opportunities may decline in certain areas while rising in others. While focusing on core strengths is advantageous, diversifying into additional service lines could ensure their business resilience during economic downturns in their existing areas of specialization. Therefore, quantity surveying is now an amalgamation of various disciplines, encompassing legal contracts, building economics, and data management [9]. In this position, the quantity surveyor is anticipated to play a role throughout the complete duration of the construction project and beyond, assuming a heightened managerial responsibility [33]. For example, quantity surveyors are required to participate in project management, carry out cost analysis of construction technology, or select suitable construction technology based on a limited amount of money, reasonable arrangement of the construction schedule, or an innovative construction scheme according to the project cost. The project cost's judicial appraisal is carried out for project price disputes arising in the project, proposal of the improvement direction of BIM and other building digital tool software according to their own experience, or directly participation in the research and development of construction cost software. Moreover, the essential emerging competencies for quantity surveyors are reflected in the holistic management of processes related to risk, quality, and value engineering [3,9,36,37].

Quantity surveyors must uphold good professional ethics and adhere to ethical standards in the construction industry as they advance in their careers [18,67]. This will enhance their attractiveness to owners as contributors of value in construction projects. The construction industry is commonly considered one of the most prevalent sectors for corruption [18]. The conceptual aspect of construction, extended supply chains, confidentiality, and the intricate nature of the industry render it highly vulnerable to unscrupulous and dishonest behaviors [67]. Adhering to good professional ethics helps them avoid certain troubles in their careers, such as tender collusion, kickbacks, concealment of sub-standard work, and overbilling, among others [67,68]. This, in turn, enhances the credit rating of quantity surveyors. Meanwhile, quantity surveyors also have good psychological quality. The study indicates that standards of morality may be compromised when management applies excessive pressure on employees to deliver favorable outcomes [67]. Strong anti-pressure ability will ensure that quantity surveyors quickly adapt to tedious work.

China's global strategy has propelled its construction industry to enter overseas markets. The research shows that the quantity measurement industry has undergone a substantial transformation due to evolving industry and owner requirements, as well as increased competition in the global construction industry marked by large-scale projects and diverse specialists [18,69]. The younger generations of quantity surveyors will encounter new challenges when working with individuals from diverse cultural backgrounds. For example, a quantity surveyor employed in Malaysia needs to factor in the estimation of additional construction land costs, considering that a majority of Malaysian construction workers are required to pray at designated times for religious reasons. This entails the necessity of providing prayer rooms [9]. Therefore, quantity surveyors should have an international vision and cross-border thinking and be good at arranging engineering activities or cost management according to the customs and religious beliefs of different countries and nations. Moreover, quantity surveyors encounter diverse opportunities and challenges in fields beyond the construction industry, such as development assessment, tax planning, technical audits, fire insurance assessment, fire loss adjustment, and maintenance management [20].

Faced with a complex and evolving market or customer demands, quantity surveyors should continuously enhance their skills and expertise. This involves aligning with national strategic deployment and industry development trends, planning for learning and updating new knowledge, and proficiently using advanced technology to improve the accuracy and quality of work results. The goal is to optimize the economic benefits of construction projects. In this context, quantity surveyors need to embrace lifelong learning to cope with the changing and increasing occupational competency requirements [33].

2.3. Research Gaps

Through summarizing and analyzing the existing research findings, domestic and foreign scholars have systematically investigated the competency frameworks and indicators of quantity surveyors. They have identified the challenges and opportunities for the career development of quantity surveyors, laying a good foundation for deepening the cultivation of quantity surveyors' core competencies, which is mainly reflected in the following aspects.

Firstly, the digital transformation of the construction industry is an inevitable trend in future market development, with digital technology represented by BIM sweeping the world. However, the shift from conventional methods to innovative approaches poses significant complexity, particularly in the construction sector, which exhibits a slower pace in embracing advancements compared to industries like manufacturing [43,70]. The construction industry faces challenges such as a shortage of talent, insufficient expertise in BIM, and limited practical experience among graduates. These issues are considered the primary obstacles hindering the application and promotion of BIM in the field of construction [19,43]. The growing demand has escalated the requirements for quantity surveyors within the industry to receive advanced training and education and cultivate a more profound understanding of BIM-related products and processes. The adoption of BIM relies heavily on the capacity of existing surveyors and recent graduates to gain the skills and training for applying BIM. This imposes an extra load on employers [62], causing certain construction companies to hesitate in implementing BIM, citing apprehensions related to financial and temporal consequences [5]. Construction companies and experts posit that essential and critical competencies and knowledge are more effectively obtained through university education [25]. This is because there is a necessity to position them within a more suitable competency development framework to guarantee their ongoing relevance [20]. Moreover, college students exhibit a high aptitude for adapting new technologies, which can speed up the promotion of new technologies and solve problems at the source to achieve better results (existing studies mainly focus on the skills training of existing quantity surveyors and rarely take students as research objects). More importantly, training BIM and other digital technologies in schools can effectively lower enterprise costs in this area and can be widely supported at the social level. Consequently, enhancing engineering graduates' skills and knowledge in school education and training has been identified as a key factor contributing to the advancement of the quantity surveying profession [20].

Secondly, quantity surveyors' professional competency is reflected in meeting market and customer needs, but these needs are dynamic. The traditional training and education models are frequently criticized for their inadequate alignment with the actual needs of the industry [20,71]. The current education system falls short of meeting the requirements of the construction industry. There exists a competency gap between the quantity surveying graduates and the industry's needs [9,72]. Therefore, there is an urgent need to investigate the real needs of society to identify the competencies needed by quantity surveyors in the current and future construction industry [73]. Based on these findings, universities ought to provide inventive curricula, instructional approaches, and training or retraining initiatives that encompass not only discipline-specific competencies but also a broader set of occupational competencies [33]. Moreover, positive feedback between the university and the industry must be established to carry out school–enterprise cooperation effectively. This aims to realize complementary advantages between schools and enterprises. Universities offer avenues for the industry to enhance their practices, and the industry provides projects for the university to explore [9], thus cultivating many graduates who are popular in the market and possess a solid technical comprehension, a broader application of business skills, and a dedication to lifelong learning [33]. Hence, it is essential to modernize universities to make the engineering graduates more responsive to stay abreast of the ongoing changes in the construction industry [18].

Thirdly, the scope of work for quantity surveyors spans the entire life cycle of the project. As a result, there are numerous competency indicators, and significant differences exist due to varying service content and customer needs. If all indicators are investigated and studied, the result may be poor due to the enormous workload. This is not conducive to follow-up education practices. Therefore, it is advisable to select representative competency indicators for detailed research. Based on data from the National Bureau of Statistics of China, construction enterprises make up 70% of the total number of construction enterprises [74], and the number of quantity surveyor employees is among the highest. Taking the quantity surveyors' competencies of construction enterprises as the benchmark, the quantity surveyors' core vocational abilities of social demand are investigated and compared with the current situation of the competencies of engineering graduates to determine whether the gaps between the two can have a positive effect. It is beneficial to carry out targeted education practices based on quantity surveyors' competencies of construction enterprises.

3. Research Objective

This paper focuses on individual competencies of engineers talents and their careers as quantity surveyors of construction enterprises in China, requiring further exploration and explanation. This study investigates evidence highlighting the gaps between engineering graduates and quantity surveyors, providing valuable insights into identifying the key competencies needed for future quantity surveyors. Additionally, it aids in understanding the developmental and educational requirements of engineering students, preparing them for professional practice in the future [75]. Considering the need for further investigation, this study aims to explore the following research question:

What are the main gaps between engineering graduates and quantity surveyors of construction enterprises regarding the personal competencies needed to cope with changing and increasing client needs?

4. Method

The research was carried out in the following three stages, as shown in Figure 1.

Stage 1: Identification of competency framework of quantity surveyors in Chinese construction enterprises. This stage aimed to identify a set of personal competencies for measurement in the research, facilitating quantitative analysis of the main gaps between engineering graduates and quantity surveyors. Initially, through a detailed literature review and drawing upon the competency frameworks of institutions such as the Royal Institution of Chartered Surveyors (RICS), the Pacific Association of Quantity Surveyors (PAQS), the Association for Advancement of Cost Engineering (AACE), and the China Cost Engineering Association (CCEA), a comprehensive dimension and indicator scope for quantity surveyors' competencies were derived. Simultaneously, in alignment with the research objectives, the competency framework and indicator range for quantity surveyors in construction enterprises were determined based on the life cycle stage of construction projects, corresponding job responsibilities, and the specific behaviors or characteristics expected from quantity surveyors. This laid the theoretical foundation for exploring the competencies of quantity surveyors in Chinese construction enterprises [76]. To further enhance the scientific and rational competency framework and indicators for quantity surveyors in construction enterprises, considering the unique characteristics of China's construction industry, 10 quantity surveyors with over ten years of experience in cost management were selected from various Chinese construction enterprises for semi-structured personal interviews. These interviews aimed to refine the competency indicators obtained from the literature review and introduce new competencies and metrics identified by experienced professionals. The interviewed quantity surveyors represented diverse professional backgrounds, including housing construction, road engineering, bridge engineering, prefabricated construction, and so on, ensuring the independence and heterogeneity of the sample data. These interviews were conducted individually with each quantity surveyor; they were asked to select competency indicators for quantity surveyors in construction enterprises based on their experience and respond to open-ended questions [77]. Through a synthesis of the literature review and expert interviews, 27 competency indicators were proposed as valid for analyzing the personal competencies of quantity surveyors in construction enterprises and engineering graduates.

Stage 2: Data collection by survey administration. Building upon the performance of the previous stage, the investigation questionnaire was compiled into two parts. The first part aimed to gather basic information about respondents, including gender, educational background, work experience, and the type of corporation. The second part focused on investigating the competencies of quantity surveyors in construction enterprises, comprising 27 items. To measure these competencies, each indicator was defined using an extended Likert scale ranging from 1 to 5, where "1" represented "not important", "2" represented "somewhat important", "3" presented important, "4" represented "very important", and "5" represented "extremely important". This scale was intended for self-assessment of the frequency of each behavior. Once the questionnaire had been prepared, experts with extensive work experience in engineering education and psychology were invited to evaluate the questionnaire. This step ensures the rationality and validity of the questionnaire content, guaranteeing its quality and enhancing content validity [78].

This survey aims to compare the competency gaps between quantity surveyors and engineering graduates, and quantity surveyors and engineering graduates were taken as the investigation objects. The sample whose survey object is quantity surveyors is called the sample of quantity surveyors (hereinafter referred to as quantity surveyor sample), and the sample whose survey object is engineering graduates is called the sample of engineering graduates (hereinafter referred to as engineering graduate sample). The objective of the quantity surveyor sample was to derive competency indicators tailored to meet the demands of the Chinese market. To ensure a comprehensive understanding, participants in this sample were required to have a minimum of 5 years of industry experience, coupled with quantity surveyor certifications. This stringent criterion aimed to guarantee a profound insight into the current and future development of the country and the industry, specifically concerning the professional competencies of quantity surveyors in construction enterprises. In contrast, the engineering graduate sample consisted of recent undergraduate graduates within two years of completing their degree, with relatively limited social work experience. This group aimed to analyze the current state of their professional competencies. Quantity surveyors were mainly recruited through professional networks and social resources, often through connections with teachers and local industry associations. Engineering graduates primarily included students who had graduated from engineering majors at Guizhou Normal University within the past two years. The survey successfully gathered responses from 165 cost engineers and 97 engineering graduates.

Stage 3: Gap analysis. To address the research question, the calculation of means and standard deviations for competency dimensions was undertaken to evaluate outcomes and draw comparisons across distinct cohorts—specifically, quantity surveyors and engineering graduates. An independent-sample *t*-test was employed to assess the significance of competency gaps by examining the mean values of these two sets of data. To authenticate the survey, the gathered data underwent analysis for scale reliability through SPSS 22, ensuring internal consistency.

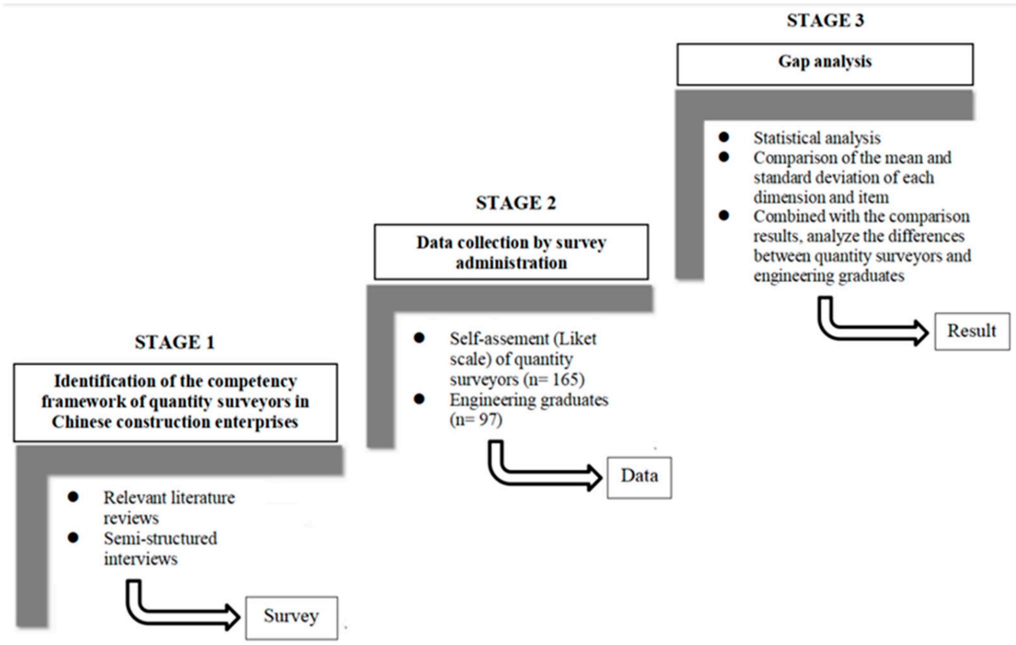

Figure 1. Research method.

5. Results and Discussion

5.1. Profile of Respondents

Basic information of quantity surveyor sample: 194 questionnaires were distributed, with 179 returned and 165 deemed valid, resulting in an effective rate of 92.18%. For the qualifications, 0.61% of survey respondents had completed an associate degree, 56.97% have a bachelor's degree, while 30.30% and 12.12% possess a master's degree and doctoral degree, respectively. In terms of working experience, the calculation shows that 10.30% had 5–10 years of industry experience, 56.97% had 11–15 years of experience, and 32.73% had over 16 years of working experience. In the context of workplace distribution, government sectors (including financial audit units) represent 0.61%, cost consulting enterprises make up 16.97%, owners contribute 7.27%, and experts, scholars, or researchers in universities constitute 9.09%. Construction enterprises dominate with 63.64%, while other sectors contribute 2.42%. The basic information of the engineering graduate sample: 116 questionnaires were distributed, 105 were recovered, and 97 were valid, resulting in an effective questionnaire rate of 92.38%. In terms of education background, 100.00% of the respondents had obtained a bachelor's degree and 12.37% were pursuing a master's degree. Regarding working experience, 57.73% had less than 1 year of working experience and 42.27% have 1–2 years of working experience. The results of the specific descriptive analysis are presented in Table 3.

As for the quantity surveyor sample, 99.39% possess a bachelor's degree or higher, with 89.7% having more than ten years of working experience, and 63.64% come from construction enterprises. This demographic indicates not only a wealth of working experience but also a profound understanding of the competencies required for quantity surveyors in construction enterprises. These respondents, being senior industry experts, boast a solid educational background and exhibit a keen interest in industry developments and new technologies. This is conducive to obtaining scientifically robust data to support subsequent research [79]. Concerning the engineering graduates, they are recent undergraduate students with less than two years since graduation, limited social work experience, and a lack of understanding of the competencies expected of quantity surveyors. Additionally, they may not possess a deep understanding of the market demands in the construction industry. Derived from the general background information, it is reasonable to assert that the survey participants have strong academic and professional backgrounds. This enhances the credibility of the collected data [20].

Table 3. The results of descriptive analysis.

The Sample of Quantity Surveyors		Frequency	Percent
Education background	Associate degree or below	1	0.61%
	Bachelor's degree	94	56.97%
	Master's degree	50	30.30%
	Doctoral degree	20	12.12%
Working experience	5–10 years	17	10.30%
	11–15 years	94	56.97%
	16 years and above	54	32.73%
Workplace	Government departments (including fiscal review units)	1	0.61%
	Cost consulting enterprises	28	16.97%
	Owners	12	7.27%
	Universities	15	9.09%
	Construction enterprises	105	63.64%
	Others	4	2.42%
The sample of engineering graduates		Frequency	Percent
Working experience	less than 1 year	56	57.73%
	1–2 years	41	42.27%

5.2. Scale Test and Exploratory Factor Analysis

5.2.1. Scale Test

To ensure the scientific rigor and validity of the questionnaire, it is imperative to assess the reliability and validity of the scale, supporting subsequent data analysis. Reliability serves as an indicator to evaluate the stability of the scale, detecting the consistency of results obtained through repeated measurements of the same phenomenon. The commonly used Cronbach's α coefficient is employed to estimate reliability, with the minimum reliability standard requiring Cronbach's α coefficient of the total scale to be greater than 0.8 and Cronbach's α coefficient of each subscale to be greater than 0.7 [80]. Using the statistical software SPSS 22, Cronbach's α coefficient for the quantity surveyor sample and engineering graduate sample was calculated as 0.937 and 0.934, respectively—both exceeding 0.8. This indicates that Cronbach's α coefficient of the scale meets quality requirements, and all measured items passed the reliability test, suggesting high internal consistency reliability [81]. Validity pertains to how well a scale can precisely gauge the attributes it intends to evaluate—the measure to which the test outcome mirrors the content under scrutiny. The greater the alignment between the measured outcome and the content being examined, the greater the validity; conversely, diminished consistency indicates decreased validity [82]. Validity analysis was conducted using the Kaiser–Meyer–Olkin test and Bartlett's test. The KMO index for the sample of quantity surveyors and engineering graduates was calculated as 0.898 and 0.888, respectively—both exceeding 0.8. Additionally, the p-value for the scale test through Bartlett's test was 0.000. The significance test suggests that the scale exhibits good structural validity and is suitable for exploratory factor analysis [83]. Consequently, the scale was deemed viable and capable of fulfilling the objectives of this study.

5.2.2. Exploratory Factor Analysis

Exploratory factor analysis is a statistical technique that converts numerous observed variables into a reduced set of independent latent factors [84]. The objective is to utilize a limited number of factors to elucidate the connections among numerous variables or factors and investigate the fundamental structure of data by examining the inherent dependencies among these variables. With less information loss, innumerable variables are condensed into a few comprehensive indicators, summarizing various information within each variable. The total indicators exhibit no correlation with one another, and each indicator's represented information remains non-overlapping. This simplifies the issue and consolidates the data. Generally, it must go through several steps, such as data inspection, factor extraction, factor rotation, factor naming, and interpretation [85]. Specifically speaking, the purpose of data testing is to determine whether the sample data are suitable for exploratory factor analysis, mainly by testing whether the variables are sufficiently correlated to determine whether common factors can be extracted, and the Kaiser–Meyer–Olkin test and Bartlett's test were used to complete the test [86]. The KMO index of the quantity surveyor sample obtained from the above section was 0.898, more significant than 0.8, and the significance level of Bartlett's test was Sig. = 0.000 < 0.001. This scale is suitable for exploratory factor analysis [87]. And in factor extraction, the common factor whose feature root is greater than 1 was selected [87]. When the factor was rotated, the maximum variance method was chosen. We then ran the SPSS 22 calculation and finally obtained five competency dimensions, with a cumulative variance contribution (total variance explained) up to 64.922%. The results of the exploratory factor analysis are shown in Table 4.

Table 4. The results of exploratory factor analysis.

Items	1	2	3	4	5	% of Variance
1. Team management competency	0.677	−0.023	0.292	0.186	0.209	15.879
8. Information communication and retrieval competency	0.632	0.235	0.224	0.181	−0.026	
15. Expression competency	0.575	0.115	0.201	0.225	0.117	
27. Organizational competency	0.767	−0.041	0.208	0.012	0.252	
13. Problem analysis competency	0.677	0.347	0.131	0.156	−0.026	
22. Problem solving competency	0.685	0.305	0.09	0.088	−0.085	
3. Innovation competency	0.547	0.355	−0.005	0.294	0.126	
9. Good physical fitness	0.598	0.011	0.226	0.337	0.209	
20. Observe law and discipline	0.226	0.178	0.096	0.736	−0.071	14.256
7. Decisions and opinions in line with public interests	−0.007	0.179	0.234	0.740	0.239	
12. Good professional ethic	0.251	0.304	0.183	0.673	0.068	
18. Safeguard customers' rights	0.285	0.171	0.202	0.683	0.096	
2. Integrity	0.259	0.126	0.27	0.759	0.049	
14. Competency in preparing construction budgets	0.212	0.825	0.147	0.111	0.038	12.914
24. Competency in reviewing construction budgets	0.226	0.777	0.219	0.275	0.097	
6. Competency in preparing tender documents	−0.009	0.669	0.181	0.156	0.276	
26. Competency in preparing quantity takeoffs	0.107	0.793	0.203	0.173	0.203	
4. Competency in understanding engineering drawings	0.26	0.581	0.22	0.239	0.021	
11. Change management competency	0.264	0.408	0.627	0.043	0.09	12.845
25. Claim processing competency	0.371	0.396	0.607	0.144	−0.05	
21. Learning competency	0.183	0.231	0.656	0.253	0.189	
16. Cost management competency	0.257	0.221	0.763	0.222	0.137	
23. Schedule management competency	0.095	0.179	0.755	0.31	0.276	
5. On-site response competency	0.345	0.048	0.607	0.279	0.12	
17. Competency in preparing completion settlements	0.049	0.06	0.065	0.069	0.752	9.028
10. Competency in reviewing project settlements	0.156	0.143	0.155	0.026	0.808	
19. Competency in project auditing	0.162	0.23	0.214	0.139	0.816	

As can be seen from Table 4, the load coefficient of each measurement item of the quantity surveyor sample is more significant than 0.5, and there is no phenomenon where one item forms a common factor by itself or spans multiple common factors, indicating that the scale has good convergence validity, differential validity, and structural validity [88]. In addition, five common factors were extracted from the scale, and their cumulative variance contribution rate reached 64.922% (the general requirement is greater than 60%), indicating that most of the information on the scale can be well-explained by these five common factors [89]. Next, each factor will be named according to the content of the measurement items in each common factor, and its rationality will be explained [90].

According to the results of exploratory factor analysis, eight items of team management competency, information communication and retrieval competency, expression competency, organizational competency, problem analysis competency, problem solving competency, innovation competency, and good physical fitness are classified into common factor 1. This factor reflects the comprehensive quality requirements for quantity surveyors in current construction enterprises. As such, engineering graduates are encouraged to develop these eight competencies in the workplace, collectively termed sustainable competency. The evolving landscape of the industry and the demands of practical work impose heightened requirements on the comprehensive quality of quantity surveyors. They are now expected to engage in project management, conduct timely analysis of engineering problems on construction sites, devise innovative solutions based on local conditions, utilize economically and technically feasible means to address existing engineering issues, and proactively prevent the emergence of hidden dangers [91]. The scale of modern engineering continues to expand, which further requires quantity surveyors to play a team role, with good expression competency and organizational competency to carry out effective team management, but they also need to be able to obtain necessary information for effective and timely communication, reduce contradictions and repetitive work [92], and adopt tools such as BIM to receive and share engineering information to develop information synergy and management synergy to effectively carry out team cooperation and solve complex engineering problems with collective wisdom [93]. The sharp increase in requirements leads to the work intensity of quantity surveyors continuing to increase. Good physical fitness is the premise of ensuring the above work, but the overall physical fitness of college students is a cause for concern, and it is necessary to strengthen exercise to meet the needs of future work.

These five items, including competencies in preparing construction budgets, reviewing construction budgets, preparing tender documents, preparing quantity takeoffs, and understanding engineering drawings for engineering projects, are classified into common factor 2, which reflects the work requirements of quantity surveyors to prepare budget documents, named budget competency. Based on the relevant literature, the most essential competency or job responsibility of quantity surveyors is to calculate the quantity of works and prepare the bill of quantities and project pricing, which requires quantity surveyors to be proficient in the content of drawings, have a solid competency to read drawings, and accurately calculate the quantity of the proposed project in accordance with legal calculation rules, then according to the quota regulation, fee collection standard, and tax composition to perform cost valuation [94]. In construction enterprises, the vital work results of quantity surveyors are reflected in the construction drawing budget and bidding documents of construction projects. At the same time, the competency in preparing construction budgets for construction projects also enables the quantity surveyors to have the competency to review the construction drawing budget, to review the problems existing in the construction drawing budget, and to put forward optimization suggestions and improvement measures. In addition, budget competency also encourages quantity surveyors to keep up with the development of the times, actively use advanced digital technology, and constantly improve work efficiency and the accuracy of work results [95].

The change management competency in the process of construction, cost management competency and schedule management competency of construction, on-site response competency, learning competency, and claim processing competency are classified into common factor 3, which reflects the quantity surveyors on the construction site and is named site management competency. In a project, one of the essential tasks of quantity surveyors is to carry out effective project cost management on the construction site, including project cost management, schedule management, contract management, etc. And the specific responsibilities include preparing the project fund use plan; reviewing the project volume; auditing the project progress payment and material purchase payment [96]; analyzing the deviation between the actual amount of funds used, the amount of projects, and the amount of planned funds and projects; submitting claims for engineering changes in time; putting forward opinions on controversial measurement and pricing issues; and evaluating the impact of engineering changes on engineering projects to realize the dynamic management of engineering costs [96]. In addition, the development of the construction industry and the diversification of customer demands require quantity surveyors to enhance their adaptive capacity, pay attention to the improvement of engineering practice competency, be good at constantly learning and innovating the ways and methods of engineering cost management on the construction site, and sum up and accumulate rich experience in engineering projects so as to improve the adaptive capacity to deal with engineering problems on site.

Observing law and discipline, decisions and opinions in the line with public interests, good professional ethics, safeguard customers' rights, and integrity are classified into common factor 4, which reflects the professional spirit and ethical attitude of quantity surveyors and is named engineering ethics. Modern engineering is related to the national economy, people's livelihood, and the quality of regional development. Laws, regulations, and industry norms are the basic standards to ensure the quality of the project, requiring quantity surveyors to strictly follow the relevant provisions, adhere to integrity and self-discipline, be responsible for the work report provided by themselves, avoid cheating, remain ideological and not influenced by others [97], adhere to seeking truth from facts, respect objective facts, always ensure the accuracy of project cost information, pay attention to maintaining their reputation, safeguard public interests, fulfill social responsibilities, rationally select green materials and relevant methods to reduce the harm to nature and the public, carry forward excellent professional ethics, uphold the spirit of artisans, have noble professional ethics and a rigorous work attitude, constantly improve the level of service to add value to the project, and maintain the core interests of customers [98].

The competencies in preparing completion settlements, reviewing project settlements, and project auditing are classified into common factor 5, which reflects the work content and requirements of the quantity surveyors after the completion of the project, named settlement competency. Due to the long construction phase, ngineering changes, material price changes, weather factors, human factors and force majeure will cause inconsistency between the project cost and the contract price, which requires the quantity surveyors to carry out an audit before the project settlement report [99]. And these works need quantity surveyors based on construction contracts and relevant national laws and regulations, budget quotas, and fee collection standards to review and account the transactions of owners and construction enterprises during the construction process, then determine the completion cost that conforms to the actual construction of the project, which includes a quantity audit, quota sub-item application audit, etc., as well as checking the approval documents and contract terms, implementing the project design change visa and the hidden acceptance record, verifying the unit price and the project quantity and other work, and reviewing the timeliness of various visas. In addition, it is also necessary to put forward opinions on the settlement of economic disputes and legal disputes between owners and construction enterprises during the project settlement to effectively avoid the waste of funds and realize the effective control of the project cost [94].

Based on the above analysis, the five common factors obtained by exploratory factor analysis can be regarded as the five dimensions of quantity surveyors' competencies in construction enterprises. The dimensions of competency were: (a) sustainable competency (eight items), (b) budget competency (five items), (c) site management competency (six items), (d) engineering ethics (five items), (e) settlement competency (three items). Each dimension of competency is composed of several clustered elements required for a competent quantity surveyor in Chinese construction enterprises. The division of the above dimensions is convenient to carry out the analysis of competency gaps between engineering graduates and quantity surveyors of construction enterprises.

5.3. Main Gaps

To address the research question (What are the main gaps between engineering graduates and quantity surveyors of construction enterprises in terms of the personal competencies needed to cope with changing and increasing client needs?), the competency dimension and index gaps comparing engineering graduates and quantity surveyors of construction enterprises were determined. Firstly, the mean value and standard deviation of each item in the quantity surveyor sample and engineering graduate sample were analyzed. Then the difference between the competency dimension and the mean value of each item was compared, and the significance level of the difference of each dimension and item was verified by *t*-test. The main results appear in Table 5 and Figure 2.

Table 5. The personal competency dimension means for quantity surveyors and engineering.

Competency Dimension	Quantity Surveyors (n = 165) Mean	Std. Dev.	Engineering Graduates (n = 97) Mean	Std. Dev.	Mean Difference	Mean Difference Percentage	*t*-Test for Equality of Means
Overall Mean	4.361	0.419	4.113	0.512	0.248	6.03%	0.000 ***
Sustainable competency	4.397	0.457	4.135	0.666	0.262	6.33%	0.000 ***
Budget competency	4.452	0.533	4.153	0.627	0.299	7.20%	0.000 ***
Site management competency	4.375	0.584	4.101	0.560	0.273	6.67%	0.000 ***
Engineering ethics	4.457	0.526	4.320	0.636	0.137	3.17%	0.074
Settlement competency	3.921	0.654	3.663	0.676	0.258	7.04%	0.003 **

Note: ** $p < 0.01$, *** $p < 0.001$.

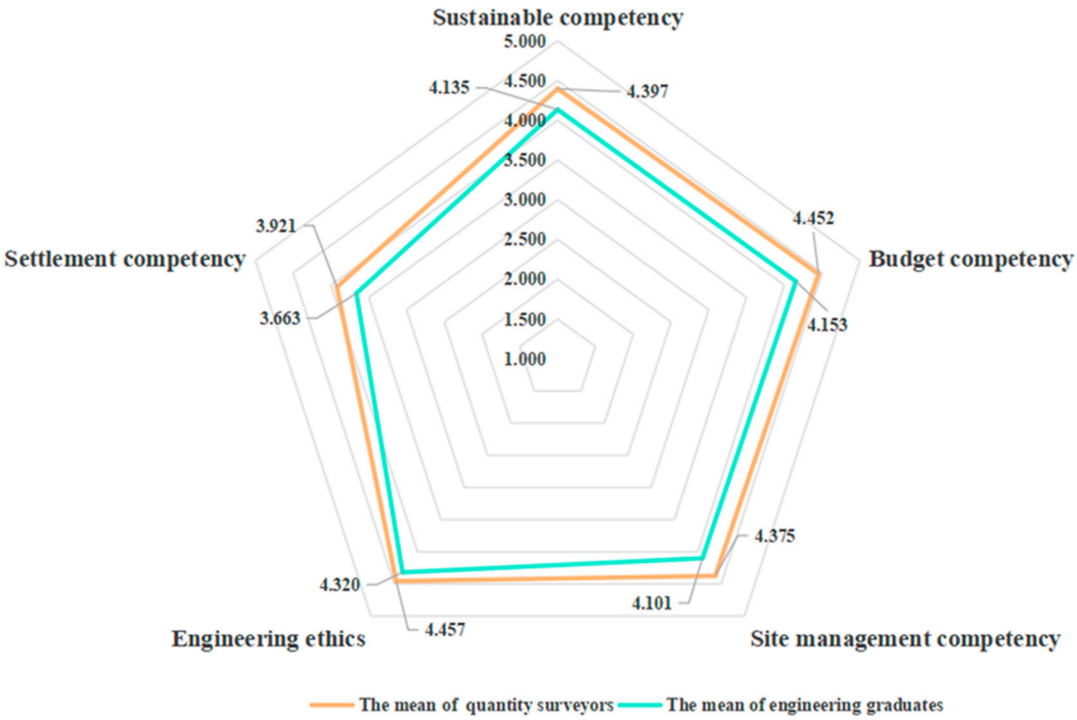

Figure 2. Comparison of competency dimensions between quantity surveyors and engineering graduates.

The population mean and standard deviation of the quantity surveyor sample were 4.361 and 0.419, respectively, and those of the engineering graduate sample were 4.113 and 0.512, respectively. The total score of the former sample was higher than that of the latter sample, with a difference of 0.248 (6.03%), and the results of the *t*-test showed a significant difference between the two samples ($p < 0.001$). Moreover, the scores of the dimensions of the quantity surveyor sample were 4.397, 4.452, 4.375, 4.457, and 3.921, and the scores of the dimensions of the engineering graduate sample were 4.135, 4.153, 4.101, 4.320, and 3.663, respectively. The mean scores of all competency dimensions are higher for quantity surveyors than for engineering graduates. Of the five dimensions of competency, four dimensions are found to differ significantly between quantity surveyors and engineering graduates. These four dimensions of competency are, in descending order: sustainable competency (6.33% difference), budget competency (7.20% difference), site management competency (6.67% difference), and settlement competency (7.04% difference). On the other hand, one dimension of competency, namely, engineering ethics (3.17% difference), does not show a significant difference. Particularly interesting is the highest gap, found for the dimension of budget competency, which underscores the difficulties encountered when working on projects in the present context and emphasizes the importance of addressing the development of this competency in engineering profiles from an early stage. The findings align with the perspective of certain researchers, who attribute enhanced professional competency development to practical, intricate, and contextualized experiences [75]. Further research is advised to tackle this matter more effectively.

Several shared characteristics in the outcomes can be noted for quantity surveyors and engineering graduates. In both samples, the highest mean scores are for engineering ethics, with 4.457 and 4.320, respectively, followed by budget competency, with 4.452 and 4.153, respectively. Additionally, the lowest scores are for site management competency and settlement competency, with 4.375 and 4.101, respectively, and 3.921 and 3.663, respectively. From these results, it can be derived that both quantity surveyors and engineering graduates demonstrate a strong sense of responsibility and adherence to laws and disciplines. However, both groups tend to allocate less emphasis to site management competency and settlement competency (in particular, the score of settlement competency in the quantity surveyor sample is significantly lower than the score of the other four dimensions), believing that quantity surveyors do not need to participate in project management and that the completion settlement of construction projects is only the general finishing work, instead of recognizing the role of these activities in adding value to the project [100].

Based on these findings, we propose enhancing activities during professional education or cost management courses for engineers with lower results to strengthen these competencies (site management competency as well as settlement competency) or those with more considerable differences (budget competency) to better prepare engineers or engineering graduates for the challenges they are likely to encounter in their professional careers. It was already highlighted by other authors that customers require quantity surveyors to extend their business scope to project management and to participate in project management to carry out effective cost management and schedule management to facilitate adding value to engineering projects [101]. A construction enterprise also needs to reduce the total cost of the project further, requiring quantity surveyors to flexibly change the management strategy according to the actual situation of the site, not only to ensure that the project cost does not overspend, but to achieve savings as far as possible and create better economic benefits. Furthermore, the claim is one of the main profits of construction projects; thus, knowing how to adhere to principles in the construction industry with human relations and objectively deal with reasonable claims for engineering changes are the necessary abilities that quantity surveyors should have. Actually, there are also some problems in the project management of construction sites in China. For example, document management is out of sync with the construction schedule, which results in part of the data being missed, the existing data documents not being saved or kept in the wrong way, relevant documents being out of date so that the claim is late or the claim fails, less attention being paid to the completion of the project settlement, and the settlement being ignored when analyzing the causes and treatment measures that caused big difference between the settlement price and the contract price and lower project profit [102]. Nevertheless, these situations or problems are an opportunity for universities and engineering students to carry out targeted training, which will help them seize the opportunity, enhance personal abilities, and expand employment opportunities [75].

By concentrating on the gaps of competency indicators belonging to each dimension, it is possible to identify behaviors that show notable differences between quantity surveyors and engineering graduates. Of the 27 items, 23 are higher in quantity surveyors than in engineering graduates (Figure 3). Table 6 summarizes the significant findings for the competency criteria gaps. The results show high positive differences between quantity surveyors and engineering graduates related to good professional ethics (item 12) at 15.74% and innovation competency (item 3) at 15.19%. This is followed by remarkable differences in competency indicators for safeguard customers' rights (item 18) at 13.83%, claim processing competency (item 25) at 13.45%, and change management competency (item 11) at 11.03%. High differences are also detected for behaviors related to competency in reviewing construction budgets (item 24, 9.14%), cost management competency (item 16, 8.74%), competency in preparing completion settlements (item 17, 8.11%), competency in preparing tender documents (item 6, 7.99%), competency in preparing quantity takeoffs (item 26, 7.65%), and competency in project auditing (item 19, 7.04%).

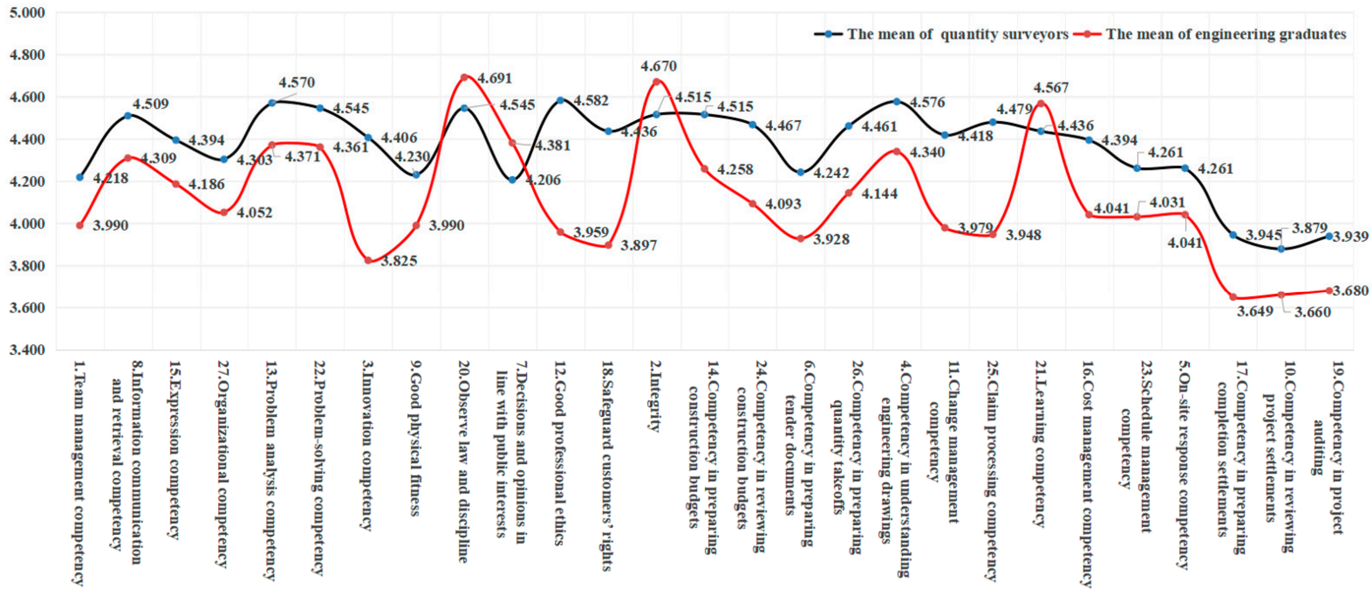

Figure 3. Comparison of competency indicators for quantity surveyors and engineering graduates.

On the other hand, negative differences (but not significant) are perceived only regarding four competency indicators: integrity (item 2) at −3.32%, decisions and opinions in line with public interests (item 7) at −3.99%, observe law and discipline (item 20) at −3.11%, and learning competency (item 21) at −2.87%. While these adverse differences were not statistically significant, they could be attributed to the heightened stress and workload experienced by quantity surveyors. Additionally, the significance placed by engineering graduates on their development and future might differ, especially considering they are in the early stages of their professional careers. Engineering graduates, who have not been affected by the working environment and job positions, can complete engineering tasks in strict accordance with laws, regulations, and industry norms and make objective decisions based on project success goals. In addition, heavy work leaves quantity surveyors with less time and energy to learn and update their knowledge, which may lead to a reduction in learning ability and integrity level.

The results show the general gaps, indicating lower performance among engineering graduates in addressing team or engineering problem resolutions. This can be attributed to their inclination towards individualism, stemming from their limited experience in team collaboration and the traditional emphasis of engineering degrees, which often overlooks the development of social awareness and team skills. To instill these competencies in engineering schools, there is a need to modify the teaching approach [75]. The demand for new teaching methodologies has transformed traditional lectures at universities into active learning approaches, with the goal of boosting motivation to enhance students' success in their professional careers.

Table 6. Competency indicators: the gaps between quantity surveyors and engineering graduates.

Indicator	Competency Dimension	Quantity Surveyors (n = 165)		Engineering Graduates (n = 97)		Mean Difference	Mean Difference Percentage	*t*-Test for Equality of Means
		Mean	Std. Dev.	Mean	Std. Dev.			
Highest differences								
12. Good professional ethics	Engineering ethics	4.582	0.625	3.959	0.957	0.623	15.74%	0.000 ***
3. Innovation competency	Sustainable competency	4.406	0.594	3.825	0.829	0.581	15.19%	0.000 ***
18. Safeguard customers' rights	Engineering ethics	4.436	0.628	3.897	0.973	0.539	13.83%	0.000 ***
25. Claim processing competency	Site management competency	4.479	0.721	3.948	0.928	0.531	13.45%	0.000 ***
11. Change management competency	Site management competency	4.418	0.690	3.979	0.935	0.439	11.03%	0.000 ***
24. Competency in reviewing construction budgets	Budget competency	4.467	0.630	4.093	0.958	0.374	9.14%	0.001 **
16. Cost management competency	Site management competency	4.394	0.696	4.041	0.815	0.353	8.74%	0.000 ***
17. Competency in preparing completion settlements	Settlement competency	3.945	0.767	3.649	0.722	0.296	8.11%	0.002 **
6. Competency in preparing tender documents	Budget competency	4.242	0.750	3.928	0.904	0.314	7.99%	0.004 **
26. Competency in preparing quantity takeoffs	Budget competency	4.461	0.658	4.144	0.777	0.317	7.65%	0.001 **
19. Competency in project auditing	Settlement competency	3.939	0.786	3.68	0.942	0.259	7.04%	0.024 *
Lowest differences								
20. Observe law and discipline	Engineering ethics	4.545	0.639	4.691	0.566	−0.146	−3.11%	0.057
7. Decisions and opinions in line with public interests	Engineering ethics	4.206	0.703	4.381	0.783	−0.175	−3.99%	0.063
2. Integrity	Engineering ethics	4.515	0.677	4.670	0.657	−0.155	−3.32%	0.072
21. Learning competency	Site management competency	4.436	0.735	4.567	0.628	−0.131	−2.87%	0.144

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

This statement emphasizes the existence of a certain degree of competency gaps between technical specialists and technical managers in the construction industry (quantity surveyors with project management competency can be regarded as technical managers, and engineering graduates as technical experts) [75]. It enhances understanding of the disparities between the two roles. Previous authors have identified challenges encountered by engineers transitioning to roles like business managers or project managers, aligning with the outcomes of this research. These challenges include enhancing management skills and team motivation [103]. Nonetheless, the research findings underscore the magnitude of gaps in budget competency and site management competency, indicating a significant need for the enhancement of engineering curricula. Hence, if engineering graduates want to have a better development, they have to face up to these gaps, take the initiative to participate in social practice, and gain project management competency so that they can better adapt to future career needs and further expand the future development space and promotion channels [104].

5.4. Educational Implications

On the whole, the main reason for the gaps between the competencies of engineering graduates and quantity surveyors is that the course teaching content is out of line with social standards, the students lack social practice training, and the engineering talents cultivated do not meet the social needs. Therefore, how to carry out real social practice training in school and develop students' active learning habits are the problems that need to be emphasized at present.

Therefore, engineering education curricula should focus on developing students' particular social skills, such as budget competency, site management competency, and settlement competency. From the results of the above data analysis, the competency gaps between engineering graduates and quantity surveyors are mainly manifested as poor practical competency and low accuracy of work results, which is because the universities did not introduce social standards in teaching and the students' work results have not been evaluated by the society or a third party. Considering the realities of school teaching, construction costs can adopt a discipline competition format to enhance the effectiveness and perfect the practical teaching system. By participating in various discipline competitions, students are exposed to the construction industry and the social market, engaging in simulated training and specialized exercises to complete the competition tasks [105]. Aligning with social needs, enterprise requirements, and professional positioning, the program benchmarks against certifications such as cost engineer, constructor, and the national BIM skill level examination, systematically enhancing students' professional capabilities. To objectively assess students' performance, a third-party platform or enterprise assessment platform could be utilized, with industry professionals contributing to the graduation assessment. This ensures that students' achievements meet societal standards and helps identify existing issues. Establishing a specialized management organization for discipline competitions, with designated individuals overseeing coordination and arrangement, shifts from decentralized to centralized management. This approach deepens connections with enterprises, associations, and industry regulatory authorities. Additionally, implementing rules and regulations facilitates the normalization of market demand and industry development research, allowing for the timely update of necessary professional knowledge content, adjustments to competition catalogs, and alignment with market dynamics to broaden the development prospects of engineering majors.

Further research is needed to explore new methods of project management. It has been emphasized that actual project development is an incentive for competency development, particularly providing opportunities for engineering students to enhance practical competency. In addition, this can be achieved either by applying active learning methodologies in real construction projects or better integrating the deployment of social skills during their engineering studies. The specific practices are as follows. To begin with, colleges and universities should actively facilitate school–enterprise cooperation with enterprises to center to improve students' professional competency. By setting up school–enterprise cooperations with business department on campus, companies can delegate part of their business to the campus business department [106]. Furthermore, it will not be wrong to recommend excellent students to enterprises for internships to improve the professional and comprehensive competency of engineering graduates and test the practical competency of professional students with social competition mechanisms and actual engineering projects, respectively. In addition, we need to deepen the understanding of business operations, team building, human resource management, market analysis, and other management knowledge by exposing students to enterprise environments. Moreover, we must encourage students to participate in innovation and entrepreneurship competitions actively to design innovative solutions or entrepreneurial plans, focusing on industry problems and professional items and carrying out project practice in a problem-oriented way. To solve the problem found in the above process, students can have an internship or conduct social entrepreneurship or joint research and development of universities and enterprises to analyze and extend the scope and direction of professional problems with real working scenarios, further improving the project plan and effectively promoting in-depth problem settlement and the results transformation for creating economic and social value. Lastly, engineering students can also start their businesses and cooperate with enterprise [107], such as independent entrepreneurial activities, which are based on on-going innovation and entrepreneurship practices. They can also identify project programs at the university, to foster and transform professional competency of project financing, business negotiation, and others. These actions gradually narrow the gaps between engineering graduates and quantity surveyors through university–enterprise cooperation and integration between industry and education to cultivate their practical operation competency and encourage students to form a good habit of active learning from project benefits.

Thirdly, from the data analyzed above, there is a worrying problem reflected in the fact that the scores of engineering graduates in the aspects of law-abiding and professional ethics are higher than those of quantity surveyors, which indicates that the legal awareness and moral level of engineering graduates decline after entering social work. Therefore, on the one hand, universities need to strengthen ideological and political education, exploring ways to make students' faith firm and keep their original intention. At the same time, they should encourage thematic education in schools on engineering problems and the adverse effects of individual misconduct on society and the environment. On the other hand, carrying out engineering ethics education cannot be ignored, including objective, fair, proactive, and responsible personnel training objectives, to cultivate students to form a conscious awareness and the active ability to handle engineering activities from a correct engineering ethics perspective and criteria, so that they can firmly establish a sense of the overall situation and maintain the interests of the country and the public with a strong sense of social responsibility and mission [108].

In general, engineering majors should take discipline competition and innovation and entrepreneurship competition as the starting point, guided by social needs, actively improving the professional curriculum system and teaching content, and driving the sustainable development of the discipline. While well-behaved in discipline competitions, universities try to achieve a virtuous cycle of sustainable development of engineering majors by applying innovation and entrepreneurship competitions to cultivate the commercial thinking and ability of teachers and students, introducing market-oriented operation mechanisms and keeping organizational vitality according to market rules. In this circuit, the renewal of social demands promotes the continuous improvement and optimization of the course system and teaching content of engineering majors to ensure the constant training of engineering graduates who meet the needs of society. Moreover, the challenge is to identify suitable methods and settings for this transformation and to locate capable educators and mentors ready to embrace this shift. There is a need for innovative approaches to train engineers for upcoming professional demands [106,107].

The match and fit between college talent training and market demand have become an important index to test whether college education realizes its main functions. For example, the Technical and Further Education Mode represented by Australia is industry-oriented and competency-based, and the main training goal is that students can have the ability and quality to obtain a job upon graduation [109]. Talent training in colleges and universities should be more in line with the needs of the labor market, which should strengthen the connection between higher education and the labor market to improve employability, especially practical ability and application analysis ability, as the important breakthrough point to improve the quality of talent training in higher education [110]. Based on this concept, the environmental design major of a university in China has improved its talent training program based on market demand. It set up relevant professional courses according to the actual needs of the market and enterprises and implemented an order-based talent training model for students' employment through school–enterprise cooperation, which effectively improved students' ability to use professional knowledge and vocational skills and enhanced their employment competitiveness, as well as reducing the transition period for students to enter the workforce while increasing the initial salary level of graduates [111].

6. Conclusions and Limitation

Quantity surveyors play an important role in the digital transformation process of the construction industry. It requires universities to cultivate a large number of engineering graduates in line with the needs of the social market to increase the number of quantity surveyors to promote the transformation. Through a detailed literature review, this paper sorts out the competency framework and indicators of quantity surveyors. Then, based on the background of China's construction industry and the results of expert interviews, the competency framework and indicators of quantity surveyors in construction enterprises are determined and a questionnaire survey is conducted among quantity surveyors and engineering graduates. Exploratory factor analysis of the quantity surveyor sample is carried out to determine the five core competency dimensions of quantity surveyors in construction enterprises, namely, sustainable competency, budget competency, site management competency, engineering ethics, and settlement competency. The comparison of the samples of quantity surveyors and engineering graduates shows significant differences in the overall ability between quantity surveyors and engineering graduates. Of the five dimensions, sustainable competency (0.000 ***), budget competency (0.000 ***), site management competency (0.000 ***), and settlement competency (0.003 **) have significant differences, while there is no significant difference in the dimension of engineering ethics (0.074). The most significant difference is budget competency (7.20% difference), and the differences in the other four dimensions are sustainable competency (6.33% difference), site management competency (6.67% difference), engineering ethics (3.17% difference), and settlement competency (7.04% difference). The scores of quantity surveyors in the five dimensions are higher than those of engineering graduates, indicating that quantity surveyors generally believe that their skills surpass those of engineering graduates in every scenario, which is understandable given their extensive experience. Among the 27 items, integrity (item 2), decisions and opinions in line with public interests (item 7), observing law and discipline (item 20), and learning competency (item 21) are not significant, distributed in the dimension of engineering ethics (three items) and site management competency (one item).

Secondly, some other problems are also found through data analysis. For quantity surveyors, the importance of settlement competency is significantly lower than that of other dimensions, reflecting that quantity surveyors in Chinese construction enterprises do not pay enough attention to the completion settlement of construction projects. For engineering graduates, their awareness of law compliance and professional ethics is higher than that of quantity surveyors, indicating that these qualities or competencies of quantity surveyors will decline after entering the workplace, which is worrisome. Consequently, it is strongly advised to promote lifelong learning competency and other personal competencies from the early phases of quantity surveyors' careers, ensuring a balanced blend of training for both technical and interpersonal competencies. For the current situation of insufficient settlement competency of quantity surveyors, it is necessary to design feasible training courses or plans on campus to seize the market opportunities and actively explore the education and teaching modes that can guarantee students that firmly believe in ideals and beliefs, abide by the code of engineering ethics, and shoulder social responsibilities bravely. Transformational programs can be an adequate means of strengthening these competencies and help to prepare better professionals needed in this new era.

Therefore, this study enhances comprehension regarding the cultivation and assessment of students' proficiency within engineering settings by scrutinizing the existing disparities between students and professionals in the cost management domain. In the final analysis, the competency gaps between engineering graduates and quantity surveyors are mainly manifested in weak social practice competency. Hence, colleges and universities should actively introduce market-oriented operation mechanisms, and, through university–industry collaboration and specialty-innovation integration, continuously improve and optimize the practical teaching system and content and establish a dynamic adjustment mechanism of personnel training in engineering oriented to social demands, taking practical engineering projects as the carrier and active learning as the means to continuously improve the social practice competency of engineering students for achieving sustainable and circular development in keeping pace with the times. There is no doubt that elucidating the most sought-after competencies aids in prioritizing the necessary resources for enhancement and narrowing the competency gaps.

Certain limitations of this study pertain to the characteristics of the samples, as all participating students were from the same university and all investigated quantity surveyors were from the same country, China. Additionally, during the questionnaire completion, surveyed quantity surveyors and engineering graduates may introduce a degree of subjectivity into their competency assessments. Particularly with students, there is a likelihood that they might perceive their competencies more positively, given that they have not had the chance to work as quantity surveyors in a company. Lastly, due to constraints in time and energy, the number of questionnaires did not extend further.

Author Contributions: Conceptualization, P.Z. and S.-G.M.; methodology, P.Z., S.-G.M. and Y.S.; software, S.-G.M. and Y.S.; validation, P.Z. and S.-G.M.; formal analysis, P.Z.; investigation, P.Z., S.-G.M. and Y.S.; resources, P.Z.; data curation, P.Z., S.-G.M. and Y.S.; writing—original draft preparation, P.Z. and S.-G.M.; writing—review and editing, P.Z., S.-G.M., Y.S. and Y.-N.Z.; visualization, P.Z. and S.-G.M.; supervision, P.Z.; project administration, P.Z.; funding acquisition, P.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Guizhou Provincial Key Topics of Graduate Education and Teaching Reform (YJSJGKT [2021]014), Guizhou Provincial Science and Technology Projects (JC [2023] General 026).

Institutional Review Board Statement: Article 32 of the Notice on Issuing the Measures for Ethical Review of Life Sciences and Medical Research Involving Human Beings ([2023] No. 4) and the list of technological activities that require ethical review and review in the Notice on Issuing the Measures for the Review of Science and Technology Ethics ([2023] No. 167) issued by the National Health Commission and the Ministry of Science and Technology of the People's Republic of China that indicate ethics approval is not required for this type of study.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are contained within the article.

Acknowledgments: The authors would like to thank the anonymous referees for their valuable comments and suggestions.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Mbachu, J. Quantity surveyor's role in the delivery of construction projects: A review. *Quant. Surv. (NZIQS)* **2015**, *25*, 1–21.
2. RICS. Pathway Guide: Quantity Surveying and Construction. 2018. Available online: https://www.rics.org/content/dam/ricsglobal/documents/join-rics/qs_and_construction.pdf (accessed on 31 August 2018).
3. Yogeshwaran, G.; Perera, B.; Ariyachandra, M.M.F. Competencies expected of graduate quantity surveyors working in developing countries. *J. Financ. Manag. Prop. Constr.* **2018**, *23*, 202–220. [CrossRef]
4. Ramdav, T.; Harinarain, N. A strategic framework for the survival of the quantity surveying profession. *J. Eng. Des. Technol.* **2020**, *18*, 1487–1518. [CrossRef]
5. Seidu, R.D.; Young, B.E.; Clack, J.; Adamu, Z.; Robinson, H. Innovative changes in quantity surveying practice through BIM, big data, artificial intelligence and machine learning. *J. Appl. Nat. Sci.* **2020**, *4*, 37–47.
6. Perera, B.; Hemaijth, S.; Dilanthi, A.; Ginige, K. Quantity surveyor as the technical appraiser in the Sri Lankan financial industry. In Proceedings of the Built Environment Education Conference, CEBE, Ahmedabad, India, 22–30 November 2007. Available online: https://www.researchgate.net/publication/46419176_Quantity_surveyor_as_the_technical_appraiser_in_the_Sri_Lankan_financial_industry (accessed on 30 November 2007).
7. Nalewaik, A.; Bennett, N. Qualifications and barriers to professional recognition in cost engineering. In Proceedings of the ICEC 8th World Congress Proceedings, Durban, South Africa, 23–27 June 2012. Available online: https://so1.cljtscd.com/scholar?hl=zh-CN&as_sdt=0,5&q=Qualifications+and+barriers+to+professional+recognition+in+cost (accessed on 27 June 2012).
8. Shafiei, M.M.; Said, I. The competency requirements for quantity surveyors: Enhancing continuous professional development. *Sri Lankan J. Hum. Resour. Manag.* **2008**, *1*, 17–27. [CrossRef]

9. Shayan, S.; Kim, K.P.; Ma, T.; Freda, R.; Liu, Z. Emerging challenges and roles for quantity surveyors in the construction industry. *Manag. Rev. Int. J.* **2019**, *14*, 82–96.
10. Smyth, H.; Pryke, S. Collaborative relationships in construction. *Collab. Relatsh. Constr.* **2008**, *14*, 245.
11. Alaloul, W.S.; Hasaniyah, M.W.; Tayeh, B.A. A comprehensive review of disputes prevention and resolution in construction projects. *MATEC Web Conf. EDP Sci.* **2019**, *270*, 05012. [CrossRef]
12. Chamikara, P.; Perera, B.S.; Rodrigo, M.N. Competencies of the quantity surveyor in performing for sustainable construction. *Int. J. Constr. Manag.* **2020**, *20*, 237–251. [CrossRef]
13. Chong, B.; Lee, W.; Lim, C. The roles of graduate quantity surveyors in the Malaysian construction industry. *Int. Proc. Econ. Dev. Res.* **2012**, *37*, 17–20.
14. Ashworth, A.; Hogg, K.; Higgs, C. *Willis's Practice and Procedure for the Quantity Surveyor*; John Wiley & Sons: Hoboken, NJ, USA, 2013; ISBN 9781119832126.
15. Cunningham, T. The Work and Skills Base of the Quantity Surveyor in Ireland-An Introduction. Dublin Institute of Technology. 2014. Available online: https://arrow.tudublin.ie/cgi/viewcontent.cgi?article=1034&context=beschreoth (accessed on 23 September 2014).
16. Kim, K.P.; Ma, T.; Baryah, A.S.; Zhang, C.; Hui, K.M. Investigation of readiness for 4D and 5D BIM adoption in the Australian construction industry. *Manag. Rev. Int. J.* **2016**, *11*, 43.
17. Cartlidge, D. *New Aspects of Quantity Surveying Practice*; Routledge: London, UK, 2011; ISBN 9781138673762.
18. Wao, J.O. Predicting the future of quantity surveying profession in the construction industry. *J. Constr. Proj. Manag. Innov.* **2015**, *5*, 1211–1223.
19. Drogemuller, M.; Muldoon, R.; Stuart, J.; Kim, K.P.; Ahn, J.; Kim, S. Exploratory study on cognitive style in a BIM environment in the Australian construction industry. *Manag. Rev. Int. J.* **2017**, *12*, 62–80.
20. Dada, J.O.; Jagboro, G.O. Core skills requirement and competencies expected of quantity surveyors: Perspectives from quantity surveyors, allied professionals and clients in Nigeria. *Australas. J. Constr. Econ. Build.* **2012**, *12*, 78–90. [CrossRef]
21. Sacks, R.; Barak, R. Teaching building information modeling as an integral part of freshman year civil engineering education. *J. Prof. Iss. Eng. Ed. Pract.* **2010**, *136*, 30–38. [CrossRef]
22. Barison, M.B.; Santos, E.T. The competencies of BIM specialists: A comparative analysis of the literature review and job ad descriptions. In Proceedings of the 2011 ASCE International Workshop on Computing in Civil Engineering, Miami, FL, USA, 19–22 June 2011. [CrossRef]
23. Gu, N.; London, K. Understanding and facilitating BIM adoption in the AEC industry. *J. Auto. Constr.* **2010**, *19*, 988–999. [CrossRef]
24. Noor, S.N.A.M.; Tobi, S.U.M.; Salim, K.R. Competencies of quantity surveyors in construction industry: Document reviews from different quantity surveyor professional bodies. *IOP Conf. Ser. Mater. Sci. Eng.* **2020**, *864*, 012098. [CrossRef]
25. Chan, E.H.; Chan, M.; Scott, D.; Chan, A.T. Educating the 21st century construction professionals. *J. Prof. Iss. Eng. Ed. Pract.* **2002**, *128*, 44–51. [CrossRef]
26. Yan, L.; Yin, Y.L.; Ke, H. The research on the professional competency standard and setting of cost engineering course philosophy. *J. Res. High. Educ. Eng.* **2007**, 111–115+136. Available online: https://kns.cnki.net/kcms2/article/abstract?v=oslmGXurZ-qPU87S88vy4-dOq0oQ6ySZfNGpQXEfL_fs2YXjpubyK79aBw-Q4cIyr4kArdiHUzcZSYPNF05Fg4xFZm4u7dqAR08Fw1RsuYqHnSUn_z5hnKLG_lTeor6KHDbG8yF95U4=&uniplatform=NZKPT&language=CHS (accessed on 28 March 2007).
27. Perera, S.; Pearson, J. Alignment of Professional, Academic and Industrial Development Needs for Quantity Surveyors: The Post Recession Dynamics. 2011. Available online: https://researchdirect.westernsydney.edu.au/islandora/object/uws:36048/datastream/PDF/view (accessed on 31 January 2011).
28. Yap, J.B.H.; Skitmore, M.; Lim, Y.W.; Loo, S.C.; Gray, J. Assessing the expected current and future competencies of quantity surveyors in the Malaysian built environment. *Eng. Constr. Archit. Manag.* **2022**, *29*, 2415–2436. [CrossRef]
29. Xiao, Q.R. Data analysis of cost engineer qualification examination system based on data analysis. In Proceedings of the e-Learning, e-Education, and Online Training: 6th EAI International Conference, eLEOT 2020, Changsha, China, 20–21 June 2020; pp. 29–42. [CrossRef]
30. Smith, P. Project cost management–Global issues and challenges. *Procedia-Soc. Behav. Sci.* **2014**, *119*, 485–494. [CrossRef]
31. Leonard, D. Future Challenges in Cost Engineering: Creating Cultural Change through the Development of Core Competences. *AACE Int. Trans.* **2000**, D1A. Available online: https://so1.cljtscd.com/scholar?hl=zh-CN&as_sdt=0,5&q=Future+challenges+in+cost+engineering:+creating+cultural+change+through+the+development+of+core+competences&btnG= (accessed on 31 December 2000).
32. Ye, K.H.; Yan, N.N. Core competencies of cost engineers in China under the background of the new era. *Eng. Cost Manag.* **2018**, 84–89. Available online: https://kns.cnki.net/kcms2/article/abstract?v=oslmGXurZ-pCSk6y3-xG58_U-kCcJL3Q9veheAO_Bo0m_zR4dTG3q97HC363hi3Om7F5a4t0eEXrLN07UcgVHxt_ubwI1zvm2t2bGk3g03BJTWwD5PsqzRZTEeWMOlU5QvXHWubX7-1d3S5rgc2EyQ==&uniplatform=NZKPT&language=CHS (accessed on 10 October 2018).
33. Thayaparan, M.; Siriwardena, M.; Amaratunga, R.; Malalgoda, C.; Keraminiyage, K. Lifelong learning and the changing role of quantity surveying profession. In Proceedings of the 15th Pacific Association of Quantity Surveyors Congress, Colombo, Sri Lanka, 23–26 July 2011. Available online: https://salford-repository.worktribe.com/preview/1500036/Lifelong_learning.pdf (accessed on 26 July 2011).

34. Davenport, D.; Smith, R.; Oudin, M. Towards a common professional qualification for European construction and civil engineering cost economists. In *The Many Facets of International Education of Engineers*; CRC Press: Boca Raton, FL, USA, 2020; pp. 23–24. Available online: https://so1.cljtscd.com/scholar?hl=zh-CN&as_sdt=0,5&q=Towards+a+common+professional+qualification+for+European+construction+and+civil+engineering+cost+economists&btnG= (accessed on 31 December 2020).
35. AIQS. AIQS Competency Standards for Quantity Surveyors, Construction Economist and Cost Engineers. 2012. Available online: https://www.aiqs.com.au/sites/default/files/uploaded-content/website-content/aiqs_competency_standards_for_quantity_surveyors_construction_economists_and_cost_engineers.pdf (accessed on 31 December 2012).
36. Antwi-Afari, M.; Owusu-Manu, D.G.; Pärn, E.; Edwards, D.J. Exploratory investigation of challenges and expectations of innovative quantity surveyors and quantity surveying firms in Ghana. *Int. J. Technol.* **2018**, *9*, 1480–1489. [CrossRef]
37. Kim, K.P.; Park, K.S. Housing information modelling for BIM-embedded housing refurbishment. *J. Facil. Manag.* **2018**, *16*, 299–314. [CrossRef]
38. Stride, M.; Hon, C.K.; Liu, R.; Xia, B. The use of building information modelling by quantity surveyors in facilities management roles. *Eng. Constr. Archit. Manag.* **2020**, *27*, 1795–1812. [CrossRef]
39. Aibinu, A.; Venkatesh, S. Status of BIM adoption and the BIM experience of cost consultants in Australia. *J. Prof. Iss. Eng. Ed. Pract.* **2014**, *140*, 04013021. [CrossRef]
40. Stanley, R.; Thurnell, D. The benefits of, and barriers to, implementation of 5D BIM for quantity surveying in New Zealand. *Austr. J. Constr. Econ. Build.* **2014**, *14*, 105–117. [CrossRef]
41. Wong, P.; Salleh, H.; Rahim, F. A relationship framework for building information modeling (BIM) capability in quantity surveying practice and project performance. *Inf. Constr.* **2015**, *67*, e119. [CrossRef]
42. Ismail, N.A.A.B.; Drogemuller, R.; Beazley, S.; Owen, R. A review of BIM capabilities for quantity surveying practice. In Proceedings of the 4th International Building Control Conference 2016 (IBCC 2016), Kuala Lumpur, Malaysia, 7–8 March 2016; MATEC Web of Conferences. EDP Sciences: Les Ulis, France, 2016; Volume 66, pp. 1–7.
43. Saka, A.B.; Chan, D.W. Knowledge, skills and functionalities requirements for quantity surveyors in building information modelling (BIM) work environment: An international Delphi study. *Archit. Eng. Des. Manag.* **2020**, *16*, 227–246. [CrossRef]
44. Vigneault, M.A.; Boton, C.; Chong, H.Y.; Cooper-Cooke, B. An innovative framework of 5D BIM solutions for construction cost management: A systematic review. *Arch. Comput. Methods Eng.* **2020**, *27*, 1013–1030. [CrossRef]
45. Elhag, T.; Boussabaine, A.; Ballal, T. Critical determinants of construction tendering costs: Quantity surveyors' standpoint. *Int. J. Proj. Manag.* **2005**, *23*, 538–545. [CrossRef]
46. Crafford, G.; Smallwood, J. Clients'views on quantity surveying competencies. *Acta Structilia J. Phys. Dev. Sci.* **2007**, *14*, 33–55.
47. Ma, T.; Luu, H. The Changing Role of Quantity Surveyors in the Green Building Development in South Australia. In Proceedings of the 38th AUBEA Conference, Auckland, New Zealand, 22 November 2013. Available online: https://www.library.auckland.ac.nz/external/finalproceeding/Files/Papers/46530final00049.pdf (accessed on 22 November 2013).
48. Frei, M.; Mbachu, J.; Phipps, R. Critical success factors, opportunities and threats of the cost management profession: The case of Australasian quantity surveying firms. *Int. J. Proj. Organ. Manag.* **2013**, *5*, 4–24. [CrossRef]
49. Larson, P.D. Advances in technology are bringing change to the role of the cost engineer. *J. Cost. Eng.* **2006**, *48*, 3.
50. PAQS. Competency Standards for Quantity Surveyors in the Asia-Pacific Region. 2000. Available online: https://www.paqs.net/node/219 (accessed on 30 June 2001).
51. SISV. Skills Accreddited Professional Quantity Surveyor (APQS) Competencies Requirements. 2023. Available online: https://www.sisv.org.sg/doc/qs/A1.APQS_Competencies_Requirements.pdf (accessed on 30 April 2023).
52. CCEA. Notice on Issuing the Code of Conduct for Construction Cost Consulting Units and the Code of Ethical Conduct for Cost Engineers. 2002. Available online: https://www.chinaacc.com/html/2005/5/hu65926423191550027981.shtml (accessed on 19 May 2005).
53. Musa, N.; Babalola, M.; Oyebisi, T. Competencies required of quantity surveying profession in Nigeria towards achieving the millennium development goals in the built environment. *Sustain. Environ.* **2010**, 233–244. Available online: https://so1.cljtscd.com/scholar?hl=zh-CN&as_sdt=0,5&q=Competencies+required+of+quantity+surveying+profession+in+Nigeria+towards+achieving+the+millennium+development+goals+in+the+built+environment.+&btnG= (accessed on 31 December 2010).
54. Fung, W.P.; Salleh, H.; Rahim, F.A.M. Capability of building information modeling application in quantity surveying practice. *J. Surv. Constr. Prop.* **2014**, *5*, 1–13. [CrossRef]
55. Ashworth, A.; Perera, S. *Contractual Procedures in the Construction Industry*; Routledge: London, UK, 2018; ISBN 9781138693937.
56. Sun, C.L.; Xu, Z.W. On the setting and evaluation of engineering ethics standards in the professional accreditation of engineering cost in higher education. *J. Res. High. Educ. Eng.* **2018**, 78–83. Available online: https://kns.cnki.net/kcms2/article/abstract?v=oslmGXurZ-rDlxVKeSsrkqYWbpy_pcISYmSIaojnxjk_ewST8bI_syVs-GlBZ-qYRNOQNMboolz55PKMfyKSG9aqPIAc8IteO1jdGrksUwnZc-GFWPfe0OEthb3N_IYg_3IheBIOyC4Vo6o7oxl1aA==&uniplatform=NZKPT&language=CHS (accessed on 28 July 2018).
57. Xu, Y.Q.; Su, Y.Y.; Gao, Q. Research on the influence of cost engineer competency on project performance. *J. Con. Econ.* **2016**, *37*, 97–100.

58. Guo, L.H. Control of settlement audit risks for cost engineers. *J. Friends Account.* **2011**, 67–68. Available online: https://kns.cnki.net/kcms2/article/abstract?v=oslmGXurZ-oEEDGga-CggAwjQ8dHq_I4XU0sjJILZFZoLkq02FrT9lMwTVf-KpxCvcdH1_cCRODo_7HUeUg6ArHCHxIRHUSsjJQ_r_Tblai4MENNrgTkRpbNy79xV28Oxnw8zsi1GA8=&uniplatform=NZKPT&language=CHS (accessed on 5 January 2011).
59. Zhang, L.; Li, H.; Xu, Q.; Sun, Y.F. Research on the capability evaluation index system of engineering cost professionals under the background of full process engineering consulting. *Proj. Manag. Technol.* **2022**, *20*, 41–46.
60. Oke, A.; Timothy, I. Perception of construction professionals to the performance of Nigerian quantity surveyors. *J. Build. Perform.* **2010**, *1*, 64–72.
61. Shafik, M.; Case, K. *Advances in Manufacturing Technology XXXIV: Proceedings of the 18th International Conference on Manufacturing Research, Incorporating the 35th National Conference on Manufacturing Research, University of Derby, Derby, UK, 7–10 September 2021*; IOS Press: Amsterdam, The Netherlands, 2021; pp. 7–10. Available online: https://so1.cljtscd.com/scholar?hl=zh-CN&as_sdt=0,5&q=Advances+in+Manufacturing+Technology+XXXIV:+Proceedings+of+the+18th+International+Conference+on+Manufacturing+Research&btnG= (accessed on 10 September 2021).
62. Mayouf, M.; Gerges, M.; Cox, S. 5D BIM: An investigation into the integration of quantity surveyors within the BIM process. *J. Eng. Des. Technol.* **2019**, *17*, 537–553. [CrossRef]
63. Li, X.; Wang, C.; Alashwal, A. Case study on BIM and value engineering integration for construction cost control. *Adv. Civ. Eng.* **2021**, *2021*, 8849303. Available online: www.hindawi.com/journals/ace/2021/8849303/ (accessed on 4 February 2021). [CrossRef]
64. Sacks, R.; Eastman, C.; Lee, G.; Teicholz, P. *BIM Handbook: A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers*; Sacks, R., Ed.; Wiley: Hoboken, NJ, USA, 2018; p. 688. Available online: https://so1.cljtscd.com/scholar?hl=zh-CN&as_sdt=0,5&q=A+guide+to+building+information+modeling+for+owners,+designers,+engineers,+contractors,+and+facility+managers.&btnG= (accessed on 31 December 2018).
65. Zhang, Y.; Luo, H.; He, Y. A system for tender price evaluation of construction project based on big data. *Procedia Eng.* **2015**, *123*, 606–614. [CrossRef]
66. Sun, C.; Jiang, S.; Skibniewski, M.J.; Man, Q.; Shen, L. A literature review of the factors limiting the application of BIM in the construction industry. *Technol. Econ. Dev. Econ.* **2017**, *23*, 764–779. [CrossRef]
67. Lee, C.C.T.; Cullen, D. An Empirical Comparison of Ethical Perceptions among the Consultant's Quantity Surveyor and Contractor's Quantity Surveyor in the UK Construction Industry. In Proceedings of the Construction, Building and Real Estate Research Conference, New Orleans, LA, USA, 2–4 April 2018. Available online: https://uwe-repository.worktribe.com/preview/874881/Cobra%202018%20Final%20(DC%20reviewed)%20V3%20FOR%20SUBMISSION%20-%20UWE.pdf (accessed on 4 April 2018).
68. Adnan, H.; Hashim, N.; Mohd, N.; Yusuwan; Ahmad, N. Ethical issues in the construction industry: Contractor's perspective. *Proc. Soc. Behav. Sci.* **2012**, *35*, 719–727. [CrossRef]
69. Smith, P.V. *Trends in the Australian Quantity Surveying Profession 1995–2003*; World Congress on Cost Engineering, Project Management and Quantity Surveying; AACE American Association of Cost Engineers; International Cost Engineering Council: Canbera, Australia, 2004; pp. 1–15. Available online: http://hdl.handle.net/10453/7332 (accessed on 31 January 2004).
70. Gledson, B.; Henry, D.; Bleanch, P. Does Size Matter? Experiences and Perspectives of BIM Implementation from Large and SME Construction Contractors. 2012. Available online: https://nrl.northumbria.ac.uk/id/eprint/10069/1/BIM_Gledson_Henry_Bleanch.pdf (accessed on 31 December 2012).
71. Alshawi, M.; Goulding, J.; Nadim, W. Training and education for open building manufacturing-closing the skills gap paradigm. In *Open Building Manufacturing*; ManuBuild: Cape Town, South Africa, 2007; p. 189. Available online: https://www.researchgate.net/publication/324438158_Open_Building_Manufacturing_Core_Concepts_and_Industrial_Requirements#page=207 (accessed on 30 April 2007).
72. Zhao, H.; Zhang, L.F.; Jiang, H.J. Research on basic competence elements of undergraduates majoring in engineering cost: A case study of mainland China. In Proceedings of the 2017 2nd International Conference on Humanities and Social Science (HSS 2017), Shenzhen, China, 24–26 February 2017. Available online: https://so1.cljtscd.com/scholar?hl=zh-CN&as_sdt=0,5&q=Research+on+basic+competence+elements+of+undergraduates+majoring+in+engineering+cost:+a+case+study+of+mainland+China.&btnG= (accessed on 26 February 2017).
73. Wao, J.O.; Flood, I. The role of quantity surveyors in the international construction arena. *Int. J. Constr. Manag.* **2016**, *16*, 126–137. [CrossRef]
74. The National Bureau of Statistics of China. *China Statistical Yearbook-2023*; China Statistical Publishing House: Beijing, China, 2023. Available online: https://www.stats.gov.cn/sj/ndsj/2023/indexeh.htm (accessed on 31 December 2023).
75. Ballesteros-Sanchez, L.; Ortiz-Marcos, I.; Rodriguez-Rivero, R. Investigating the gap between engineering graduates and practicing project managers. *Int. J. Eng. Educ.* **2021**, *37*, 31–43.
76. Tian, Z.C.; Chen, W.H. Research on development path and strategy of whole process engineering cost consulting service in the New Era. *Constr. Econ.* **2022**, *43*, 5–10.

77. Zheng, L.; Zhang, Y.J.; Jiang, Z.J. Research on the integrity evaluation index system for registered cost engineers. *J. Mod. Man. Sci.* **2013**, 105–107. Available online: https://kns.cnki.net/kcms2/article/abstract?v=oslmGXurZ-r3_zKdXdKScEvBMValyt7inlvdwgNoIerODAVr0J6q-k0FzKcZdzLh-4XP7SX98TA7rLJursilKpTG6JnROPmoD280qzDEUELBvuCRvqrGTaobtSLPXzo3OESi_3v6pNo=&uniplatform=NZKPT&language=CHS (accessed on 10 August 2013).
78. Zhang, H.M.; Tan, H.; Yu, X.S. Social support for rehabilitation of children with disabilities under the healthy China strategy:dimensional exploration and scale development. *J. Wuhan Univ. Sci. Technol. (Soc. Sci. Ed.)* **2023**, *25*, 611–620.
79. Zhang, W.; Cheng, L.H.; Cao, D.Q. Research on the relationship between the safety atmosphere and the unsafe behavior of people in non-coal mines. *Gold* **2023**, *44*, 94–97+101.
80. Jiang, J.S.; Qiao, Z.; Luo, J.Y. An analysis of the driving mechanism for the internationalization of local accounting firms under the the belt and road initiative. *J. Financ. Account. Mon.* **2024**, *45*, 93–101.
81. Xing, B.; Xie, D.D.; Li, S.H. Rural homestay fine service: Measurement and validation based on tourists Online comments. *J. Tour. Sci.* **2023**, 1–17. [CrossRef]
82. Liang, H.M.; Yang, S.R. Research on the development of dimensions and instruments for measuring workload of primary and secondary school teachers. *J. Mod. Educ. Manag.* **2023**, 72–82. [CrossRef]
83. Song, L.Q. The actual state and breakthrough path of digital literacy of primary and secondary school teachers in our country based on the assessment of 9405 primary and secondary school teachers. *J. China Educ. Tech.* **2023**, 113–120. Available online: https://kns.cnki.net/kcms2/article/abstract?v=RyaFSLOYMk441xGi-ha5ezchE5vmfbN1_Db3h8Ya83IjDyhNBq-A5_474Ez7X3Gl-RulWCad2G2QDa8gPoy5lpCevlFV4K0ZFUhufp1qgHjt6HSUkIPoOwaLINywX5isvq-Lf_pKdrw=&uniplatform=NZKPT&language=CHS (accessed on 10 December 2023).
84. Ding, T.Y.; Wu, K.; Li, P.; Lu, A.Y. Validity and reliability of the Chinese version of the positive mental health scale in urban adults. *Chin. Ment. Health J.* **2023**, *37*, 532–537.
85. Zhang, P. Research on the Influencing Mechanism of Project Managers Moral Hazard on Project Success-Towards Construction Projects. Ph.D. Thesis, Dalian University of Technology, Dalian, China, 2016.
86. Li, S.W.; Luo, J.L.; Guo, L.M.; Wang, J.Y. Cycle evolution of the impact of ability-enhancing, motivation-enhancing and opportunity-enhancing strategic human resource management on product innovation in S. & T. Enterprises. *Nankai Bus. Rev.* **2022**, *25*, 90–102.
87. Zhu, R.L.; Wang, S.N.; Li, L.; Li, X.T. Development of comprehensive vitality scale for the elderly based on classical test theory and analytic hierarchy process. *Acta Phys. Sin.* **2023**, *75*, 927–936.
88. Liu, F.J.; Zhang, M.Y. Research on the influence mechanism of corporate social responsibility perception on consumers' willingness to use of internet financial platform. *J. Coll. Essays Financ. Econ.* **2019**, 81–91. Available online: https://kns.cnki.net/kcms2/article/abstract?v=oslmGXurZ-rnoUo_qBIu5tL54FRNwkQq5fDcmG4xVpcEyj4KYmNY8heVl7WsK7-uy98CSn0xv0QKopEHO3puK3FlAnn9UCkr1pX7gOQDUmgHKMzz80LgIqhe56zQ2UfUc8xM_sbtvvC8ttzsqwBtQw==&uniplatform=NZKPT&language=CHS (accessed on 10 April 2019).
89. Zhou, Q.D.; Hao, D.F.; Qiu, Z. Investigation and optimization strategies for the current situation of sports education in universities in the new era: Based on a survey of college students. *J. Stud. Ideol. Educ.* **2023**, 130–135. Available online: https://kns.cnki.net/kcms2/article/abstract?v=RyaFSLOYMk53sN1nhN27fbCkiMeuaeWfitcpXNk4VMZAJXUDNlnsZ6z4JL3TjF1q3LGTMHr15bRNajt3rFWnV6vqY0558mfuAvUlSZ8esCU4y7VJy5TFgxgv9u_SczvPyewPQP_lQFA=&uniplatform=NZKPT&language=CHS (accessed on 25 November 2023).
90. Wang, Y.P.; Li, H.Y.; Yao, Y.B.; Li, D.L.; Fan, Q.W.; Liu, X.P. Multi-time scale change characteristics and influencing factors of total solar radiation in Dunhuang City. *Arid. Zone Res.* **2023**, *40*, 1885–1897.
91. Liu, X.Q.; Ge, W.Q.; Li, B. Reform and practice of the new engineering talent training model based on ability based training. *J. China Univ. Teach.* **2023**, 30–37. Available online: https://kns.cnki.net/kcms2/article/abstract?v=RyaFSLOYMk4KVRhFXUzWg6n27Z6F5zLla-DlybKdTft1rMtsTIpspLJ_5DGFm6EikKm1K8RKHQF-RDOqdVC-GArqqIzezee3UodUZwIh_DASVISVwQnVHKjGZzKR3Vt8cHuPjIfwiUg=&uniplatform=NZKPT&language=CHS (accessed on 15 November 2023).
92. Zhang, B.; You, N.; Yu, B.J. Study on investment control of the whole process in hospital construction project: Based on the perspective of follow-up audit. *Constr. Econ.* **2023**, *44*, 43–49.
93. Sun, S.N.; Liu, X.J.; Xiao, J.H.; Zhang, Z.H.; He, P.B. Research on BIM application in the whole life cycle of ship lift. *J. Yang. Rive* **2023**, 1–10. Available online: https://kns.cnki.net/kcms2/article/abstract?v=C06iYwc_NfQvbG04Rpc76fZgFRffl8yw9jJfbY-YWdFjzuPPZfmwU1CbyGvcsgDI9NmYWNgVsnsbAuLKuRd9FWkNIIXeOYNyTd16K1KVDPb8s7hKz2kDJVcuApC7MfJU3jfA8vIZPmw=&uniplatform=NZKPT&language=CHS (accessed on 21 November 2023).
94. Zhu, Y. Exploring the whole process control strategy of engineering cost based on the pricing model of bill of quantities under the background of BIM. *Constr. Mach. Tech. Manag.* **2023**, *36*, 114–115+118.
95. Fang, Y. Measures of optimizing the engineering cost management of petrochemical construction projects. *J. Chem. Eng. Manag.* **2023**, 16–18+25. Available online: https://kns.cnki.net/kcms2/article/abstract?v=oslmGXurZ-qHIHUZl5UIg8plu4qlbc6v4Sopro2GoDJ6k5fu4P6QtfOjWcHGucldv7jqVrR2SzAL_R8jxlllG7-A_N0gHW6_DIKnaFzhdeO-nVk9c4RGbbMvOSH5go3BYs5JSK1CdkNgyhl509nc3g==&uniplatform=NZKPT&language=CHS (accessed on 1 May 2023).
96. Zhang, H.B.; Yan, B. Research on the development of engineering cost management types. *Constr. Econ.* **2021**, *42*, 72–74.
97. Zhou, E.Z.; Cong, H.Q. Analysis of the current situation of engineering ethics codes in China based on the investigation of 37 codes. *Stud. Phil. Scie. Tech.* **2023**, *40*, 91–98.

98. Li, J.; Xiao, S.K.; Zuo, W.; Niu, L.Z. Cost control of on-site visa management for engineering construction projects. *Frie. Acco.* **2016**, 42–44. Available online: https://link.cnki.net/urlid/14.1063.F.20161107.1513.022 (accessed on 7 November 2016).
99. Fu, X.H. Research on dynamic management of local coal mine engineering cost. *Coal Tech.* **2013**, *32*, 278–279.
100. Jiang, J.; Feng, W.; Gao, H.; Sun, Y. Research on the architect responsibility system promotion countermeasures: Based on the comparison of the relationship between the rights and responsibilities of architects in China and the United States. *Constr. Econ.* **2023**, *44*, 5–11.
101. Su, R.; Cao, J.M.; Zhao, N.; Shi, Y.P. Exploration and application of the main and auxiliary teaching mode for applied universities. *J. Shijiazhuang Univ.* **2023**, *25*, 133–137.
102. Luo, L.; Zhong, Z.W.; Hou, W.; Huang, T.; He, Q.H. Study on the strategy of enhancing the capability of whole process engineering consulting service. *Constr. Econ.* **2022**, *43*, 85–92.
103. Walther, J.; Miller, S.E.; Sochacka, N.W. A model of empathy in engineering as a core skill, practice orientation, and professional way of being. *J. Eng. Educ.* **2017**, *106*, 123–148. [CrossRef]
104. Hodgson, D.; Paton, S.; Cicmil, S. Great expectations and hard times: The paradoxical experience of the engineer as project manager. *Int. J. Proj. Manag.* **2011**, *29*, 374–382. [CrossRef]
105. Zhang, J.; Xie, H.; Li, H. Improvement of students problem-solving skills through project execution planning in civil engineering and construction management education. *Eng. Constr. Archit. Manag.* **2019**, *26*, 1437–1454. [CrossRef]
106. Zhang, J.; Xie, S.; Li, H. Project based learning with implementation planning for student engagement in BIM classes. *Int. J. Eng. Educ.* **2018**, *35*, 310–322.
107. Al-Atroush, M.E.; Ibrahim, Y.E. Role of cooperative programs in the university-to-career transition: A case study in construction management engineering education. *Int. J. Eng. Educ.* **2022**, *38*, 181–199.
108. Zhang, P.; Cao, X.Y. Research on the improvement of BIM talent training mode for construction management specialty in universities in western China under the background of integration of industry and education. *Ind. Technol. Vocat. Educ.* **2023**, *21*, 33–39.
109. Zhou, J. Study on the correlation between major setting, talent Cultivation, and market demand in universities: A case study of undergraduate universities in Jiangxi Province. *Educ. Rec. Mon.* **2018**, 35–47. [CrossRef]
110. Song, Q. The mismatch between supply and demand of college graduates' employability and the countermeasures: From the view of supply-side reform. *Mod. Educ. Manag.* **2018**, 106–111. [CrossRef]
111. Rong, X. Talents training strategies for applied undergraduate colleges based on regional market demand—A case study of environmental design major of Tianping College of Suzhou University of Science and Technology. *Vocat. Tech. Educ.* **2020**, *41*, 33–36.