

What Competences Do Maintenance Electricians Need?—A Mixed-Methods Study From Vocational College Graduates

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Based on the demands of the labor market, this study focuses on the competence of maintenance electricians. The researcher collected 200 recruitment advertisements for graduates with backgrounds in electrical equipment technology companies, conducted seven one-on-one interviews with maintenance electricians from six companies, and conducted a questionnaire survey on a group of maintenance electricians. Researchers find out the competences of maintenance electricians and a four-dimensional competence model comprised of professional competence, method competence, social competence, and professional attitudes and values has also been built.

Keywords: maintenance electricians, employability, competences of college graduates, vocational education

Research Background

Employability is perceived as the sum of skills that make graduates attractive to employers (Harvey, 2001), as well as a set of knowledge, skills, and personality traits that facilitate graduates' employment and contribute to their career development (Yorke, 2006; Pool & Sewell, 2007). Many researchers have investigated the structure of employability, which contains professional expertise, technical skills, self-efficacy, social competencies, working attitudes, and so on (Hillage, 1998; Yorke & Knight, 2004; Zhu, 2009; Tong & Gao, 2022; Tong, 2022; Jiang, 2023). Maintenance electricians are specialized in the installation, commissioning, operation, maintenance, and repair of mechanical equipment and electrical wiring system and devices. Their majors are primarily associated with electrical equipment technology. Currently, the majority of maintenance electricians in China graduate from higher vocational schools, with backgrounds related to electrical equipment technology. According to the statistics from the Ministry of Education of the People's Republic of China, the

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total number of electrical equipment technology graduates in 2021 is about 100,000 (MOE, 2021). Despite a large number of graduates, there is still a severe lack of qualified electricians. In the fourth quarter of 2022, maintenance electricians were ranked 21st among the 100 most in-demand jobs in the national human resources market. One of the primary causes lies in the wide discrepancy between the job requirements and the structure and level of graduates' knowledge and caliber, which leads to the inability of many fresh graduates to work as electricians. This study aims to understand the employability requirements for electrical equipment technology graduates from the perspective of the labor market, to assist schools in teaching professional knowledge and skills in a more targeted manner, and to enhance the employability of graduates. With maintenance electricians as the research object, the competence of graduates with degrees in electrical equipment technology is investigated by using the empirical research method from the perspective of the labor market demands.

Literature Review

Different types of professional skills required for an electrician's work place a high demand on troubleshooting and resolution competences in authentic work. The foundation for an electrician to troubleshoot faults includes certain professional theoretical knowledge, an analytical mind, strong hands-on skills, practical ability, and the qualities of being bold and meticulous. Maintenance electricians need strong learning competence and the ability to identify problems in a timely manner, as well as a strong sense of safety (Liu, 2017). From the analysis of an electrician's actual work, an electrician should possess professional knowledge such as mastering PLC technology, English proficiency, and innovative competence. The specific methods for troubleshooting circuit faults are divided into logical analysis (based on circuit diagrams for analysis), experience judgment (communicating with equipment operators), experimental observation, and step-by-step measurement. These methods reflect that an electrician's work requires logical analysis skills, diagram reading skills, communication skills, observation skills, and hands-on operation skills.

The National Occupational Skills Standard of China classifies electrician requirements into three categories: professional ethics, fundamental knowledge, and skills, with technical skills divided into five levels (Ministry of Human Resources and Social Security, 2018). The Institution of Engineering and Technology (IET) sets out the competence and commitment required for a qualified electrician in five modules, which involve engineering knowledge and technical skills, the design, development, commissioning, or maintenance of equipment, the exercise of personal responsibility, effective communication and interpersonal skills, and the awareness of safety, codes of conduct and environment. Previous literature indicates that professional knowledge, practical skills, information skills, communication skills and personality traits, verbal competencies, inferential competencies, bimanual coordination, learning ability, ability to identify problems, and safety awareness are included in the employability of graduates with degrees in electrical equipment technology (Liu, 2017; Zhao & Chen, 2007; Yang, 2014; Jia, 2014; Yang, 2015). In these papers, the competence of a qualified electrician has been clarified to a certain extent. However, these are primarily government documents and speculative studies introducing experiences lacking the support of empirical data, which leads to subjectivity and one-sidedness. Based on previous research findings, this study employs the empirical method to analyze the competences of graduates, thereby making up for the deficiency of existing studies to some extent.

The research questions of this study include:

- To maintenance electricians, what kind of professional competences are crucial?
- To maintenance electricians, what kind of method competences are important in work?

- To maintenance electricians, what social competences are needed in work?
- What professional attitudes and values are crucial to maintenance electricians?

Research Method

Discourse Analysis

The researcher collected 200 recruitment advertisements for graduates with backgrounds in electrical equipment technology in 2023 from three online career job sites: 51Job, Boss Zhipin, and 58 Local Job.

51Job website has a larger volume of job advertisements and a wide range of positions across different industries. The site also features detailed job descriptions and employer requirements. Boss Zhipin focuses on more immediate recruitment needs, often showcasing positions with fast hiring processes. It also emphasizes direct communication between employers and candidates. 58 Local Job website offers numerous local opportunities, particularly in smaller cities and towns. This site has more listings for smaller companies or local branches of larger corporations.

Random stratified sampling is based on the type of units hiring maintenance electricians, salary levels, etc. The maintenance, low-voltage, and logistics electrician accounted for most of these positions. Our research mainly focuses on work requirement about educational qualifications, work experience, skills and competencies and certifications in these positions.

Most job postings require at least a bachelor's degree in electrical engineering, electrical equipment technology, or a related field. Many positions which open to fresh graduates, a significant number of job advertisements prefer candidates with internship experience or practical training in relevant fields. Key work skills mentioned in the advertisements include proficiency in CAD software, knowledge of PLC programming, familiarity with electrical circuit design, and understanding of industrial automation. Certain positions list industry certifications, such as certified electrical engineer (CEng) or equivalent, as preferred qualifications.

By coding the recruitment advertisements content, the competences characteristics of graduates that employers desired were extracted. Cluster analysis of contents with the same or similar meaning was conducted during the coding process. For instance, teamwork ability, strong team spirit, and solidarity were all coded as team spirit. The preliminary competences dimensions and categories were extracted by analyzing the labor market requirements for electrical equipment technology graduates from recruitment advertisements.

Selected job advertisement reflects the requirements for professional abilities such as rule awareness, safety awareness, hands-on skills, a sense of responsibility, the ability to handle emergencies, and team awareness for maintenance electricians. During the coding process, synonymous and similar contents are clustered together. For example, team collaboration ability, good team spirit, and unity are all coded as team spirit. In 200 recruitment samples, the frequency of each professional ability is recorded, with values ranging from 0 to 200. The higher the value, the greater the importance placed on those professional competences by the recruiting units.

Interview With Semi-open Questions

The researcher conducted one-on-one interviews with semi-open questions online. The interviewees, seven maintenance electricians from six companies, were all graduates with backgrounds in electrical equipment technology. The interviews covered four aspects, including the maintenance electricians' general job situation, job duties, key events, and professional skills and competencies, among which key events laid emphasis on the interviewees' most fulfilling or frustrating work experiences. The necessary occupational skills and job requirements of maintenance electricians in actual work situations were revealed by the interviews.

During the interview text coding process, the main nodes extracted include nine major parts: basic job information, knowledge and skills, methodological competences, social competences, professional competences, personal characteristic, success events, failure events, and others.

The researcher used NVivo 14.0, a qualitative analysis software, to code and analyze the interview transcripts. Professional competence with more coding references plays a more important role in graduates' competences.

Table 1

Work Characteristics of the Interview Sample

Interviewee	Company	Position	Length of service	Job description	Number of words
ZYM	SDD	Maintainer of the Security Department	15 months	Maintenance and repair of electrical circuits and appliances	13,551
LJ	BJH	Maintenance Electrician of the Technical Service Department	15 months	Inspection, maintenance, and troubleshooting of equipment	11,555
LY	QYT	Maintenance Electrician of the Maintenance Department of the Mechanical and Electrical Office	16 months	Equipment maintenance and line laying	10,752
CZL	BJB	Maintenance Electrician of the High-Voltage Test Team	5 years	Meter reading, and maintenance and inspection of equipment	16,784
RXQ	BJYY	Logistics Maintenance Electrician of the Power Security Department	8 years	Equipment maintenance and meter reading	10,219
DJJ	BJXH	Equipment Maintenance Technician of Equipment Group of the Technology Security Department	9 years	Maintenance of equipment breakdown	11,562
YSL	BJXH	Maintenance Supervisor of the Condition Security Department	15 years	Installation, commissioning, maintenance, and repair of equipment	14,266

Questionnaire Survey

The researcher conducted a questionnaire survey on a larger group of maintenance electricians by developing a Likert-5 scale of “professional competence and job requirements of maintenance electricians”. A total of 64 valid questionnaires were collected, consisting of 63 male electricians and one female electrician. And 87.5% of respondents were between the ages of 21 and 25, with the majority being young electricians with one-three years of work experience. The reliability of the scale was examined, in which the Cronbach's α was 0.979 and the KMO value was 0.788, indicating good reliability and construct validity of the questionnaire. The options, varying from very important, fairly important, average, less important, and unimportant, were assigned values from 5-1 respectively. Then, the mean value of each professional competence could be calculated based on the score assignment, which reflected the significance of various professional competencies.

Research Findings

It is found, through the data analysis, that the competences of graduates majoring in electrical equipment technology could be evaluated mainly from four dimensions: expertise and skills, professional practical capability, social capability, and professional attitudes and values.

Professional Competence

Professional competence refers to the specific knowledge, skills, and abilities that are directly related to the tasks and responsibilities of a particular profession. It is found that the professional knowledge required of a

maintenance electrician goes into two categories: expertise and knowledge in electrical field and professional skill of electricity, by the virtue of text analysis of national standards including *National Vocational Skills Standards (Electricians)* and the *Safety Technical Training Outline and Assessment Standards for Low-voltage Electricity Workers*, combined with the questionnaire survey and interviews.

When I met the problem of emergency power supply from the UPS, I performed a series of emergency operations, such as reducing the load and using a generator, saving many highly valuable pieces of equipment. When an unexpected situation arises, completing operations like warming up the generator, stabilizing the speed, voltage, and current is ensured by the knowledge and skills accumulated over time. Therefore, professional knowledge and skills are an indispensable part of a maintenance electrician's professional abilities.

—Interviewee RXQ

Expertise in electrical field consists of management for safety production, electric shock accidents, on-site rescue, electric-shock-proof technology, etc. The knowledge of electricity includes DC circuits, electromagnetic foundations, AC circuits, electronic technology, low-voltage electrical appliances, common motors, etc. As to the work of repairing electricians, the most important task and also the core professional skill consists of the installation and line laying of electric appliance, the commissioning and maintenance of relay control circuit and basic electronic circuit, the installation, commission, and repair of electrical equipment, and the decoration and maintenance of automatic control circuit.

Method Competences

Method competences refer to a set of abilities that are essential for effectively performing tasks, solving problems, and applying knowledge in practical situations. The method competence required for maintenance electricians includes learning competence, hands-on competence, execution competence, observation competence, and logical analysis competence. Learning competence refers to the capacity to continually learn new technologies and methods on the job, constantly refining one's professional skills. With the continuous progress and development of technology, the precision and complexity of mechanical equipment and the iteration of operating systems place high demands on an electrician's learning competence.

In our authentic work, there are many things we haven't encountered before, and we need to continuously learn and accept new knowledge during the work process. Only then can you be competent in your current job and improve your personal abilities. Therefore, learning ability is extremely important for the work of a maintenance electrician.

—Interviewee YSL

As the mechanical equipment becomes more sophisticated, and its operating system is accordingly upgrading with the continuous advancement of science and technology, learning ability is crucial to electricians. The fundamental requirements for electricians are applied talents. 90% of recruitment advertisements make clear requirements for this competency. The execution capability evaluates the ability to complete tasks assigned by the enterprise with both quality and quantity guaranteed. Those that are adept at execution can fix problems in a timely manner, hence preventing enterprise losses. Moreover, observation competence is essential for electricians in identifying potential safety hazards and signs of failure, as well as in troubleshooting. Last, logical reasoning and analysis competence matter in troubleshooting equipment and solving complicated problems.

Social Competence

Social competence refers to the abilities that facilitate effective interaction and collaboration with others in a professional environment. The study reveals that although the principal requirement for maintenance

electricians is technical skills, this occupation still calls for social capability. It refers to the ability of effective communication with co-workers. Maintenance electricians need to communicate with each other frequently, listen to others, and express their own opinions. Besides, they need to ask questions, receive feedback, and learn from each other in different shifts. The most frequently cited by respondents is the ability to teamwork, which is related to the work nature of electricians. In the survey of 64 people, 50 respondents believed that maintenance electricians often or always need to engage in mutual cooperation.

Table 2

The Requirement in Method Competences

	Research data presentation	Number of coding in recruitment advertisements	Number of coding reference in interviews	Questionnaire survey evaluation
Learning competence	Ability to learn continuously new technologies and theories. It is required for handling an ever-higher degree of integration of new equipment purchased by the enterprise each year and varying operating systems on PLC of numerically-controlled machine tools.	48	16	4.469
Problem solving competence	Ability to solve problems of basic tasks in daily work, such as line laying, modification, welding of electronic components, and so on.	184	8	4.500
Executive competence	Ability to respond immediately to unexpected instructions or requirements and solve problems timely in equipment failure.	166	2	4.547
Observation competence	Ability to keenly detect abnormal situations such as unusual sounds and the faint smell of burning electrical equipment when the system is operating.	138	4	4.547
Logical analysis competence	Ability to quickly locate the corresponding problem points on the PLC according to the alarm information, and troubleshoot the faults of the lines and components according to the drawings when the failure occurs with the alarm.	6	13	4.375

Table 3

Social Capabilities Required of Electrical Equipment Technology Graduates

	Research data presentation	Number of coding in recruitment advertisements	Number of coding reference in interviews	Questionnaire survey evaluation
Communication capability	Frequent communication is needed with operation workers who use the equipment on daily basis and understand the specific situation well so that they could give immediate information about the equipment. This is very important for solving some occasional problems.	68	13	4.375
Cooperation capability	To solve the problem of short circuits, at least two electricians are needed for the work, with one person doing maintenance at the construction site, and another observing the condition and measuring the position of the gate box.	50	21	4.516

For example, when dealing with equipment breakdown, teamwork is needed that one person is responsible for supervising the power supply, and another is for fault handling. Most electrician positions require the engagement of at least two people. Thus, the electrician with good teamwork ability would contribute to the smooth development of work.

Professional Attitudes and Values

Professional attitudes and values refer to the personal qualities, ethical standards, and mindset that influence how individuals approach their work and interact with others in a professional setting. The research findings show that the professional attitude and values of maintenance electricians include responsibility, carefulness, hard work, and awareness of safety, and the code of conduct. First, responsibility is the attitude that an electrician ought to have when working, to ensure that the problem will be solved properly with the right attitude and immediate action, as well as prevention measures. “Responsibility is essential because failure occurs very frequently if you only repair what has broken without any sense of responsibility.” (DJJ). Second, carefulness could be reflected in every aspect of the electrician’s work, such as careful detection of abnormal situations in equipment inspection, creative and scrupulous response to emergencies, careful disposal of metal scraps in equipment maintenance, avoidance of short circuits, and so on. Third, safety awareness gains the highest mean score in the questionnaire survey, because electricians must always put safety in the first place, keep the rules in mind, and strictly observe the safety practice for the dangerous nature of electrician work.

Before the test, we take a test device in hand, wear a mask, put on overalls with a pair of insulation shoes and gloves.

—Interviewee CZL

Table 4

Professional Attitudes and Values Required of Graduates of Electrical Equipment Technology

	Research data presentation	Number of coding in recruitment advertisements	Number of coding reference in interviews	Questionnaire survey evaluation
Responsibility	Electricians must avoid deliberately simplifying matters without considering the follow-up maintenance when they go to connect a wire at the distribution cabinet. Wires must be marked based on whether it connects to electricity, and their types: live wire, ground wire, or neutral wire.	118	5	4.594
Carefulness	In the process of wiring, a lot of thread ends and sheaths will be cut off, which must be carefully cleaned after the operation, because those metal fines could cause a short circuit when energized, possibly leading to serious accidents.	14	12	4.578
Hard-working	The electrician is a hard occupation that sometimes involves a great deal of physical work, such as working all day long under high voltage at electricity consumption peak time.	74	5	4.531
Safety awareness	A new worker who accidentally touched the cover plate while maintaining the equipment, which led to a circuit shock, was knocked out on the ground and then sent to the hospital for emergency rescue.	100	15	4.750
Rule awareness	Every time you remove your hand from the wire and touch it again, you must use the electric test pen to determine whether or not the wire is charged. Even after the switch has been pulled off, each wire must be tested.	42	14	4.594

Observing the basic operation rules could minimize insidious dangers, which ensures the safety of electricians. Graduates, who adhere to the safety practice, and assume active, responsible, and down-to-earth attitudes in work, are most favored in the labor market.

Conclusions and Perspectives

Based on the text analysis of electrician recruitment advertisements, interviews with employees in this field, and the questionnaire survey, a competence model is built for maintenance electricians from four aspects: professional knowledge and skills, social capability, professional practical capability, and professional attitudes and values, as shown in Figure 1:

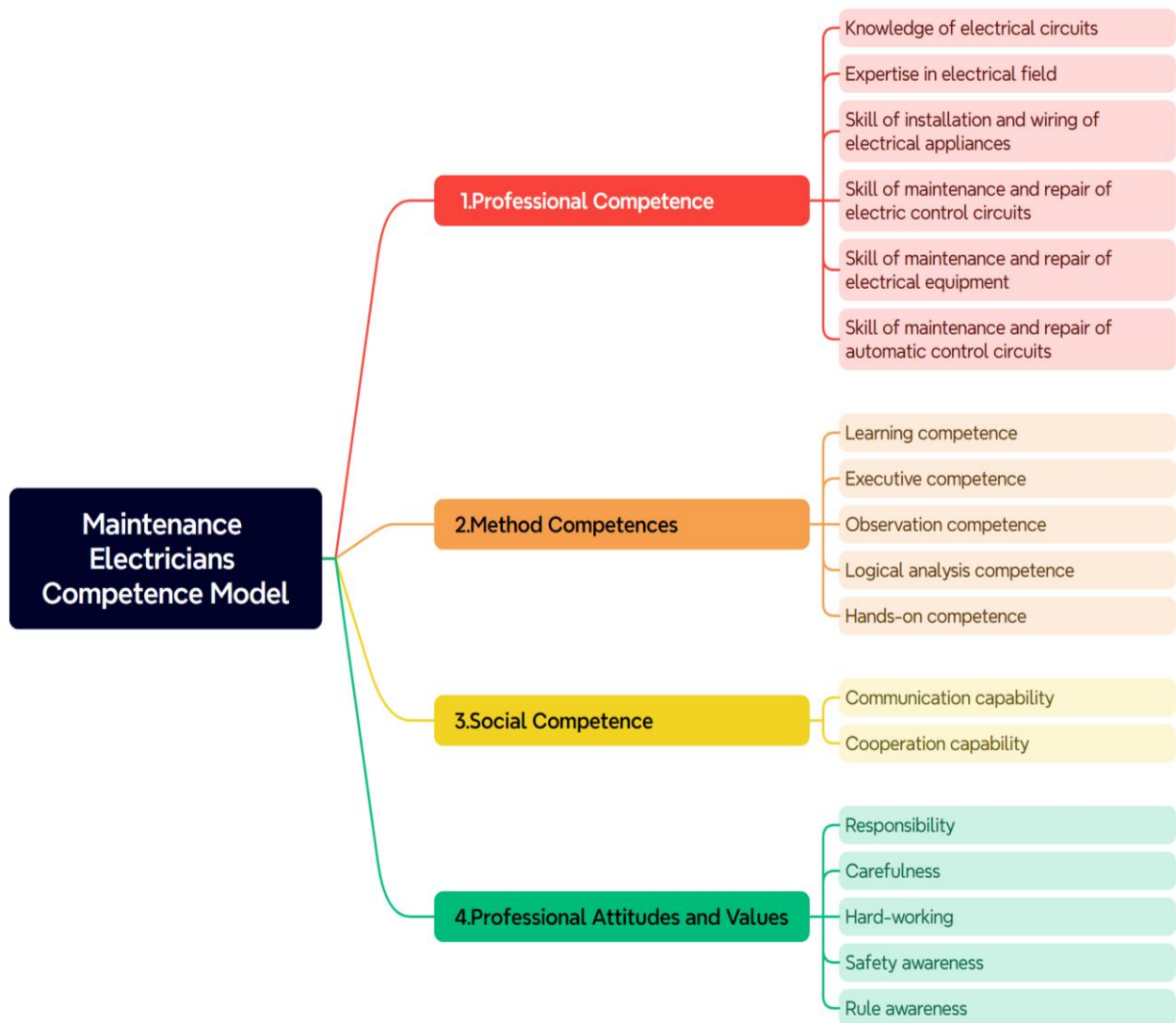


Figure 1. Competence model of maintenance electricians.

By virtue of the feedback from the labor market, it can be concluded that in addition to expertise and skills, enterprises and employers value practical ability, social competence, and professional attitudes more. These abilities cannot be acquired solely through study at vocational schools, but demand more active engagement in

corresponding internships and practical activities to accumulate actual work experience in the workplace. At the same time, school teaching should not only be restricted to the knowledge in textbooks, but should also design appropriate practical projects, which allow students to experience what it feels like in the authentic workplace, thereby enhancing their comprehensive competences.

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