Journal of Scientometric Research, 2025; 14(3):876-888.
https://www.jscires.org

Research Article

Exploring the Competency Needs of Internet of Things (IoT) Training Instructors: A Systematic Literature Review

Ima Luciany Milansari*, Putu Sudira, Candra Dinata

Technology and Vocational Education, Graduate School, Universitas Negeri Yogyakarta, Special Region of Yogyakarta, INDONESIA.

ABSTRACT

The rapid development of technology in the Internet of Things (IoT) challenges instructors/trainers in preparing workers to face this technological change. This research describes the competency needs of IoT training instructors by reviewing various competency standard documents from governments and articles. The study follows the Systematic Literature Review (SLR) regulation that consists of two main steps: planning and conducting. The analysis results revealed 3 themes of competency needs for IoT training instructors included vocational teacher's competencies, IoT worker's competencies, and Industrial Revolution 4.0 (IR 4.0) competencies. Based on the study, this review proposed 7 competencies for an IoT training instructor those are pedagogy-andragogy strategies, technical proficiency, technology and digital literacy, industrial business management, leadership and team management, life skills, and interdisciplinary skills. The research results carry considerable consequences for both educators and those involved in designing curricula. This research can provide valuable guidance in developing curricula and training programs to improve instructor competency so that they can provide quality and relevant education in facing the future dynamic challenges of IoT technology.

Keywords: Competency needs, Instructor, Internet of Things, Systematic literature review.

Correspondence:
Ima Luciany Milansari
Technology and Vocational Education, Graduate School, Universitas Negeri Yogyakarta, Special Region of Yogyakarta, INDONESIA.
Email: imaluciany.2022@student.uny.ac.id
ORCID: 0009-0002-3110-1384

Received: 22-08-2025;
Revised: 17-09-2025;
Accepted: 04-11-2025.

INTRODUCTION

The emergence of various technologies in the Industrial Revolution 4.0 (IR 4.0) era, such as intelligent robots; Artificial Intelligence (AI); Virtual Reality (VR); cloud solutions; machine learning; big data; and the Internet of Things (IoT), have drastically changed the landscape of various business industry sectors.[1-5] In the IR 4.0 era, IoT is becoming contributors most capable of changing the order of various jobs.[6-11] IoT is also widely adopted in various areas of life, such as the manufacturing industry; health; education; agriculture; and transportation, that are a unique system that allows multiple devices to be connected through the use of various technologies that can provide convenience and improve a process.[12-15]

Based on the analysis results by the statistical institute in Germany (IoT Analytics), the development of IoT technology continues to increase from year to year.[16] The results show that the number of IoT connectivity globally in 2022 will grow by 18% to 14.3 billion. In 2023, the IoT Analytics agency predicts the number of IoT-connected devices globally will increase by 16% to 16.7 billion. Seeing the great potential of using IoT, developers continue to refine and improve IoT applications.[16,17]

Automation and technological integration have shifted the types of work needed and created new job opportunities.[18-21] In this era, as demand for new skills such as data analysis and automation system management increases, workers are expected to have problem-solving skills; optimize processes; demonstrate reliable technical competence; be able to adapt to change; have an innovative spirit; and ability to continue learning along the way their career.[21-24] Therefore, the main key to success in today's world of work is to take an education and skills development approach responsive to the dynamics of Industry 4.0.[25,26] On the other hand, developing these skills is not easy to do, and this is influenced by several factors, including the many technological concepts involved, skills and initial knowledge in using hardware, and the level of students' ability in programming.[27] To meet these challenges, teachers must quickly adapt to new teaching approaches and technologies.[24] The role of teachers in the industrial era 4.0 is not only supporting the technical learning process but also related to the role of involvement with professional institutions and driving workshop innovation.[28] There are at least four main competencies that teachers need to have in the industrial era 4.0, pedagogical competencies related to the ability to motivate students; social competence; personality competence; and the professional competencies teachers need to transfer knowledge and technology.[29]

DOI: 10.5530/jscires.20251225

The problem follows research conducted by Moreira Choez shows the importance of a high level of technological literacy among teachers, emphasizing the importance of technical skills in education today.[30] The findings suggest the need to implement customized teacher training strategies further to improve teachers' digital competencies in these specific areas. The importance of teachers' technological competence is in line with the research by Diao and Hu. Regarding how to improve the teaching competence of Technical and Vocational Education and Training (TVET) teachers, this study believes that to achieve this goal, we need not only ICT ability support but also a more scientific TVET teacher teaching competence scale to assist teachers in education management institutions in formulating more appropriate teaching and training plans, effectively improving teachers' teaching competence.[31] From this point of view, the use of the TVET teacher teaching competence scale to enhance the quality of vocational education teaching and sustainable development goals are closely related.

TVET teachers and trainers must have good individual competence to achieve the desired training objectives. These competencies will be used before starting training, during training, and after training. The core competencies TVET teacher and trainer needs to have in general are personality and professionalism; teaching, learning, and training; technical skills and innovation. Apart from that, teaching staff are also expected to be able to develop the competencies (knowledge, skills, and attitudes) needed to use technology in formal and non-formal education.[32] TVET teachers, apart from having the ability and skills in teaching, are also required to master technical skills.[33] The technical skills in question include digital literacy, programming, data analysis, management, and planning.[34] Fitsilis[35] added that to create training that is in line with the development of Industry 4.0, three skills are needed: technical skills, transversal skills, and contextual skills.

This research seeks to explore the technical and non-technical competencies required by IoT training instructors. Despite the growing demand for IoT training, there remains a lack of systematic reviews that identify the specific competencies necessary for instructors in this field. This gap can hinder the effectiveness of training programs and the readiness of human resources to meet the challenges of the IoT era. By systematically analyzing the existing literature, this study aims to fill this gap, offering a comprehensive framework of competency requirements. The findings are expected to contribute to the design of targeted training programs, policy development, and the overall enhancement of IoT education and workforce readiness.

METHODOLOGY

The method used in this research is a Systematic Literature Review (SLR). SLR is a systematic research method used to collect, critically evaluate, integrate, and present data from various sources (such as books, articles, conference proceedings, regulations, and dissertations) so that an overview of the important points of a topic of current knowledge is obtained.[36,37] The SLR method used in this research consists of 2 main stages, namely "Planning" and "Conducting".[37,38] The steps shown in Figure 1 and objectives of each stage are explained in the sub-chapters.

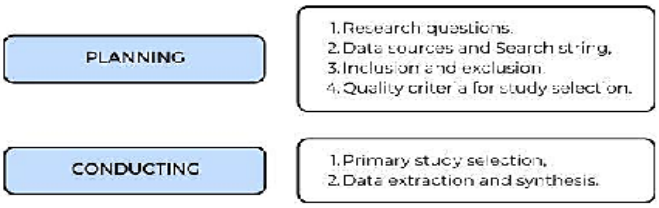

Figure 1: The Step of SLR.

Planning

The planning stage is the initial step used to carry out the review. This stage aims to define the procedures that will be carried out in carrying out the review, ensure the consistency and validity of the review, and plan the sources that will be used in the review so that a general picture is obtained. The steps in the planning stage include formulating research questions, determining data source and search string, determining inclusion and exclusion criteria, and determining quality criteria for the sources obtained.

Research Questions

This research focuses on analyzing the competency needs of IoT training instructors, especially in Indonesia. The research questions used as a guide in this review are:

RQ1: What competencies are needed to become a training instructor?

RQ2: What competencies are needed to become an IoT worker?

RQ3: What competencies are needed by workers in the era of Industrial Revolution 4.0?

Data Sources and Search String

Keywords help find appropriate searches and determine databases that suit the research question. This research used Scopus and Google databases to obtain appropriate data. Competency standards from several countries were obtained by browsing the organization's website, while research articles were used to gain additional insights according to existing developments. The data search summary shown in Figure 2 and Table 1.

Inclusion and Exclusion

The data sources for government and private institution competency standards used as references in this research refer to the conditions and competency needs from 2010 until 2024. The article data sources used come from journals and conferences

Table 1: Summary Data Search String.

Data Base	Keyword	Justification for use of terms	Articles Founded	After Initial Screening	After Advanced Screening
Scopus	"competencies" OR "competency" AND "IoT" OR "internet of thing"	Includes specific competencies required in the mastery and application of IoT technology.	123	17	3
	"competencies" OR "competency" AND "vocational teacher" OR "vocational educator" OR "instructor" OR "teacher instructor"	Includes a range of terms used in the international literature to refer to educators in vocational education. The term is aligned with the conceptual framework that places educator competencies as a key element in supporting learner skills development.	661	32	7
	"internet of thing" OR "IOT" AND "instructor" OR "teacher" AND "competencies"	The term is used to help identify literature that focuses on developing instructor competencies to support IoT implementation. It explores various aspects, such as how instructors understand IoT technology, integrate it in the curriculum, and equip learners with skills that are in line with industry demands.	28	4	1
Google (gov. website)	Instructor competencies, vocational teacher competencies	Find competency standards that focus on education and training in relevant technical skills.	7	7	3
	Iot worker competencies, iot competencies	Lead to competency standards that focus on the competency needs of workers in the IoT field.	8	8	6

published in the last ten years (2014-2024). This research will not include data sources that do not describe the competency of instructors, vocational teachers and/or IoT workers. Competency standards for government/private institutions published before 2010 are not included in consideration of the standard's regency. A summary of the data inclusion and exclusion criteria in this review can be seen in Table 2.

Quality Criteria for Study Selection

The quality of the source is assessed based on the following statements by giving a "Y" mark if it matches the statement and an "N" mark if it does not.

QA1: The source discusses the competencies required of a vocational instructor/trainer/teacher.

QA2: The source discusses the competency framework or models of IoT.

QA3: The source discusses interdisciplinary skills related to IoT.

Conducting

The second stage is processing the data sources obtained and then analyzing and synthesizing the results.

Primary Study Selection

Initial search results obtained 15 competency standards from several countries related to the role of an instructor and worker in the IoT field. In addition, based on a search of the Scopus databases, 53 articles related to the previously found search terms were obtained. The initial documents obtained from the database can be seen in Appendix 1.

Data Extraction and Synthesis

Documents and articles obtained and going through the selection stage according to the criteria have resulted in 9 competency standard documents from state and private institutions and 11 articles related to instructor competency qualifications and IoT worker qualifications. To analyze the results of the literature study in more depth, the first stage is an operational definition of the findings. In the second stage, the researcher created a context-appropriate qualification arrangement based on sentences in the related sources. The conviction was synthesized and arranged briefly to make it easier to understand. Third, each mutually relevant qualification is included in sub-competencies. Overlapping study results will be analyzed repeatedly until appropriate conclusions are obtained. Finally, each

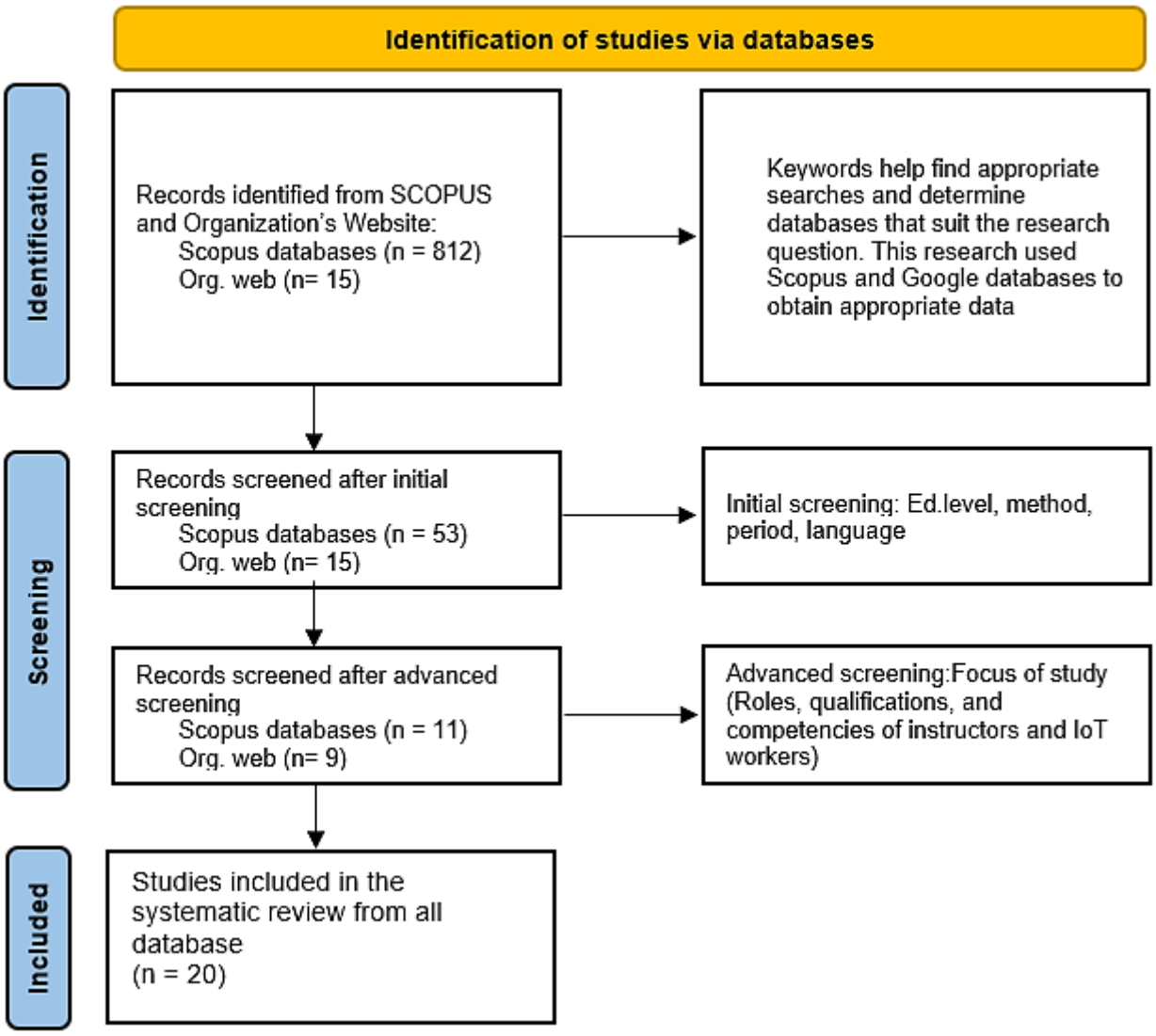

Figure 2: SLR Summary with PRISMA flow diagram.

Table 2: Review Inclusion and Exclusion Criteria.

Source	Criterion	Inclusion	Exclusion
Article	Educational level	Vocational education and training	General education
	Focus of study	Roles, qualifications, and competencies of instructors and IoT workers	Others
	Method	Qualitative, Quantitative, Mixed method	-
	Period	2014-2024	Before 2014
	Language	English	Non-English
Institutional documents	Period	2010-2024	Before 2010
	Language	English, Indonesian	Other languages

sub-competency category is reorganized into core competencies required by IoT training instructors. The reliability of the findings was established by reviewing the input of a Vocational Education and Training (VET) expert with experience in IoT work. Documents and articles used as the main reference in this review can be seen in Table 3.

RESULTS AND DISCUSSION

This study reviews three categories of competencies: competencies of vocational education teachers, competencies of workers in the IoT field, and competencies of workers in the Industry 4.0 era. This division is done to provide a comprehensive framework for understanding the competency needs of an IoT instructor.

Table 3: Summary of Literature Study.

Author and Year	Title	Job Role	QA1	QA2	QA3
(39)	Regulation of the Minister of State Apparatus Empowerment and Bureaucratic Reform of the Republic of Indonesia Number 47 of 2021 concerning Competency Standards for Functional Instructor Positions	Instructor	Y	N	N
(40)	Minister of Education and Culture Regulation No. 90 of 2014 concerning Qualification and Competency Standards for Instructors in Courses and Training	Instructor	Y	N	N
(41)	International Board of Standards for Training, Performance, and Instruction (IBSTPI) - Instructor Competencies 2021	Instructor	Y	N	N
(42)	Decree of the Minister of Manpower of the Republic of Indonesia No. 300 Yr. 2020 Concerning the Implementation of SKKNI in the Information and Communication Category for the Main Group of Telecommunications in the IoT Sector	IoT workers	N	Y	Y
(43)	Bhutan National Competency Standards for Internet of Things (IoT) Technician	IoT workers	N	Y	N
(44)	ICTCYS609 - Evaluate threats and Vulnerabilities of IoT Devices	IoT workers	N	N	Y
(45)	ICTIOT502 - IoT Devices Program	IoT workers	N	Y	Y
(46)	ICTIOT503 - Design and Test IoT devices and Networks	IoT workers	N	Y	Y
(47)	IoT Security Verification Standard (ISVS) - OWASP	IoT workers	N	Y	Y
(48)	Plan and Develop Advanced Knowledge and Skills for Future Industrial Employees in the Field of Artificial Intelligence, the Internet of Things, and Edge Computing	IoT workers	N	Y	Y
(49)	A List of Skills Required for Internet of Things (IoT) Talent	IoT workers	N	Y	N
(50)	State-Level Views on Professional Competencies in the Field of IoT and Cloud Information Security	IoT workers	N	Y	Y
(51)	Developing the Standard Competencies for Vocational Teacher Candidates of Mechanical Engineering	Instructor	Y	N	N
(52)	Competence-based analysis of needs in VET teachers and trainers: an Italian experience	Instructor	Y	N	N
(53)	Intercultural teaching competence: a multidisciplinary model for instructor reflection	Instructor	Y	N	N
(54)	21st Century Skills: Student Perception of Online Instructor Role. Interdisciplinary Journal of e-Skills and Lifelong Learning	Instructor	Y	N	N
(55)	Being an ethical model: The perspectives of trainers	Instructor	Y	N	N
(56)	Examining Higher Education Instructor Perceptions of Roles and Competencies in Online Teaching	Instructor	Y	N	N
(57)	The Role of Trainers in Implementing Virtual Simulation-based Training: Effects on Attitude and TPACK Knowledge	Instructor	Y	N	N
(58)	An Integral Pedagogical Strategy for Teaching and Learning IoT Cybersecurity	IoT instructors and workers	Y	Y	Y

The competencies of vocational education teachers are analyzed as instructor competencies because IoT instructors often come from vocational education environments that emphasize practical skills. IoT worker competencies are relevant to identify the technical and professional skills needed in this specific field. Meanwhile, the competencies of Industry 4.0-era workers include cross-disciplinary skills that reflect the global need for flexibility, innovation, and digitalization, which is the main context for IoT.

Instructor Competencies

The definition of educator in Law of the Republic of Indonesia No. 20/2003 on the National Education System is "professional staff tasked with planning and implementing the learning process, assessing learning outcomes, providing guidance and training, as well as conducting research and community service, especially for educators at tertiary institutions". In this regulation, the teaching staff comprises teachers, lecturers, counselors, tutors, instructors, and facilitators.[39] They have their important roles in the education and training process.

The role of teaching staff in Indonesia is still dominant, and even though a lot of technology can be utilized in the learning process, the role of teaching staff has a very important meaning. They are responsible for mentoring, delivering material, and developing participant skills. Teachers are not only conveyors of information but also learning facilitators who inspire, guide, and create a positive learning environment.[40] To carry out these roles, instructors need to have adequate competencies to provide learning experiences that are relevant, in-depth, and have a positive impact.

Competency standards serve as guidelines for assessing instructors' abilities (knowledge, skills, and behavior) in implementing learning. The formulation of instructor competencies outlined in Indonesian government regulations consists of pedagogical, personality, social, professional, technical, and managerial competencies.[41,42] In other competency standards, qualifications for instructors are added, namely designing and facilitating learning and evaluating learning.[43]

Nader Ganayem and S Zidan[44] identified the instructor's role into four dimensions, namely the work collaboration dimension (leading students in collaborative work; instructing students to collaborate in a multicultural environment; developing students' collaborative work skills; maintaining communication in work groups; and solving existing problems among group members), the dimension of higher order thinking (developing activities that lead to the development of thinking; involving students in assessment; generating creative thinking in working groups; and challenging students with new topics), the dimension of using digital means of pedagogical capabilities (directing students with platforms differentiated learning; teaching students the use of various tools in a digital environment), as well as the multicultural communication dimension (attracting students' interest in new cultures; instructing students to work in a multicultural environment). Thanasi-Boçe revealed that the role of the instructor can be a factor that contributes to building satisfaction in direct learning, although the results are not significant. The instructor's role contributes to student satisfaction only when there is a positive perception of learning.[40]

The competency model for VET teachers and trainers developed by several experts generally covers four domains of the role of VET teachers and trainers: pedagogy, substantive, organization, and development and research.[45] Liu[46] classified the instructor's role into four dimensions: pedagogical, managerial, social, and technical. Other competency models that are requirements for instructors are basic competencies, facilitation competencies, and curriculum design competencies.[47] Successful learning in vocational education requires special knowledge regarding how to facilitate students with certain specific skills, so the andragogy approach and knowledge of integrating technology with content knowledge is an appropriate alternative in VET learning.[47,49]

Andragogy is an educational approach for adults to improve skills by prioritizing independence.[50] Motivation originating from personal aspirations, needs, or self-development goals is also an important factor underlying participants' desire to learn.[51] In andragogy education, the role of teachers in education and training is to help students diagnose learning needs (diagnostic function), plan with students a series of experiences that will produce the desired learning (planning function), create conditions that create a desire to learn in students (function motivation), selecting the most effective methods and techniques to produce the desired learning (methodological function), as well as providing the human and material resource skills required by learners to live a decent life for the rest of their lives.[50]

The purpose of education and training is not only to provide a place to transfer knowledge but more than that, education and training aim to transfer value. In this context, instructors need to have skills in conveying information and other aspects. Competent instructors can integrate ethical, moral, and social values into learning, create an environment that motivates the development of these values, and be consistent role models for the values they have conveyed.[52] Other competencies that are suitable for vocational educators are mastery of the theory and practice of engineering techniques, being an expert in their field as proven by competency certification, having managerial skills, having a strong personality, always adapting to technological developments, and being able to provide career insight to students.[53,54,48]

The ever-changing learning atmosphere and diverse characters in training allow instructors to respond wisely to the various feelings and emotions in the learning environment. The instructor's emotional intelligence, such as being able to read students' emotional signals, understand their psychological

needs, and provide appropriate support, will create a learning atmosphere that supports and motivates students to participate in the training actively.[55,56] The instructor's ability to arouse trainee motivation can help trainees on their journey toward professional development.[57] Massive online-based training also requires different strategies and approaches to learning. Therefore, instructors must have additional competencies related to mastery of technology in learning.[48,58]

Based on the literature study results, researchers compiled the findings by categorizing the skill requirements for instructors into several domains, namely pedagogy-andragogy, technology, professionalism, personality, and social. The andragogy approach to vocational education and training emphasizes adult learning and the practical application of technical skills.[59] VET's central role in sustainable development, which produces competent workforce candidates, places VET as a place for lifelong learning.[60]

Andragogy is important in VET learning. The demand for independent learning from students will lead them to increase their maturity so that they can make decisions independently. Raising the effectiveness of training can be supported by having instructors who understand the training content, how to deliver it appropriately, and the use of appropriate tools. It can involve training participants in learning.[61] Table 4 summarizes the general competency requirements required by training instructors. Competencies are classified into five areas (pedagogy-andragogy, technology, professional, personality, and social).

Table 4: General Instructor Competency.

Competency Area	Key Elements
Pedagogy-Andragogy	Curriculum development knowledge and abilities
	Understanding student character
	Understanding of training principles
	Mastery of the training process
	Evaluation and assessment
Technology	Mastery of technology in learning
Professional	Self-development
	Content knowledge
	Metacognitive skills
Personality	Communication
	Emotional intelligence
	Motivation
	Personality
Social	Collaboration and cooperation
	Inclusive attitude
	Work adaptation

Job Competencies for Internet of Things (IoT) Workers

IoT consists of complex and cross-sector systems, so a different learning approach is needed to improve the ability to connect various concepts; technology; and scientific disciplines. Basic to advanced knowledge and skills related to IoT include understanding IoT, IoT implementation scenarios, IoT architecture, IoT implementation, IoT components, IoT industrial Machine to Machine (M2M) protocols, sensors, programming, IoT communications, cybersecurity, cryptography, networking, data analysis, database development, to IoT maintenance.[62] In Indonesia, training instructors must meet several qualifications, such as having a certificate of competency expertise in the relevant field, having an instructor certificate, having taken a certain formal education, and having at least 3 years of experience in their field.[42]

The Indonesian government has decided on work competency standards in the IoT sector as stated in KEPMENAKER No. 300 of 2020 concerning work competency standards in the IoT field.[63] In this regulation, workers are required to have skills such as designing IoT connectivity architecture, designing IoT platforms, creating IoT platforms, designing IoT hardware, building IoT software, analyzing; designing; and building IoT application systems, building and testing IoT security systems, monitoring, evaluating and maintaining IoT performance. Competency standards from abroad add references to competency needs for IoT workers, including the ability to design, build, and integrate IoT systems and evaluate threats behind IoT systems.[64-67]

IoT business strategy

The wide use of IoT technology requires instructors to have a deep understanding of technical aspects, implementation areas, and business strategies related to IoT.[66] Instructors need to understand how this technology can be effectively integrated into various industrial contexts and how it can generate added value for the business. Joeng and Yu[68] created four criteria related to business management model innovation in the IoT industry: application, agility, diversity, and connectivity. Joeng and Yu added the contents of each criterion discussing evaluations related to changes in company values during the IR 4.0, assessment of organizational responsibility to changes in the external environment, evaluations of system implementation in various types of new businesses that have emerged, and evaluations related to the company's cooperation system. Steps that can be taken in designing a successful enterprise IoT strategy are determining business goals and expected results, identifying accompanying hardware and devices in a connected solution, preparing data points and metrics that align with the results, choosing device connectivity and data formats, implementing security; governance; and policies at each layer, identify the reference data sets needed to transform sensor data, consider

machine learning and predictive analytics, define analytics hot paths for real-time processing, define analytics cold paths for long-term processing, and design intuitive user experiences for business decision makers.[69]

IoT Design, development, and testing

IoT is a system that can describe where everything can be connected and communicate intelligently, like human-to-human; human-to-object; and object-to-object.[70] Several points need to be considered before designing an IoT system, such as the target user of the system, the purpose of the system, the features required, the communication method used, the type of IoT software and hardware, data usage, the IoT security system, and the interface used.[63,71] Considering this, the competencies required for workers in this aspect include designing IoT connectivity architecture, designing IoT platforms, creating IoT platforms, designing IoT hardware, building firmware for IoT devices, analyzing IoT application systems and flows, designing IoT application systems, designing User Interface (UI) and User Experience (UX) of IoT applications, building mobile-based IoT applications, building web-based IoT applications, designing security systems for connectivity; platforms; devices; and IoT applications, testing security systems on connectivity; platforms; devices; and IoT applications.[63] The need for technical skills required by professionals in the IoT sector will continue to grow, and a significant increase in demand will occur along with rapid technological change.

System integration and connectivity of IoT

This competency refers to connecting and communicating various connected devices into a coordinated network. IoT connectivity is a means to connect sensors and applications with other devices, as well as IoT clouds and gateways. These skills also ensure devices can communicate effectively, maintain security standards, and deliver the desired functionality. This integration process allows the data being monitored or controlled to move smoothly, quickly, and without errors from upstream to downstream on the IoT network.[27] Things that need to be considered in IoT system integration are contract separation between service producers and service consumers, scalability, ease of testing, ease of development, system reliability and robustness, ease of implementation, and inter-domain operability.[72]

IoT security

Security systems are an important part of the IoT environment that must be developed along with changes in the complexity of IoT. An important aspect of implementing an IoT security system is ensuring that devices connected to the network have an adequate security layer, using secure network services, using passwords that are strong and not easy to guess, using a secured interface, and ensuring that they use secure data storage and transfer.[73] In connection with this, IoT training instructors who will teach prospective workers in this field must have competencies such as being able to build; utilise; manage; and apply security techniques to architecture; IoT network services and applications such as cryptography and authentication protocols, and content protection.[74,75]

Miloslavskaya and Tolstoy[76] state that information technology security competency for workers in the IoT sector consists of two things, namely network and telecommunications security and system and application security. His research included information system security competency standards from the National Initiative for Cybersecurity Education (NICE) as competency requirements needed by professionals in IoT and cloud security. These competencies are divided into seven categories, namely: 1) secure provider (conceptualizing, designing and building secure information technology systems, with responsibility for several aspects of system development); 2) operate and maintain (providing support, administration and maintenance necessary to ensure effective and efficient performance and security of information technology systems); 3) protect and defend (identify, analyze and mitigate threats to internal information technology systems or networks); 4) investigations (investigating cyber incidents and/or crimes against information technology systems, networks and digital evidence); 5) collect and operate (special denial and deception operations and collection of cybersecurity information that may be used to develop intelligence; 6) analyze (highly specialized review and evaluation of incoming cybersecurity information to determine its usefulness for intelligence); 7) supervision and development (providing leadership, management, direction, and/or development and advocacy).

IoT management strategy

Management strategy aims to achieve operational efficiency and informational decision-making and create sustainable added value for the organization. IoT management strategies include a deep understanding of business goals, selecting and implementing appropriate IoT devices, efficient data management, and security of the entire network of connected devices.[77] Data management is one of the most important strategies in IoT systems. This data management is very important considering the high level of interconnection of devices that can access sensitive information and generate large amounts of data.[78]

Diène[79] designed a data management system approach based on four taxonomies. First, data storage solutions consist of data heterogeneity management; scaling; data volume; and distributed data storage. Second, a data indexing solution consists of a geographic hash table; distributed hash table; distributed indices for multidimensional data; and distributed indices for features in sensor networks. Third, source-oriented and data middleware solutions, consisting of data storage locations; actor-based solutions; multi-layer architecture; data aggregation;

and cloud-based solutions. Fourth, architecture-based solutions consisting of service-oriented architecture and service discovery. IoT management strategies also include developing innovative business models, determining supportive policies, and continuously improving the performance, accessibility, trustworthiness, quality, and functionality of IoT systems.[63,77,80]

IoT evaluation strategy

IoT evaluation is a systematic approach used to assess the performance, security, and overall effectiveness of IoT infrastructure. This evaluation strategy includes threat modeling, implementation review, authentication, and access control review, device risk analysis, device firmware implementation review, fuzzing protocols, network traffic analysis, code review, encryption review, penetration testing, as well as privacy reviews.[63,81] IoT evaluation strategies are carried out for several reasons, such as optimizing technical performance, data security and privacy, operational efficiency, conformity with business goals, meeting standards, continuous innovation, and providing user satisfaction. Specific technical competencies for IoT developers are included in the technical proficiency dimension. Table 5 shows a summary of the needs for these competencies.

Table 5: IoT Worker Competencies.

Competency Area	Key Elements
Technical Proficiency	IoT business strategy
	Design, development, and testing of IoT
	IoT system integration
	IoT Connectivity
	IoT security
	IoT management strategy
	IoT evaluation strategy

Work Competencies in the Industrial Revolution Era 4.0

In the industrial era 4.0, which widely applied Cyber Physical System (CPS) based technology, people must continue developing their skills. Technology-related knowledge is crucial in the industrial era 4.0 due to the increasing development of new technologies emerging in this era.[82] The four main skills that need to be possessed in this industrial era 4.0 are knowledge and skills related to information; media; and technology, the ability and willingness to continue learning and innovating, skills in life and learning, and the ability to communicate effectively.[83] Ana adds that these skills can be obtained if someone has several things within themselves. First, someone will gain skills related to information, media, and technology if they are literate in technology, including media, visuals, multiculturalism, and global awareness. Second, innovation skills will be created when someone has curiosity, creativity, and the courage to take risks. Third, someone will be skilled in life if they have responsibility, ethics and morals, productivity, adaptability, flexibility, and can give direction to themselves. Fourth, it can be said that we can communicate effectively if the communication style is interactive and has a national and global orientation.

Instructors who work in fields related to IR 4.0 technology cannot escape the demands of the ability to master an interconnected environment. Understanding concepts in various scientific disciplines is a valuable asset in this industrial era 4.0, surpassing the advantage of being a specialist expert in just one field.[84] The rapidly developing digital era also requires someone to have agility, namely the ability to compete and develop by responding to changes and emerging market opportunities through innovative solutions.[75,84] Training instructors must also have several other technical and non-technical skills and knowledge besides cognitive knowledge. Competencies such as quickly adapting and collaborating in a multicultural environment, willingness to continue learning and developing oneself, professionalism, problem-solving abilities, knowledge and skills related to security, good analytical skills, having emotional intelligence such as self-awareness and self-emphatic, as well as being literate and interactive with digital technology are the competency assets that instructors who work in the Industrial era 4.0 must have.[85,86]

Instructors need to comprehensively understand various aspects related to the development of Industry 4.0.[28] The first aspect is related to industrial management in the context of the Industrial Era 4.0. Skills in this aspect include the ability to discuss the relevance of agile project management in the context of Industry 4.0, the ability to identify performance indicators in the field of quality management in the context of Industry 4.0, the ability to use industrial process modeling tools taking into account intelligent production concepts, the ability to design real-world data analysis systems time, as well as the ability to discuss the impact of Industry 4.0 on quality management. The second aspect is related to optimization and technology in the value chain. Skills in this aspect include the ability to choose appropriate optimization techniques to solve practical problems in industrial applications, use optimization software to solve practical problems in industrial applications, and explain the Sustainable Supply Chain Management (SSCM) model. The third aspect is related to digital manufacturing, which includes the ability to describe the Digital Factory concept, understand the functionality and limitations of currently existing digital technology, determine digital transformation models for industrial case studies, and others. The fourth aspect is innovative product design and development skills, which consist of recognizing the benefits of implementing innovation, analyzing strategic elements of new product innovation, and exploring ideas for product innovation in the context of Industry 4.0. The five aspects of data analysis consist of the ability to describe the Intelligent Decision Support System (IDSS) concept, apply IDSS techniques such as machine

learning to solve industrial problems, and use data visualization techniques in handling big data collections.

Instructors must also understand the business models used in Industry 4.0, general matters related to Industry 4.0, industrial management in the Industrial 4.0 era, the application of optimization and technology in the value chain, digital manufacturing, and innovative product design and development.[28] The instructor's ability to lead is also a consideration in learning in the industrial era 4.0. These leadership competencies include the professional ability to motivate individuals and groups, the ability to support the talents and creativity of others, work with various personality types, the ability to create an environment that can create and develop one's talents, and the ability to maintain relationships with other people.[87] Industrial developments require instructors to have multidisciplinary digital competencies that include attitudes towards digitalization, information literacy, digital problem solving, handling digital devices, application of digital security standards, reflective assessment of one's performance in a digital and interconnected environment, and collaborating through digital communication.[88] Table 6 below summarizes the competencies required by workers in the industry 4.0 era.

Table 6: Industrial Era 4.0 Competencies.

Competency Area	Key Elements
Information, media, and technology literacy	Technology literacy, media, visual, and global awareness.
Digital competency	Data analytics and decision support, machine learning, digital factory concept, Intelligent Decision Support Systems (IDSS).
Life skill and agility	Responsibility, ethics, morality, productivity, flexibility, adaptability and responsiveness to market opportunities.
Innovation and creativity	Curiosity, creativity, risk-taking and the ability to create innovative solutions.
Leadership and team management	Communication, ability to motivate individuals/teams, support creativity, work with different personality types, and build rapport.
Industrial business model knowledge	Industrial automation, digital business model, understanding of agile project management, quality performance indicators, industrial process modeling, and real-time data analysis.

Proposed Competency Framework for IoT Training Instructors

This competency framework was designed as a result of an in-depth literature review to identify the competency needs of IoT training instructors who are able to answer the demands of the digital era and the Industrial Revolution 4.0. The framework offers comprehensive guidance covering seven main domains, namely pedagogy-andragogy strategies, technical proficiency, technology and digital literacy, industrial business management, leadership and team management, life skills, and interdisciplinary skills. Each domain is designed to ensure that instructors not only master technical aspects such as IoT device design, system management, and technology integration, but also possess non-technical skills, including the ability to motivate, innovate, adapt, and collaborate across disciplines.

With this holistic approach, the framework provides a solid foundation for IoT training instructors to face the challenges of the Industrial Revolution 4.0 era, while meeting the need for applicable and competency-based learning. Figure 3 illustrates the proposed competency framework for IoT training instructors.

Pedagogy-Andragogy Strategies: Refers to the instructor's ability to design, implement, and evaluate effective teaching methods according to the needs of the trainees. Pedagogy strategies emphasize formal and structured learning, while andragogy focuses more on adult learning approaches that are oriented towards experience and practical application.

Technical Proficiency: This competency covers the ability to understand and master technical skills such as IoT device design, system management, technology integration, and IoT device troubleshooting. This ensures instructors have deep expertise in core technologies relevant to IoT training.

Technology and Digital Literacy: Refers to the ability to understand, use, and adapt digital technologies effectively in the learning and teaching process. Instructors must be able to utilize software, digital learning platforms, and understand the latest technology trends to support training success.

Industrial Business Management: This competency refers to an understanding of industry dynamics and the ability to manage business aspects related to IoT. This includes project management, market needs analysis, as well as the development of business strategies relevant to IoT technologies.

Leadership and Team Management: Describes the instructor's ability to lead a team, build cooperation, and manage conflict effectively. This competency is essential for creating a collaborative training environment that supports the achievement of common goals.

Life Skills: This competency covers essential non-technical abilities, such as communication skills, adaptability, problem solving, creativity, and critical thinking. These competencies help

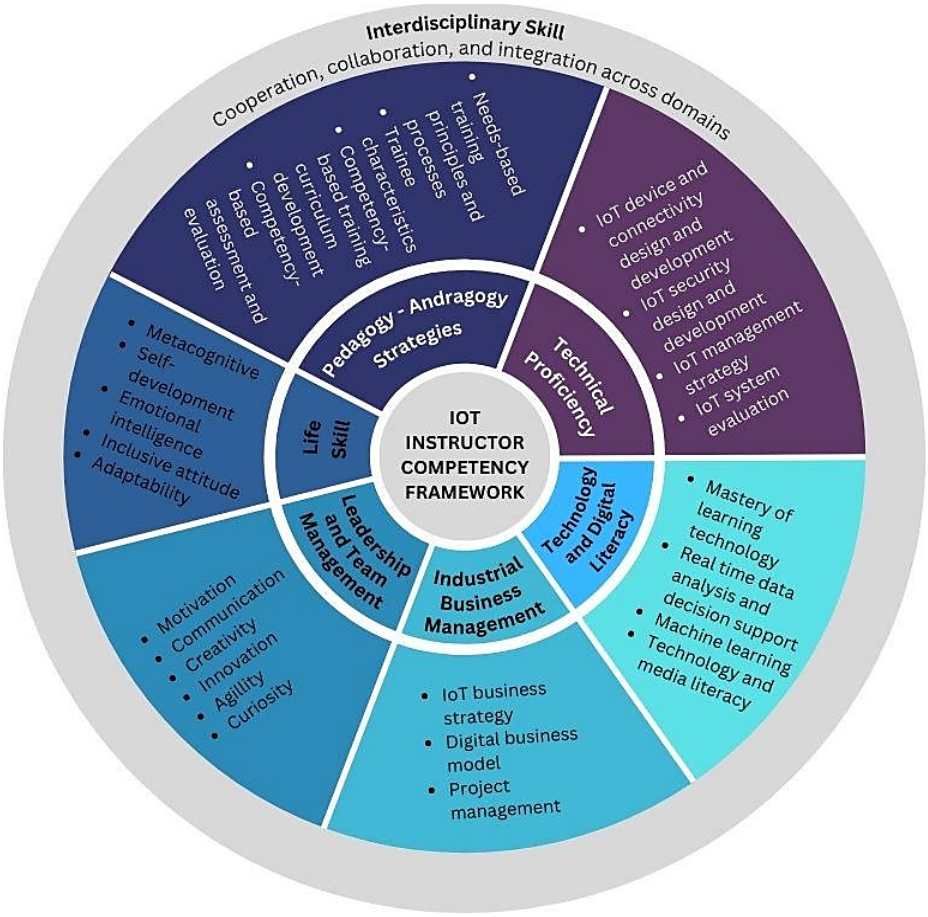

Figure 3: IoT Instructor Competency Framework.

instructors to deal with complex situations and dynamic changes in the Industrial Revolution 4.0 era.

Interdisciplinary Skills: Reflects an individual's ability to interact effectively in a multidisciplinary environment to solve complex problems and produce holistic innovations. This competency demands skills in building interdisciplinary synergies through dynamic cooperation, effective communication, and integration of knowledge and methods from various disciplines. In professional and academic contexts, interdisciplinary skills play an important role in fostering cross-sector collaboration, improving decision-making effectiveness, and enriching perspectives in the analysis and development of solutions. Thus, this competency is a key element in adapting to developments in science and technology that are increasingly integrated and oriented towards a multidimensional approach.

CONCLUSION

Ensuring that IoT training participants receive comprehensive experience and master comprehensive and relevant skills according to industry demands can be done by providing competent instructors. The study results regarding the work qualifications of IoT instructors and workers, discussed in the previous sub-chapter, can be used to conclude the competency qualification requirements for IoT training instructors. Based on the studies that have been carried out, 3 themes of competency needed for IoT training instructors can be summarized as qualifications for IoT training instructors (general competency related to the role of instructor, job-related competencies in the IoT field, and worker competency in the IR 4.0 era). Fulfilling instructor competency requirements can provide significant benefits in training, such as providing in-depth understanding, practical views, and necessary skills to training participants. A strong understanding of the latest developments in IoT technology can enhance an instructor's ability to guide students to understand key concepts, overcome technical challenges, and develop innovative solutions. In addition, competent instructors can also provide insight into the real applications of IoT technology and help participants understand its impact in various industries. Combining technical training and human skills for prospective workers will help them to be better prepared to face the challenges of paradigm changes in the manufacturing industry.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

RECOMMENDATIONS

In further research, validation can be carried out to confirm the findings of literature studies regarding the competency needs of IoT training instructors by involving experts (industry and academics) who have experience and expertise in related fields. Expert validation is needed to provide input on aspects that this research may not fully cover. The involvement of experts will also enrich a broader practical and theoretical perspective on research results so that their contribution to creating a new curriculum can be more relevant and in line with the demands of industry needs and current technological developments. This validation will strengthen the research foundation and provide further confidence that the findings can be applied effectively in education and training. In addition, the need to add references to competency standards required for instructors and workers in the IoT field from other countries also needs to be considered in future research. Comparing and integrating international competency standards will help develop a more comprehensive and globally relevant curriculum. By considering the views and requirements of different countries, this research can produce a more holistic framework, covering various aspects of expertise that are considered important in the IoT industry. Thus, this approach will ensure that the competencies taught are not only in line with the needs of the local job market but can also prepare the workforce to compete effectively in the global market.

REFERENCES

1. Delke V, Schiele H, Buchholz W, Kelly S. Implementing Industry 4.0 technologies: Future roles in purchasing and supply management. Technol Forecast Soc Change. 2023;196:122847.
2. Leong RZL, Tee JJ, Lim LH, Teo S Sen. Decolourization of Crystal Violate and Methylene Blue Wastewater Using Anaerobic Fermented Bio-Waste. Water Conserv Sci Eng. 2023;8(1):15.
3. Mallik AK. The future of the technology-based manufacturing in the European Union. Results Eng. 2023;19:101356.
4. Telukdarie A, Munsamy M, Katsumbe TH, Maphisa X, Philbin SP. Industry 4.0 Technological Advancement in the Food and Beverage Manufacturing Industry in South Africa-Bibliometric Analysis via Natural Language Processing. Information. 2023;14(8):454.
5. Villegas-Ch W, Govea J, Jaramillo-Alcazar A. Tamper Detection in Industrial Sensors: An Approach Based on Anomaly Detection. Sensors. 2023;23(21):8908.
6. Ahmed SF, Alam MS Bin, Hoque M, Lameesa A, Afrin S, Farah T, *et al.* Industrial Internet of Things enabled technologies, challenges, and future directions. Comput Electr Eng. 2023;110:108847.
7. Bhadu J, Bhamu J, Saraswat P. An Analytic Hierarchy Process (AHP) Approach for Prioritizing the Industries 4.0 Technologies (I4.0T). Evergreen. 2023;10(2):667-75.
8. Braumann J, Singline K, Schwab M. Visual Programming for Robot Control: Technology Transfer Between AEC and Industry. In 2024. p. 453-69.
9. Gurukkal R. Digital Influx in Knowledge Fields. High Educ Futur. 2023;10(1):7-10.
10. Rahman MS, Ghosh T, Aurna NF, Kaiser MS, Anannya M, Hosen ASMS. Machine learning and internet of things in industry 4.0: A review. Meas Sensors. 2023;28:100822.
11. Wei X, Zhang J, Conrad AO, Flower CE, Pinchot CC, Hayes-Plazolles N, *et al.* Machine learning-based spectral and spatial analysis of hyper- and multi-spectral leaf images for Dutch elm disease detection and resistance screening. Artif Intell Agric. 2023;10:26-34.
12. Borgosz L, Dikicioglu D. Industrial internet of things: What does it mean for the bioprocess industries? Biochem Eng J. 2024;201:109122.
13. Boyes H, Hallaq B, Cunningham J, Watson T. The industrial internet of things (IIoT): An analysis framework. Comput Ind. 2018;101:1-12.
14. Nuryanto UW, Basrowi B, Quraysin I. Big data and IoT adoption in shaping organizational citizenship behavior: The role of innovation organizational predictor in the chemical manufacturing industry. Int J Data Netw Sci. 2024;8(1):225-68.
15. Sorri K, Mustafee N, Seppänen M. Revisiting IoT definitions: A framework towards comprehensive use. Technol Forecast Soc Change. 2022;179:121623.
16. Sinha S. State of IoT 2023: Number of Connected IoT Devices Growing 16% to 16.7 Billion Globally. 2023. https:/ /iot-analytics.com/number-connected-iot-devices/.
17. Atzori L, Iera A, Morabito G. The Internet of Things: A survey. Comput Networks. 2010;54(15):2787-805.
18. Fareri S, Apreda R, Mulas V, Alonso R. The worker profiler: Assessing the digital skill gaps for enhancing energy efficiency in manufacturing. Technol Forecast Soc Change. 2023;196:122844.
19. Frey CB. The Future of Work: Is This Time Different? In 2020. p. 13-5.
20. Ghobakhloo M. Industry 4.0, digitization, and opportunities for sustainability. J Clean Prod. 2020;252:119869.
21. Střešák D. Workforce Vulnerability Due to Automation and the Importance of Lifelong Learning in the V4 Countries. Sociológia - Slovak Sociol Rev. 2023;55(5):467-95.
22. Caratozzolo P, Mejía-Manzano LA, Sirkis G, Rodriguez-Ruiz J, Noguez J, Membrillo-Hernández J, *et al.* Board 67: A guide for Generation Z students to meet the Future Skills requirements of Industry 4.0 [paper presented]. In: ASEE Annual Conference and Exposition, Baltimore, Maryland [Internet]. 2023 [cited 2023 Dec 23]. Available from: https://peer.asee.org/42895
23. Ismail AA, Hassan R. Technical Competencies in Digital Technology towards Industrial Revolution 4.0. J Tech Educ Train. 2019;11(3):55-62.
24. Kim P. Future Implications of the Fourth Industrial Revolution on Education and Training. In 2020. p. 17-24.
25. Gajek A, Fabiano B, Laurent A, Jensen N. Process safety education of future employee 4.0 in Industry 4.0. J Loss Prev Process Ind. 2022; 75.
26. Sudana IM, Apriyani D, Nurmasitah S. Revitalization of Vocational High School Roadmap to Encounter the 4.0 Industrial Revolution. J Soc Sci Res. 2019;(52):338-42.
27. Crespo R, Lopez-Caudana E, Ponce P. An Immersive Week for Undergraduate Engineering Students for Developing IoT Competencies A Case Study at Tecnologico De Monterrey in Mexico. In: 2019 IEEE 11th International Conference on Engineering Education (ICEED). IEEE; 2019. p. 90-5.
28. Lima RM, Sousa RM, Costa L, Jesus C, Mesquita D, Kengpol A, *et al.* Analysis of Teachers' Competences for Industry 4.0 Subjects: A Case of Thai Higher Education Institutions. Appl Sci Eng Prog. 2022.
29. Ana A, Kustiawan I, Ahman E, Zakaria S, Muktiarni M, Dwiyanti V, *et al.* Defining Vocational Teacher Competencies in Industry 4.0 from the Perspective of Teachers and Lecturers. J Eng Educ Transform. 2022; 35(Special Is):39-46.
30. Moreira Choez J, Milene L, Alejandra OC, Denys MM. Valorando el futuro de la educación: Competencias Digitales y Tecnologías de Información y Comunicación en Universidades. 2024;
31. Diao J, Hu K. Preparing TVET Teachers for Sustainable Development in the Information Age: Development and Application of the TVET Teachers' Teaching Competency Scale. Sustainability. 2022;14(18):11361.
32. Vovk MP, Sotska HI, Trynus O V., Muzyka OJ. Assessment of Instructors' Technology Competency to be Used in the Settings of Formal and Non-Formal Education. Int J High Educ. 2019;8(5):29.
33. Sudira P. TVET ABAD XXI: Filosofi, Teori, Konsep, dan Strategi Pembelajaran Vokasional. 2nd ed. Vol. 2. Yogyakarta: UNY Press; 2017. 1-295 p.
34. Souza ASC de, Debs L. Identifying Emerging Technologies and Skills Required for Construction 4.0. Buildings. 2023 Oct 7;13(10): 2535.
35. Fitsilis P, Tsoutsa P, Gerogiannis VC. Industry 4.0: Required Personnel Competences. In 2018 [cited 2023 Dec 20]. p. 130-3. Available from: https://stumejournals.com/journals/i4/2018/3/130.full.pdf
36. Pati D, Lorusso LN. How to Write a Systematic Review of the Literature. HERD Heal Environ Res Des J. 2018;11(1):15-30.
37. Carrera-Rivera A, Ochoa W, Larrinaga F, Lasa G. How-to conduct a systematic literature review: A quick guide for computer science research. MethodsX. 2022;9:101895.
38. Mengist W, Soromessa T, Legese G. Method for conducting systematic literature review and meta-analysis for environmental science research. MethodsX. 2020;7:100777.
39. Dewan Perwakilan Rakyat Republik Indonesia (DPR-RI), Presiden Republik Indonesia. Undang-Undang Republik Indonesia No. 20 Tahun 2003 Tentang Sistem Pendidikan Nasional [Internet]. 20 Indonesia: 2003 p. 1-57. Available from: https://pusdiklat.perpusnas.go.id/regulasi/download/6
40. Thanasi-Boçe M. The Role of the Instructor, Motivation, and Interaction in Building Online Learning Satisfaction during the COVID-19 Pandemic. Electron J e-Learning. 2021;19(5):401-15
41. Menpan Reformasi Birokrasi (Menpan RB). Peraturan Menteri Pendayagunaan Aparatur Negara dan Reformasi Birokrasi Republik Indonesia Nomor 47 Tahun 2021 Tentang Standar Kompetensi Jabatan Fungsional Instruktur. Available from: https://peraturan.go.id/id/permenpanrb-no-47-tahun-2021
42. Kementerian Pendidikan dan Kebudayaan (Mendikbud). Peraturan Menteri Pendidikan dan Kebudayaan No 90 tahun 2014 Tentang Standar Kualifikasi dan Kompetensi Instruktur Pada Kursus dan Pelatihan. Available from: https://peraturan.go.id/id/permendikbud-no-90-tahun-2014

43. IBSTPI. International Board of Standards for Training, Performance, and Instruction (IBSTPI) - Instructor Competencies 2021. Availabl e from: https://ibstpi.org/competency-sets-services/instructor-competencies/
44. Nader Ganayem A, S Zidan W. 21st Century Skills: Student Perception of Online Instructor Role. Interdiscip J e-Skills Lifelong Learn. 2018;14:117-41
45. Sartori R, Tacconi G, Caputo B. Competence-based analysis of needs in VET teachers and trainers: an Italian experience. Eur J Train Dev. 2015;39(1):22-42
46. Liu X, Bonk CJ, Magjuka RJ, Lee S hee, Su B. Exploring Four Dimensions of Online Instructor Roles: a Program Level Case Study. Online Learn. 2019;9(4)
47. Dimitrov N, Haque A. Intercultural teaching competence: a multi-disciplinary model for instructor reflection. Intercult Educ. 2016;27(5):437-56
48. Polikarpus S, Luik P, Poom-Valickis K, Ley T. The Role of Trainers in Implementing Virtual Simulation-based Training: Effects on Attitude and TPACK Knowledge. Vocat Learn. 2023;16(3):459-86
49. Arifin Z, Nurtanto M, Kholifah N, Nurhaji S, Warju W. The technology andragogy work content knowledge model framework on technical and vocational education and training. J Educ Learn. 2020;14(3):442-8
50. Knowles MS. The Modern Practice of Adult Education: From Pedagogy to Andragogy [Internet]. New York: Cambridge The Adult Education Company; 1980. 1-390 p. Available from: https://www.umsl.edu/~henschkej/articles/a_The_ Modern_Practice_of_Adult_Education.pdf
51. Niksadat N, Rakhshanderou S, Negarandeh R, Ramezankhani A, Farahani AV, Ghaffari M. Concordance of the cardiovascular patient education with the principles of Andragogy model. Arch Public Heal. 2022;80(1):4
52. Afacan E, Onağ Z, Özçelik İY. Being an ethical model: The perspectives of trainers. Int J Curric Instr [Internet]. 2022;14(3): 2034-55. Available from: https ://eric.ed.gov/?id=EJ1364297
53. Rofiq Z, Surono S, Bruri Triyono M, Setiyo Hari Purwoko B. Developing the Standard Competencies for Vocational Teacher Candidates of Mechanical Engineering. J Phys Conf Ser. 2019;1273(1):012032
54. Martin F, Kumar S, She L. Examining Higher Education Instructor Perceptions of Roles and Competencies in Online Teaching. Online Learn. 2021;25(4)
55. Hill J, Berlin K, Choate J, Cravens-Brown L, McKendrick-Calder L, Smith S. Emotions Experienced by Instructors Delivering Written Feedback and Dialogic Feed-Forward. Teach Learn Inq. 2023; 11
56. Scheirlinckx J, Van Raemdonck L, Abrahams L, Teixeira KC, Alves G, Primi R, *et al.* Social-emotional skills of teachers: Mapping the content space and defining taxonomy requirements. Front Educ. 2023; 8
57. Northup J. Strategies to Develop Skills for Positive Training Transfer. Adult High Educ Alliance [Internet]. 2018 [cited 2023 Dec 24]; Available from: https://eric.ed.gov/?id =ED590264
58. Hartley JR, Brown HQ. Competency Model Development for Online Instructors. Online J Distance Learn Adm [Internet]. 2022 [cited 2023 Dec 24]; 25(4). Available from: https ://ojdla.com/articles/competency-model-development-for-online-instructors
59. Niksadat N, Ghaffari M, Ramezankhani A, Rakhshanderou S, Farahani AV, Negarandeh R. Experiences of patient education among people affected by cardiovascular disease: a qualitative study based on Andragogy model. BMC Health Serv Res. 2023;23(1):708
60. Kanwar A, Balasubramanian K, Carr A. Changing the TVET paradigm: new models for lifelong learning. Int J Train Res. 2019; 17(sup1):54-68
61. Andoh RPK, Mensah DY, Owusu EA. Trainers' pedagogical competencies and trainees' assimilation of training content. J Work Learn. 2022;34(2):133-49
62. Paśko Ł, Mądziel M, Stadnicka D, Dec G, Carreras-Coch A, Solé-Beteta X, *et al.* Plan and Develop Advanced Knowledge and Skills for Future Industrial Employees in the Field of Artificial Intelligence, Internet of Things and Edge Computing. Sustainability. 2022;14(6):3312
63. Kementerian Tenaga Kerja (Kemnaker). Keputusan Menaker Nomor 300 Tahun 2020 tentang Penetapan Standar Kompetensi Kerja Nasional Indonesia Kategori Informasi dan Komunikasi Golongan Pokok Telekomunikasi Bidang Internet of Things 2020. Available from: https://jdih.kemnaker.go.id/ katalog-1980-Keputusan Menaker.html.html
64. Bhutan Qualifications and Professionals Certification Authority. National Competency Standards for Internet of Things (IoTs) Technician [Internet]. Bhutan; 2023 Feb [cited 2023 Dec 6]. Available from: https://www.blmis.gov.bt/tvet/MyDocument//2023/12 7120427IOT NCS2023-3.pdf
65. training.gov.au. ICTCYS609 - Evaluate threats and Vulnerabilities of IoTs Devices [Internet]. 2020 Jun [cited 2024 Feb 6]. Available from: https://training.gov.au/Trai ning/Details/ICTCYS609
66. training.gov.au. ICTIOTS502 - Program IoTs Devices [Internet]. 2020 Jun [cited 2024 Feb 6]. Available from: https://training.gov.au/Training/Details/ICTIOT502
67. training.gov.au. ICTIOTS503 - Design and Test IoTs devices and Networks [Internet]. 2020 Jun [cited 2024 Feb 6]. Available from: https://training.gov.au/Training/Details /ICTIOT503
68. Joeng ME, Yu SJ. A Study on the Strategy of IoT Industry Development in the 4th Industrial Revolution: Focusing on the Direction of Business Model Innovation. J Intell Inf Syst. 2019;25(2):57-75
69. Chehri A, Zimmermann A, Schmidt R, Masuda Y. Theory and Practice of Implementing a Successful Enterprise IoT Strategy in the Industry 4.0 Era. Procedia Comput Sci. 2021;192:4609-18
70. Madakam S, Ramaswamy R, Tripathi S. Internet of Things (IoT): A Literature Review. J Comput Commun. 2015;03(05):164-73
71. Abbas M. A List of Skills Required for Internet of Things (IoT) Talent [Internet]. 2021 [cited 2023 Dec 23]. Available from: https://iotworld.co/2021/12/a-list-of-skills-required-for-internet-of-things-iot-talent/
72. Uviase O, Kotonya G. IoT Architectural Framework: Connection and Integration Framework for IoT Systems. Electron Proc Theor Comput Sci. 2018;264:1-17
73. The OWASP IoT Security Team. https://owasp.org/www-pdf-archive/OWASP-IoT-Top-10-2018-final.pdf. 2018. OWASP Internet of Things Top 10.
74. OWASP. IoT Security Verification Standard-ISVS [Internet]. 2022 [cited 2023 Dec 24]. Available from: https://github.com/OWASP/IoT-Security-Verification-Standard-ISVS
75. Sánchez J, Mallorquí A, Briones A, Zaballos A, Corral G. An Integral Pedagogical Strategy for Teaching and Learning IoT Cybersecurity. Sensors. 2020;20(14):3970
76. Miloslavskaya N, Tolstoy A. State-Level Views on Professional Competencies in the Field of IoT and Cloud Information Security. In: 2016 IEEE 4th International Conference on Future Internet of Things and Cloud Workshops (FiCloudW). IEEE; 2016. p. 83-90
77. softwareag.com. https://www.softwareag.com/en_corporate/resources/iot/article/ iot-device-management.html. 2022. What is IoT Device Management?
78. Vishwakarma NK, Singh RK, Sharma RRK. Internet of things architectures: do organizational strategies matters? Bus Process Manag J. 2019;26(1):102-31
79. Diène B, Rodrigues JJPC, Diallo O, Ndoye EHM, Korotaev V V. Data management techniques for Internet of Things. Mech Syst Signal Process. 2020 Apr;138: 106564
80. Ramachandran, K.K., Kumar, M.S., Singh, R., Barve, A., Pillai, B.G. and Gonzáles, J.L.A., 2023, March. Internet of Things (IoT) Exploratory Analysis in Strategic Management. In 2023 10th International Conference on Computing for Sustainable Global Development (INDIACom) (pp. 1161-1166). IEEE.
81. Microsoft. Evaluating Your IoT Security [Internet]. 2017 [cited 2023 Dec 23]. p. 1-15. Available from: https://download.microsoft.com/download/D/3/9/D3948E3C-D5DC -474E-B22F-81BA8ED7A446/Evaluating_Your_IOT_Security_whitepaper_EN_US.pdf
82. Gupta M, Jauhar SK. Digital innovation: An essence for Industry 4.0. Thunderbird Int Bus Rev. 2023;65(3):279-92
83. Meirawan D, Dwiyanti V. Character of Industrial 4.0 Skilled Workers. Int J Eng Technol. 2018; 7(4.33):166-70
84. Szabó P, MÍkva M, Marková P, Samáková J, Janík S. Change of Competences in the Context of Industry 4.0 Implementation. Appl Sci. 2023;13(14):8547
85. Flores E, Xu X, Lu Y. Human Capital 4.0: a workforce competence typology for Industry 4.0. J Manuf Technol Manag. 2020;31(4):687-703
86. Kannan KSPN, Garad A. Competencies of quality professionals in the era of industry 4.0: a case study of electronics manufacturer from Malaysia. Int J Qual Reliab Manag. 2020;38(3):839-71
87. Čermáková J, Houda M, Rolínek L, Pech M. Perception of the Leadership Competency in the 4th Revolution Era in the Czech Republic. Manag Prod Eng Rev. 2023; 3-12
88. Roll MJJ, Ifenthaler D. Multidisciplinary digital competencies of pre-service vocational teachers. Empir Res Vocat Educ Train. 2021;13(1):7

Cite this article: Milansari IL, Sudira P, Dinata C. Exploring the Competency Needs of Internet of Things (IoT) Training Instructors: A Systematic Literature Review. J Scientometric Res. 2025;14(3):876-88.