CHAPTER IV
RESULTS AND FINDINGS

In this section of study, the author will delineate the results that will be divided by its research problems. The results and findings will be divided into three big sections. It begins with the preliminary studies, qualitative findings, and quantitative results.

4.1 How does the existing literature define digital competence in vocational education and for educators?

In the section, the author will determine the result from the 238 datasets retrieved from Scopus database. The results provide the aspects based on the following constructed research questions:

4.1.1. The Distribution of Publications in Vocational Educators Digital Competence

1) Documents by Year

In 2022, there was a notable rise in research publications on the digital competence of vocational education. The first systematic records appeared in 2000, marking the start of scholarly interest in this area. From 2000 to 2014, publications were relatively few, with a peak of eight in 2014, which was also the busiest year. Since the Fourth Industrial Revolution and rapid technological progress, research on digital skills among vocational high school students has steadily and significantly grown over the past decade, starting in 2015 and continuing through 2022. By 2019, the number of publications had increased to several dozen, with 26 in that year alone. In 2021, journal articles and conference papers together reached a record high of 61 publications, showing substantial growth in scholarly output in this field.

This phenomenon may be attributed to heightened concerns regarding the reimagining of vocational education within the framework of the Sustainable

Development Goals for 2030 (SDGs 2030). Recent scholarly investigations have underscored the integration of digital competence into school curricula as a prominent emerging trend, particularly within the context of engineering vocational education. Evidence of this can be seen in the Scopus database, which cataloged a total of 161 documents pertaining to digital competence analysis and developments in engineering education. Furthermore, a considerable body of literature addresses issues such as digital readiness, ICT integration, and the challenges associated with hybrid and blended learning modalities—topics that necessitate significant adaptation and recalibration by both educators and students to thrive in the digital era.

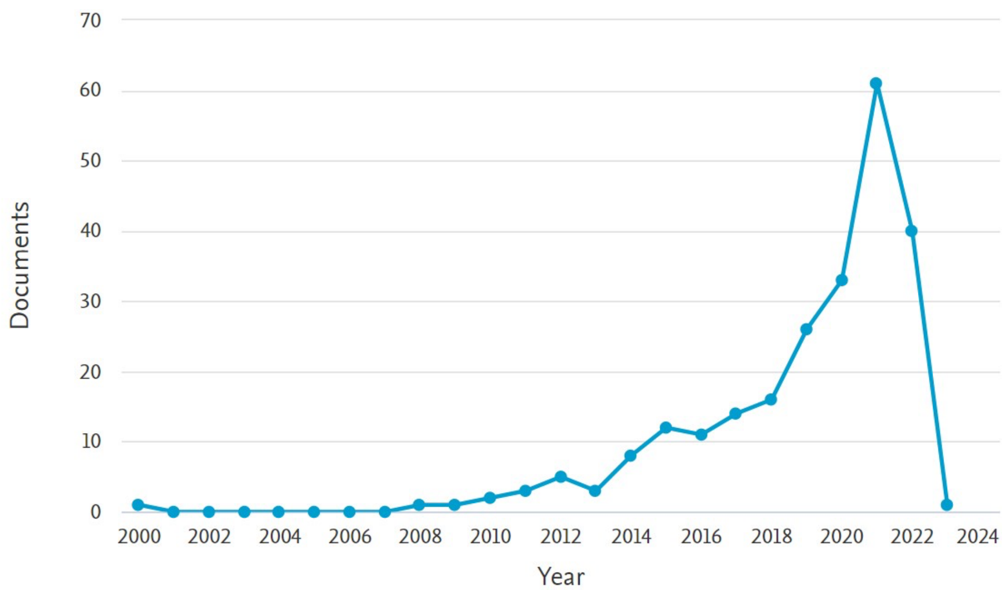


Figure 4.1 Documents' Distribution by Year

2) Documents by Country

The author conducted an analysis of countries listed in the Scopus database, focusing on the volume of scholarly publications. The findings reveal that Spain ranks first in research output concerning the digital competence of vocational educators, with 34 related documents in vocational education. Prior research indicates that both Spain and the United Kingdom—aligning with the United States in publication volume—serve as key regions for the development of digital competence. Furthermore, these countries are utilizing the DigCompEdu framework, an initiative funded by the European Commission, to assess and enhance digital skills (Redecker, 2017). The Russian Federation has been identified as the location of the second largest repository of documents pertaining to digital competence, with a total of up to 19 documents documented. Following Russia, several other prominent countries—namely Germany, the United States, the United Kingdom, Australia, the Czech Republic, Finland, and Greece—exhibit significant research activity in this domain. Notably, Indonesia is unexpectedly ranked among the top three countries in terms of research output on digital competence, despite most countries with extensive documentation being situated in Europe. Specifically, there are 16 documents that examine the digital competence of vocational educatora in Indonesia.

3) Documents by type

The exponential growth of academic publications over recent years has resulted in a notable phenomenon of informational overload among scholars, who are increasingly challenged by the overwhelming volume of published research within their respective fields. This surge in publications, which encompasses not only journal articles and conference papers but also a diverse array of other document types available in the Scopus database, underscores the complexity of scholarly communication. To address this issue, an analysis was conducted to evaluate the distribution of various document types pertinent to the subject of digital competence, with the objective of identifying publications that significantly contribute to this field. To comprehensively assess the dissemination of scholarly work, the search strategy deliberately encompassed all document types without imposing any restrictions on the scope, thereby ensuring a broad and inclusive retrieval of relevant literature.

According to the data, conference papers are among the most authoritative sources cited by scholars following journal articles when drafting manuscripts or conducting research analyses. The Scopus database categorizes six types of documents: conference papers (146 documents), journal articles (84 documents), conference reviews (7 documents), book chapters (5 documents), and data papers (1 document). Based on this analysis, it can be concluded that the most prevalent type of article related to advanced digital competence within Scopus is the conference proceeding, which accounts for approximately 59.8% of citations. Furthermore, journal articles constitute the second most frequently cited document type, representing 34.4% of the total citations.

4.1.2. The Bibliometrics Analysis of Emerging Trends

1) Co-occurrence Analysis

The analysis was initiated using VOSviewer, whereby the author conducted an examination of all keywords' co-occurrences within the Scopus dataset. The use of the 'all keywords' analysis was deliberate, aiming to provide a comprehensive overview of the research related to digital competence among VHS teachers. Figure 4.2 (Co-occurrence Based on All Keywords Analysis) presents the results, highlighting the most frequently used and studied keywords associated with digital competence in VHS.

The author observed from the figure that the analysis identified nine distinct clusters, each demarcated by a specific color: yellow, sea-blue, dark-blue, green, pink, red, purple, orange, and brown. Notably, the concepts of "Digital Competence" and "Vocational Education" are prominently situated within the red cluster, which also includes the most frequently occurring term, "Engineering Education," predominantly associated with the green cluster. These terms represent some of the most salient keywords within the dataset, each appearing more than twenty times—specifically, "Digital Competence" occurring up to twenty-nine times and "Engineering Education" up to one hundred and sixty-one times. Despite the higher frequency of "Engineering Education," its total link strength exceeds that of "Vocational Education," with values reaching up to 1,182. Conversely, the total link strength of "Digital Literacy" surpasses that of "Digital Competence," with a cumulative value of up to 245. These findings suggest complex interrelations among these key concepts within the dataset.

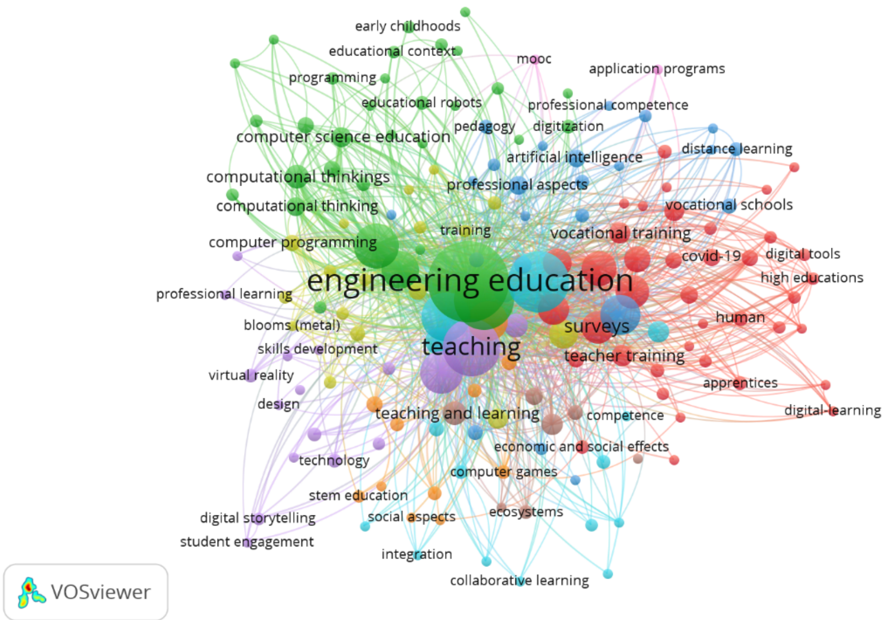


Figure 4.2 Network Visualization of Co-occurrence Analysis

To this end, the author employed Overlay Visualization to depict the existing research landscape on digital competence within vocational high schools. The visualization indicated that recent studies predominantly focus on engineering education linked with e-learning, digital literacy, digital competence, distance learning, pedagogy, and curriculum development. This suggests that engineering education significantly influences research directions in digital competence, given its importance for future-qualified education. A review of previous literature further reveals that most research related to digital literacy and competence in higher education aims to assess the levels of digital literacy and competence among teachers and students to ensure their readiness. As the pandemic gradually subsides, future research should explore strategies for preparing educators to meet the challenges of rapidly advancing technology, thereby contributing to the realization of a 'Knowledge Society." Additionally, the COVID-19 pandemic serves as a valuable lesson to foster ongoing digital literacy development among both teachers and students.

2) Co-authorship based on Organization

Organization or affiliation plays a crucial role in scholarly publications, particularly in the context of collaborative research. This analysis utilized VOSviewer to quantify citations and total publication outputs. Among 415 organizations evaluated, 117 organizations met the minimum threshold of producing at least one document and receiving five citations. The results indicated that the highest citation counts were associated with three affiliations: Nanhua University, National Quemoy University, and Southern Taiwan University, each amassing a total of 116 citations from a single document. The European Commission followed with a total of 52 citations derived from a single document. Conversely, the affiliation with the highest volume of publications only accumulated 20 citations. Notably, the analysis revealed that the author with the most extensive collaboration network did not correspondingly possess a high citation count. This suggests that, within this context, collaborative engagement does not necessarily correlate with increased citation impact.

3) Bibliographic Coupling based on Citing Source

In the final segment of the bibliometric mapping process, we conducted an analysis of sources—specifically publications—that cite other sources, forming a bibliographic coupling network, as well as the most frequently cited sources, represented through a co-citation network. These visualizations directly address our previous research question by elucidating the relationships between citing and cited sources. These relationships are characterized by various similarities and differences, which are elaborated upon in the subsequent paragraphs. (Fig. 4.3)

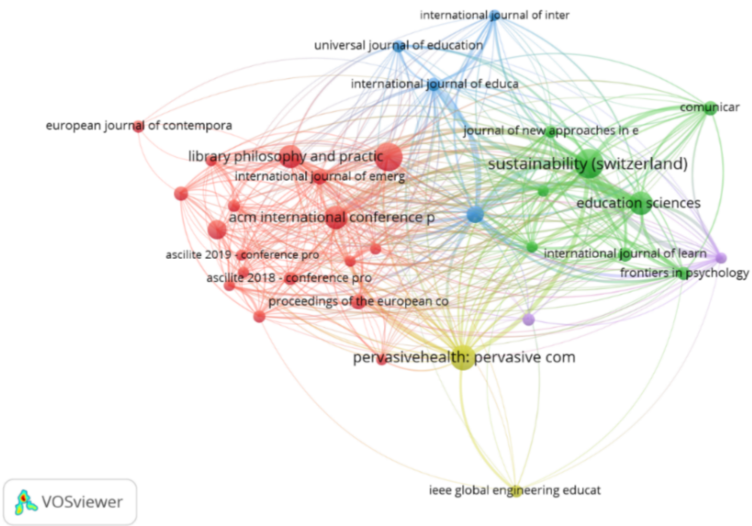


Figure 4.3 Bibliographic Coupling Analysis

Figure 4.3 depicts a bibliographically coupled network, where journals function as pivotal elements within various clusters and are designated as core publications. These journals exert a substantial influence on the citation metrics of other scholarly works. Multiple distinct clusters are identifiable; notably, the Sustainability cluster (highlighted in green), which encompasses publications related to Switzerland, demonstrates a pattern of co-citation both within its own cluster and with external groups.

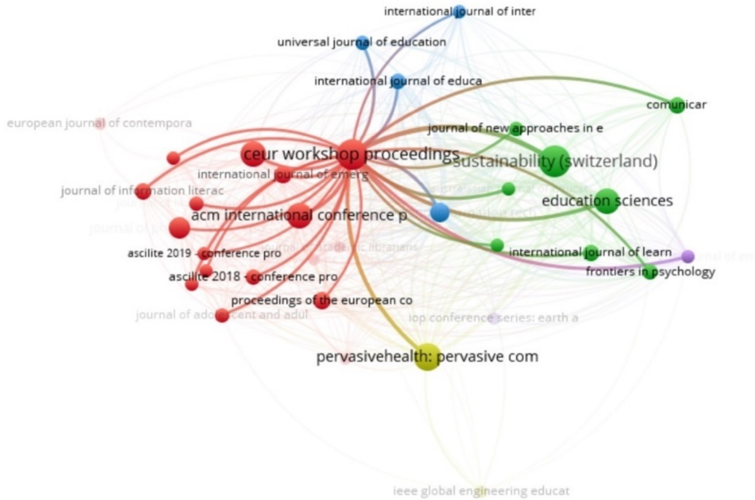


Figure 4.4 Ceur workshop proceedings related clusters

Additionally, Figure 4.4 illustrates that proceedings from the Central Europe (CEUR) Workshop (marked in red) exhibit pronounced co-citation relationships. The spatial proximity of these two clusters indicates a significant interconnectedness in their citation practices.

The smaller purple cluster is characterized by a more dispersed and less substantial composition compared to the larger yellow cluster, primarily due to its limited number of records, totaling only five documents and five clusters. Within the dataset, sustainability emerges as the most prominently represented topic across all publications. Notably, an identifiable international journal of environment cluster (purple) exists distinctly from the other clusters, despite the presence of interconnecting lines that suggest potential links. The weak connections and the spatial separation observed between the yellow and blue clusters and the purple cluster further imply limited convergence and minimal exchange of information among researchers in these respective fields.

Table 4.1 Co-cited documents based on Bibliographic Coupling

Source	Documents	Citations

Sustainability (Switzerland)	35	241
Ceur workshop proceedings	33	85
Pervasivehealth: pervasive computer	26	63
Education sciences	23	54
Acm international conference proceeding	23	27

4) Co-citation network based on cited sources analysis

The figure 4.5 illustrates a co-citation network based on cited sources. Two publications are considered co-cited within this network if a third publication cites both. The visualization reveals several clusters exhibiting similar co-citation patterns. Consistent with the previous analysis of citing sources (Fig. 4.3), the network is predominantly composed of scholarly journals. Conference proceedings are minimally cited and are therefore not represented in this figure. Notably, the yellow cluster is predominantly occupied by the journal, acknowledged once again as the most influential publication within the network. Additionally, a distinct blue cluster comprises co-cited journals related to computers in Human Behaviour, and this cluster exhibits close connections to the computers and Education cluster.

Additionally, a smaller (purple) cluster corresponding to the 'International Journal of Media' can be observed; however, it remains relatively isolated from other related sources. Notably, an intriguing red cluster comprising journals in science education—such as Sustainability, Computers in Education, and Education Sciences—can be identified. This cluster also encompasses journals addressing psychological topics. Furthermore, a distinct cluster comprising journals dedicated to 'Journalism and Mass Media Communication' emerges.

This cluster appears to be the most isolated, reflecting strong co-citation relationships within the field of 'Journalism and Mass Communication,' but weak co-citation links with other clusters. Despite this, it maintains a connection solely with the red cluster. In contrast, the remaining clusters are positioned in closer proximity, indicating a higher degree of relatedness in their citation patterns.

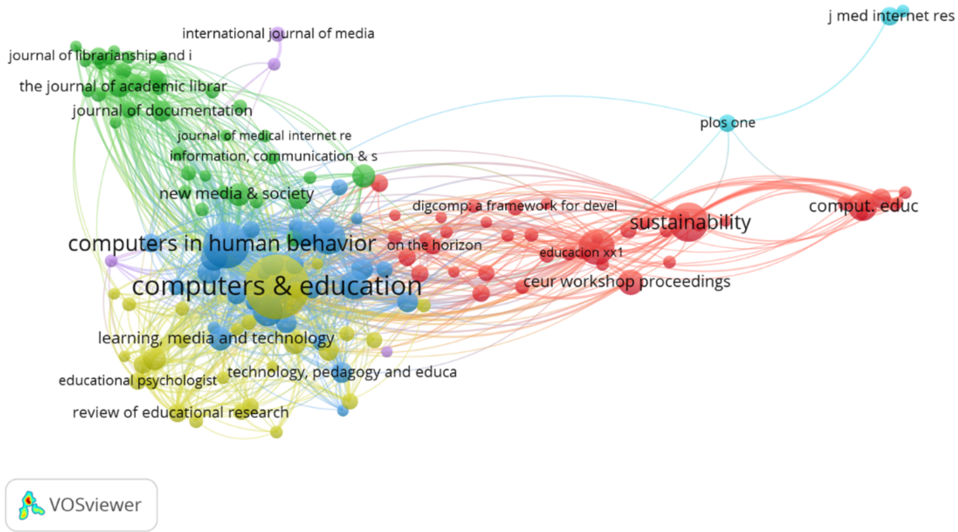


Figure 4.5 Co-citation based cited source analysis

The following is a summarized presentation of the similarities and differences observed between clusters of citing and cited sources, emphasizing their respective characteristics.

a. The journal ‘Computers & Education’ is the most frequently cited source in this field of study. Nonetheless, the journal ‘Sustainability’ is the most frequently citing source, and both journals have a significant impact on different analyses—‘Computers & Education’ as the influential cited source and ‘Sustainability’ as the stimulating citing source.
b. Sources that are frequently cited differ from those that frequently cite others; however, both citing and cited sources are predominantly contributed by journals, as evidenced by the citation analysis.

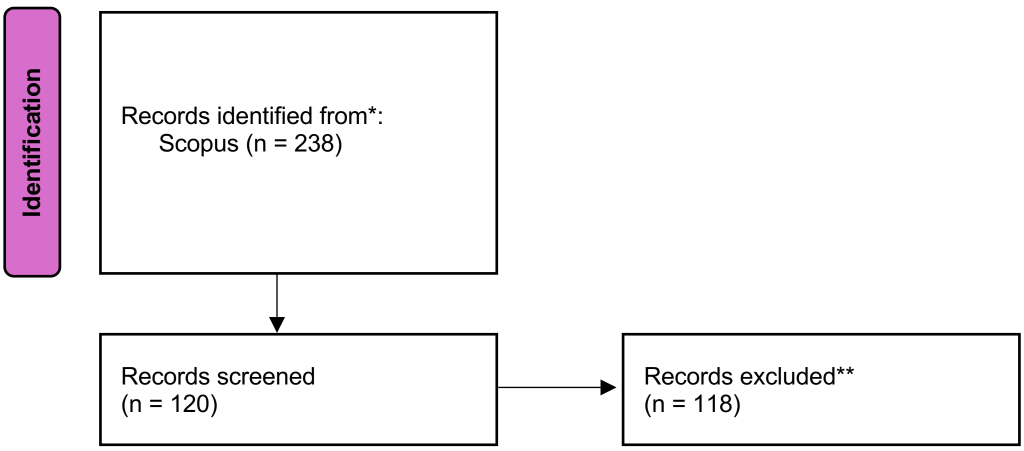
c. The sources cited can be categorized into three distinct clusters, two of which are contiguous, suggesting analogous patterns of citation.
d. The referenced sources can be categorized into several discrete clusters; the majority of these clusters, though distinct, exhibit a notable association with either ‘Computers & Education’ or ‘Sustainability’.

4.1.3. A Literature development based on Systematic Literature Review

In the results part, the researcher would equip the research questions with some answers obtained from the process of literature reviews. The phase of answering research questions would be constructed as the following lists.

1) What is the most suggested way of enhancing Vocational High School teachers’ digital competence?

Enhancing teachers’ digital competence in the digitization era has been high and is a concern. Related to the way of enhancing teachers’ digital competence, some of the studies had conducted research using several designs. Those research designs include experimental, quasi-experimental, or suggestion studies to level up the teachers' and students' digital literacy. it has been implemented at higher education levels, such as providing opportunities for the students to engage more in online learning platforms (Haluk Sivrikaya, 2020) and Self-Regulated Learning Strategies (SLRS) for teachers (Anthonysamy et al., 2020a).



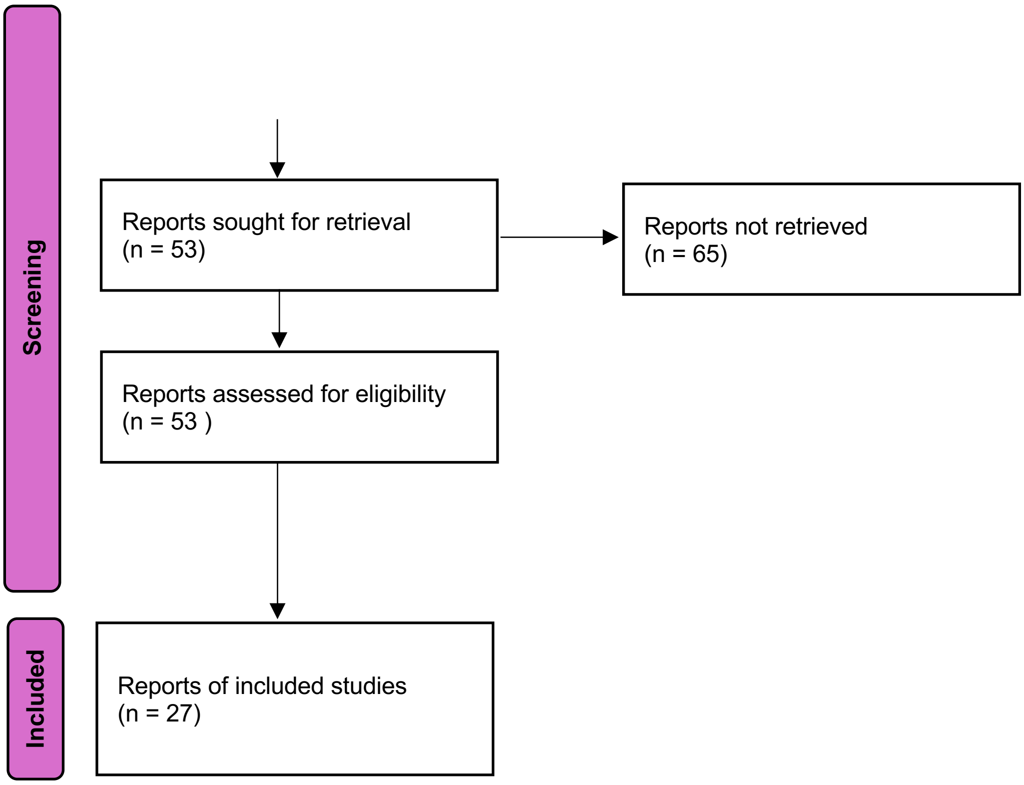


Figure 4.6 PRISMA Flow

Therefore, in this study, the researcher lightened up the further suggestion which might be implemented to enhance teachers' digital competence in vocational high schools. Twenty-four selected articles out of 30 brought up some suggestions on how to enhance the teachers' digital competence after measuring their level. There are several strategies to enhance teachers' digital competence. However, the most suggested way is conducting a further training program which could be organized by the school or governance (Astuti et al., 2021; Cattaneo et al., 2022b; Dias-Trindade et al., 2021; Fraile et al., 2018; Gómez-Trigueros et al., 2019; Guillén-Gámez et al., 2021a; Jiménez-Hernández et al., 2020a; Kurnianingsih et al., 2017; Liu et al., 2020; Portillo et al., 2020a; Sánchez-Cruzado et al., 2021; Sánchez-Prieto et al., 2021; Zakharov et al., 2022).

Additionally, other ways of leveraging teachers' digital competence in vocational high schools are providing study programs or related courses for the teachers (Záhorec et al., 2019), requiring teachers to practice working with application systems used in online learning such as Learning Management System (LMS) (Záhorec et al., 2021), implementing the digital curriculum in schools (Leary et al., 2016), having digital regional school agendas (Diz-Otero et al., 2022; Quaicoe & Pata, 2020), implementing an educational video game for developing teachers' digital competence (Gordillo et al., 2021), and conducting the standardized evaluation which could certify the teachers' digital competence (Hossein-Mohand et al., 2021).

2) What are the majority of factors that affect teachers' digital competence in vocational high school?

Teachers' exposure to using digital tools could exactly affect their perception of new technologies and influence their optimism about using digital tools (Tomczyk et al., 2021). 20 out of 30 articles mentioned the following aspects which could affect vocational high school teachers' digital competence (Guillén-Gámez et al., 2021a; Lucas et al., 2021a; Saikkonen & Kaarakainen, 2021a; Saripudin et al., 2019b). Explicitly stated that age is the most influenced factor in teachers' digital literacy. Summarizing from the analyzed articles, the followings are the lists of factors that could affect teachers' level of digital literacy.

a. Years of working, the previous authors mainly stated based on their research results that the years of working have been one of the crucial factors in teachers' digital literacy. The teacher who has many years of working experience indicated a higher level of digital literacy (Benali et al., 2018; Saikkonen & Kaarakainen, 2021a; Sánchez-Cruzado et al., 2021).
b. The teachers' digital activity. One of the studies analyzed that the teacher's digital activity could affect their ability to use digital tools. The more frequently teachers use digital tools, the more competence of teacher's digital ability (Saikkonen & Kaarakainen, 2021a).

c. Information literacy. This study revealed that information literacy (as one of the core competencies in digital literacy) impacts digital literacy ability. Individuals who frequently utilize digital tools will be used to some digital tools and could quickly master the new digital tools (Gündüzalp, 2021a).
d. However, digital literacy is hard to be improved if the individual does not have any confidence in starting to learn or master and evaluate the digital tools. Therefore, Digital confidence is the core key to teachers' digital literacy (Benali et al., 2018; Lucas et al., 2021a).
e. Gender. There are lots of prior studies that examined teachers' digital literacy based on gender, and many results showed that the male's ability is higher than the female's digital literacy (Ata & Yildirim, 2019; Guillén-Gámez et al., 2021a; Lucas et al., 2021a; Mynaříková & Novotnỳ, 2020; Pérez-Navío et al., 2021; Portillo et al., 2020b; Potyrała & Tomczyk, 2021). However, some studies also stated that gender is not one of the factors affecting teachers' digital literacy (Ngabiyanto et al., 2021).
f. Age. The age factor in influencing someone's digital literacy is commonly used. It is scrutinized that the elderly teacher has lower digital literacy than the young teacher (Guillén-Gámez et al., 2021b; Lucas et al., 2021b; Mynaříková & Novotnỳ, 2020; Pérez-Navío et al., 2021; Portillo et al., 2020b; Saikkonen & Kaarakainen, 2021b; Saripudin et al., 2021b; Sundqvist et al., 2021).
g. School subject. The demand for utilizing digital technology tools in teaching the students is sharply increasing, especially when the pandemic COVID-19 hit all countries. Each different school subject has its demands and needs in implementing digital tools. The English subject will have a piece of different teaching equipment from the machine engineering subject (Tomczyk, 2019a).

h. Workload, attitudes towards technology use, digital tool use frequency, and curriculum support (Cattaneo et al., 2022b). The teachers' workload, attitude, frequency of use, and curriculum support also impact the increase of teachers' digital literacy since those things will increase the teachers' activity frequency in using digital tools.
i. The frequent of tools that are implemented in teaching and learning (Lucas et al., 2021b)
j. The type of school and educational stage affects the teachers' digital literacy, as stated by one of the studies (Portillo et al., 2020b). The study stated that private high schools had scored higher in digital literacy than public schools. Besides, the higher stage of its education, the higher the digital literacy that the teachers possess since the use of digital media will be more advanced.
k. The last factor affecting teachers' digital literacy is teacher educators' efficacy. Moreover, the previous study explained the relation between teachers' digital literacy and self-efficacy. It showed a positive impact between self-efficacy and digital literacy. In reverse, the study stated that technology integration management does not significantly influence on teachers' digital literacy (Instefjord & Munthe, 2017b).

3) What is the majority level of teachers' digital competence in vocational education and what are their concerns in digital competence to be prioritized?

Of the 27 articles reviewed, 25 investigated the level of teachers' digital competence in vocational high schools. Several studies have highlighted specific deficiencies in teachers' digital skills, including issues related to copyright and online information assessment (*ethics in digital utilization*), content creation, problem-solving, and facilitating students' digital literacy needs. However, the extent of these digital competence weaknesses and strengths appears to vary depending on teachers' engagement with digital activities and their access to digital tools within their respective regions.

Furthermore, some prior research examined teachers' digital competence during the COVID-19 pandemic. These studies examined teachers' readiness to implement emergency remote teaching, which required integrating technological tools into the instructional process. Findings from these studies indicate that many teachers received digital competence training only recently, underscoring the importance of implementing such training prior to pandemics or similar emergencies. Digital literacy is fundamental to effective teaching and learning, equipping educators to adapt to unforeseen circumstances and technological demands in educational settings.

This section highlights the significant role of intergenerational collaboration in enhancing self-confidence among senior educators. It acknowledges that while many of these educators recognize their limitations in utilizing emerging digital technologies, engagement with younger, digitally proficient colleagues fosters increased confidence and a more receptive attitude toward technological adoption. In these collaborative interactions, younger teachers frequently act as informal mentors, offering guidance on various digital tools and platforms within a collegial and supportive context.

This reciprocal dynamic benefits both parties: senior teachers gain practical knowledge and reassurance, while younger educators consolidate their skills through teaching and demonstration. Conversely, the absence or resistance to such collaborative exchanges—often stemming from hierarchical norms or reluctance to confront knowledge gaps—can impede the development of teacher confidence. Consequently, intentional and open cross-generational collaboration is imperative for cultivating both technical competencies and self-efficacy among vocational educators.

4) What are the previous prominent frameworks in digital competence for educators?

Moreover, we also reviewed lots of framework of digital competence to be included in this study as the core guideline of instrument. This identification aims to obtain information regarding the dimensions and subdimensions of digital competencies based on a global overview through a literature review of previously used frameworks. Table 4.2 shows 9 documents that have been selected and reviewed in depth.

Tabel 4.2. Nine selected framework based on literatures

No	Framework name	Institutions	Authors	Years	Components
1	DigEuLit	European Commission	Allan Martin	2006	- Digital competence **(Level 1)** - Digital usage **(Level 2)** - Digital transformation **(Level 3)**
2	DigComp 2.0	European Commission	Anusca Ferrari	2013	- Information - Communication - Content Creation - Safety - Problem-solving
3	DigComp 2.1	European Commission	Stephani Carretero	2017	- Information and data literacy - Communication and Collaboration - Digital content creation - Safety - Problem-solving
4	DigCompEdu	European Commission	Christine Redecker	2017	- Professional engagement - Digital resources - Teaching and learning - Assessment - Empowering learners - Facilitating learners' digital competence
5	Common Digital Competence Framework for Teachers	INTEF (Instituto Nacional de Technologias Educativas y de Formacion Del Profesorado / Institute of Educational Technologies and Teacher training)	Ministry of Education and Cultures, Spain	2017	- Information and data literacy - Communication and Collaboration - Digital content creation - Safety - Problem-solving
6	A Global Framework of	UNESCO	Nancy Law	2018	- Information and data literacy

No	Framework name	Institutions	Authors	Years	Components
	Reference on Digital Literacy Skills for Indicator				- Communication and Collaboration - Digital content creation - Safety - Problem-solving
7	Digital Literacy Skills Framework	Australian Government	Philippa McLean	2020	- Digital technologies and systems - Access, organize, present, and problem-solving - Personal and community - Workplace and employment - Education and training
8	Digital Comp 2.2	European Commission	Riina Vuorikari	2022	- Information and data literacy - Communication and Collaboration - Digital content creation - Safety Problem-solving
9	TAWOCK Conceptual Model (Arifin et al., 2020)	International Journal of Evaluation and Research in Education	Arifin et al	2020	- Technology Knowledge - Andragogy Knowledge - Work Knowledge - Content Knowledge

Articles that were declared eligible and selected in detail provide various pieces of information that can be analyzed, such as the highest number of citations, the largest number of documents by year, the field or sector studied, and the country where the research was conducted. Table 4.1 shows the results of identifying nine documents that have been reviewed in more depth; the table also includes information regarding the number of citations. Of the nine articles, the one by author entitled “European framework for the digital competence of educators” has been cited 3988 times. This reference has become a global guide for digital competence for educators. However, there is no new edition of the framework that aligns with the current development of technology.

This literature review emphasizes the need to describe the analysis globally and in depth through bibliometric studies and systematic literature review (SLR) studies. The results show that digital competence in vocational education has been widely discussed, yet the development of a framework that aligns these competencies remains scarce, especially in vocational education.

Moreover, the challenge faced by vocational educators in integrating digital competence with digital teaching and industrial knowledge has become a problem and a gap that needs to be addressed. The literature generally responds that educators have accepted technological development; however, their competence levels are still low and have not been deeply involved in the ethical guidelines of the digital world, especially in teaching.

5) What are the industrial perspective Regarding digital competence in vocational education aligned with industrial development?

In the context of vocational education, the digital competence of teachers is no longer a complementary skill, but a critical necessity directly linked to the demands of the contemporary workforce. The results of this study, when triangulated with insights from expert interviews and FGD sessions, reveal that industry stakeholders strongly perceive a gap between the digital readiness of vocational teachers and the expectations of the industrial sector. As industries continue to evolve under the influence of Industry 4.0—marked by automation, artificial intelligence, data-driven processes, and interconnectivity—their demand for digitally literate workers becomes more pressing. Teachers, in this landscape, are expected to act as the first line of preparation for future technicians, engineers, and digital artisans.

However, this study identifies that vocational educators often face structural and pedagogical challenges in embedding authentic digital practices into their instructional delivery. While the survey scores show relatively high self-perceived competence in dimensions like Digital Ethics and Communication, industry informants question the depth and contextual relevance of these skills in actual practice (Rodzalan et al., 2022; Somantri & Pramudita, 2024). Many vocational teachers, for instance, may be adept at using digital platforms for communication or content delivery, but lack exposure to industrial-grade software, digital diagnostics, simulation tools, and real-time collaborative technologies used in modern workplaces. This mismatch signals a pressing need to redesign vocational teacher training so it emphasizes not just general digital literacy, but field-specific digital fluency that mirrors the technological ecosystems of relevant industries.

Industrial representatives highlight that the ability to troubleshoot, adapt to new tools, analyze digital workflows, and respond to system disruptions is a core skill that determines employability and productivity. This finding reinforces the notion that vocational teachers must not only master tools for teaching but also simulate industry-relevant problem contexts in the learning process. Similarly, the communication dimension—particularly collaborative digital communication—was echoed by industry experts as a key area where graduates often underperform, suggesting that teacher competence in this area has direct downstream effects on student preparedness.

Another crucial insight from the industry involves the role of lifelong digital competence development. Experts suggest that digital competency is not static but evolves alongside technological advancement. Hence, vocational teachers need continual upskilling supported by institutional mechanisms such as industry partnerships, training in industrial environments (industry-in-schools or teacher internships), access to proprietary digital tools, and policies that incentivize innovation. The industry's voice underscores the urgency of developing a responsive and dynamic digital competence framework, as attempted in this research, to ensure vocational teachers are equipped not only for present needs but also for emerging trends in digital transformation.

In conclusion, the integration of industry perspectives validates the relevance of the proposed framework, particularly the prioritization of dimensions that reflect both pedagogical and technological convergence. It emphasizes that enhancing teachers' digital competence is not just about equipping educators with tools but about re-aligning vocational education with national industrial goals, closing the skills mismatch, and fostering a digitally resilient workforce through teacher excellence.

4.2. What are vocational educators' perceptions, challenges, and needs regarding digital competence in classroom practice?

The second result of this study will analyze the teachers' survey using the instrument obtained from vocational educators in Indonesia. The survey discussed several factors that support the improvement and acceptance of digital competence. The first analysis was the infrastructure supporting teachers' technology integration in the classroom of vocational education.

The findings of this study suggest that the development of technological facilities in Indonesian vocational schools predominantly emphasizes the provision of conventional hardware, such as computers and laboratories, yet has not fully evolved into the establishment of a comprehensive digital learning ecosystem. Although hardware like computers and LCD projectors are seen as necessary for technological integration, their use is mostly limited to presentations and one-way information sharing information. This indicates that technology in vocational schools continues to operate within a traditional pedagogical framework, which is centered on teacher-led instruction, and has not advanced to support collaborative, autonomous, and personalized learning models aligned with 21st-century educational standards.

The limited availability of Learning Management Systems (LMS) further highlights systemic constraints in digital transformation within vocational education. An effective LMS should extend beyond mere distribution of learning materials, serving as a platform for competency-based learning, real-time monitoring of student progress, interactive communication between educators and learners, and integration with digital assessments and artificial intelligence-enabled industrial simulations.

The infrequent deployment of LMS underscores the reactive nature of digital learning initiatives, which are often instituted only during emergencies such as pandemics, rather than as components of a long-term strategic vision. This situation reveals a disconnect between physical technological infrastructure and the institutional and human resource capacities necessary for strategic technological utilization.

This study, in conjunction with digital competency theory, reveals that the implementation of the 'Professional Engagement' and 'Digital Resources' dimensions within the DigCompEdu Framework remains suboptimal in Indonesian vocational schools. While teachers possess hardware resources, there is a notable deficiency in their creative and collaborative utilization of digital tools. Furthermore, the equitable distribution of expertise laboratories has not inherently translated into effective digital integration within practical teaching environments.

This indicates that the digital competence of vocational educators is predominantly confined to technical mastery, with limited development in pedagogical and professional integration competencies. These findings highlight a significant gap between national vocational education policies and their actual execution at the school level.

Although policies aim to produce graduates capable of adapting to Industry 4.0 and Society 5.0, many schools continue to grapple with basic infrastructural deficiencies and have yet to establish a comprehensive digital learning ecosystem aligned with current industrial needs. Consequently, the challenges faced in advancing digital education in Indonesia are multifaceted, encompassing technical, structural, cultural, and pedagogical dimensions.

The analysis indicates that, although the infrastructure of most vocational schools generally includes fundamental technological facilities, the quality and utilization of these resources remain suboptimal. The existing facilities largely support traditional pedagogical approaches and elementary practical exercises, but fall short in fostering a comprehensive digital learning ecosystem capable of cultivating 21st-century skills such as innovative collaboration, critical thinking, digital creativity, and the integration of industrial technology into the learning process. Consequently, a paradigm shift is imperative—from merely providing physical infrastructure to developing an integrated, collaborative, and sustainable digital learning environment. Achieving this transformation necessitates enhancing the digital competencies of educators, formulating enduring digital development policies, and investing in platform-based learning systems that extend beyond hardware provisions. Furthermore, strategic partnerships with the digital industry, LMS platform providers, and practitioner-oriented teacher training programs will be essential in accelerating the advancement of digital vocational education within Indonesia.

This study aims to answer the question, "**What are vocational educators' perceptions, challenges and needs regarding digital competence in classroom practice?**" The data collected during the study showed that several factors influence vocational teachers' low digital competence. The researcher has conducted an analysis from transcribing, translating, checking the final data and then conducting the analsysis. The findings showed two major factors. Firstly, external factors_consisted of four themes emerging associated with external factors: (1) hardware and internet access, (2) professional training, (3) online social community, and (4) time challenges. Secondly for internal factors, there are age differences, belief on traditional teaching method, and acceptance of technology usefulness and simplicity.

4.2.1 External factors of vocational teachers' digital competency

Hardware and Internet Access

The majority of vocational education teachers attribute their limited digital competence primarily to external factors. They perceive these barriers as necessitating increased motivation and external support to facilitate the integration of technology into their teaching practices. Teachers also associate the development of their digital skills with the availability of adequate facilities and infrastructure within their schools. For instance, Eni highlighted that many schools currently lack access to essential resources and technological tools. Additionally, teachers frequently report insufficient time to engage in professional development due to administrative burdens.

In rural areas, these challenges are exacerbated by infrastructural limitations, such as the absence of 4G internet connectivity and reliance on satellite WiFi, which can be sporadically available depending on location. Consequently, educators in such regions encounter significant obstacles—stemming from geographic remoteness and infrastructural deficiencies—that hinder their ability to utilize internet-based technologies effectively.

***Eni:** "The government already required us to implement technology integration into the classroom through regulation, and they usually also conducted some training. However, it is hard to practice what we learned from the training because of a lack of access to lab facilities and good internet connection (3G or 4G in rural areas), and the government usually respond late to this problem."*

Ninda emphasized the significance of access to facilities as a crucial process to perceive the usefulness of integrating teaching with technology. The perceived usefulness of access enables teachers to more effectively apply their knowledge of technology-pedagogy integration. This challenge is particularly evident in rural and certain urban areas due to the uneven distribution of school facilities.

***Ninda:** "We are eagered and feeling excited to implement our training knowledge into our lesson plan. However, we have limited supporting access. The distribution of facilities is also late from the government. We notice that school with good access has teachers with good teaching innovation and in digital skills"*

Ninda stated that lack of access influences teachers' motivation because they do not perceive the usefulness of access, so they are also not eager to implement their training knowledge. It means that the government should also provide a good access for the teachers to implement the regulation. Regardless of the teachers' perception, several teachers have self-driven to improve their digital skill through various platforms especially Youtube. This statement was stated by Sofyan

Sofyan: *"... I was having an experience of learning through Youtube. I was teaching about screen printing. What I knew before is using iron. However, I watched through Youtube that there's another way by using mosquito lotion and it worked. Then, I practiced it through the classroom."*

Findings indicate that the process of implementing technology in educational institutions is regulated. However, this process is significantly influenced by two major factors that affect teachers' digital competence. The first factor is access to hardware and the internet, while the second factor is a lack of access to learning resources. Teachers who perceived full access are generally more motivated to integrate and use technology into their teaching and tend to possess stronger digital skills. Conversely, those with limited access may experience and perceive a low level of their digital capabilities.

The majority of teachers who lack access to hardware and the internet exhibit lower digital skills. Nonetheless, this lack of resources does not prevent teachers from learning and developing their digital skills for educational activities. Many teachers take the initiative to use personal devices and utilize online platforms, such as YouTube, websites, and social media, to enhance their digital competence and perceive the strong usefulness of technology utilization.

Government training

During the COVID-19 outbreak, teachers who lacked proficiency in digital teaching methods faced considerable difficulties in adapting to the demands of complete distance learning. It was widely acknowledged that teaching practical subjects online is among the most challenging tasks for educators. Furthermore, teachers indicated that the government's training programs were perceived as inadequate and not truly useful for the rapid implementation of online education.

Yosafat: *"…during COVID-19, we were shocked because of online learning. Furthermore, as technical teachers, we needed to conduct practice in our class, but we couldn't meet face to face because of COVID-19 restrictions. We learned about technology-pedagogy integration with other teachers through sharing. At that time, training was also held at BMTI (training bureau), which used an interactive model, including absences, daily assessment, online materials making, and others. But the training related to practice was not enough for us, and we usually tried to learn about online practice through YouTube or another platform"*

Table 4.3. Thematic coding analysis of vocational teachers FGD

Categories	Subcategories	Description	Themes	Anchor example	
Perceived usefulness	Enhancing digital competency	Lack of hardware and internet access but teachers usually use their own hardware and internet	Hardware and internet access	Teachers are trying to provide a good facility for students especially the implementation of technology, but the facilities are limited. However, we try our best by using our own implement technology in the classroom.	External Factors
	Developing digital competency	Teachers are excited to implement technology into teaching even though with lack of training information	Government training	Many teachers in vocational education have a duty to introduce tools and integrate it with technology while delivering materials. However, it is quite hard for the teachers if they don't know how. We need a comprehensive training, but the training is somehow limited.	
Perceived ease of use	Support of digital competency	Teachers are united in a social online community created for sharing and discussion through WhatsApp and Facebook channel.	Social online community	The existence of social online community was a support and being meaningful because we can share and discuss many things especially about teaching materials. However, it is often functioned as a group to share viral videos, funny things or even business.	
		The administration for teachers is really demanding	Time Challenges	We have a lot of tasks such as making lesson plan and preparing materials. However, we feel that the most demanding task for teachers is administration.	
Attitudes towards technology	Evidence of digital competence implication	Older teachers believe that young and fresh graduate teachers are more competent in the updated technology and technology implementation in the classroom.	Age differences	We are not having a trouble with pedagogical activity as we have engaged on pedagogy for a long time but not for technology integration. We should learn slowly and not as fast as the new and young teachers. Therefore, we usually ask for help, share and discuss with the young teachers related to updated technology in the classroom.	Internal Factors
		Teachers are sometimes stuck on the traditional teaching method, and they believe that it's still impactful.	Belief on traditional teaching method	We sometimes only use the way how we have been implemented for a long time. We think that it is also working, and technology is only a tool which helps us delivering the materials.	
		Teachers demonstrate a strong desire to acquire new technological competencies. However, they often lack confidence in their ability to maintain this digital competence and perceive the learning process as challenging	Acceptance of technology usefulness and simplicity	Learning reflects an individual's intrinsic willingness. Despite my enthusiasm to implement knowledge gained from various platforms in the classroom, I struggle with confidence and recalling effective strategies for execution.	

In that statement, the teachers still perceive difficulties with integrating practice and online teaching methods using digital media because they needed face-to-face interactions to explain how to use the tools. This case made the teachers describe that they are not ready yet to conduct a technology-pedagogy integration, specifically in practice subjects, because it is difficult for them to perceive the ease of an online practice.

Ruslan stated that participants increased their digital competence through a training program. He revealed that joining a training program can be a requirement for teachers to perceive a higher job position. He also described that teachers attended training because of position-oriented goal, but were rarely motivated to implement it into the classroom

Ruslan: *"...We sometimes only attend training to pursue promotion, and for continuous application we are still unable to motivate ourselves to start applying the training result correctly. However, there are also teachers who are diligent to implement their knowledge and their digital skill are increased gradually."*

Teacher Ruslan explained that teachers rarely implement their perceived training materials because they feel unmotivated to re-learn about them. However, there were also teachers who had a high motivation to implement what they learned after the training. Teachers stated that implementation leads teachers to a high level of digital competence.

The government typically organizes training programs for teachers to enhance their skills and competencies. However, some educators may misuse these useful opportunities, focusing solely on advancing their careers rather than implementing the new knowledge and skills in their classrooms. In contrast, some teachers actively engage in these training sessions and effectively apply the useful materials into teaching practices.

Although government-sponsored training can be limited due to various constraints, such as requirements or quotas, many teachers take the initiative to expand their understanding of digital media. They successfully integrate this knowledge into their teaching through online platforms like YouTube, TikTok, and Facebook.

Ethics in Social Online Community

Another factor that makes teachers perceive demotivation is an unsupportive online social community. Teacher Kurnia stated that some teachers are not prepared to perceive the development of their digital competence due to an unsupportive online social environment. It was explained that there is a social media group (MGMP) that was operated and created by the teachers for the purpose of teachers' professional development and ease of use for group discussions.

***Kurnia:**" There is a group for us as a teacher to access the group in WhatsApp and Facebook. This group named MGMP which is purposed to be a place for discussion with other teacher from the same school, regional, and even national and also for teachers' skill development. We come from different city but with the same expertise. We hoped that this group was functioned as we expected. But when we wanted to start a discussion especially about technology or tools for teaching, only few were responded but when we discussed something unrelated with the subject such as jokes or viral video, they are always interested to have interaction…"*

Teachers need support not only in terms of physical facilities but also from their colleagues. According to Yudha, teachers at all levels are part of a social media group (WhatsApp Group) where they can discuss and share information related to their expertise and the ease of digital media. However, this group is mainly used for sharing viral content, jokes, and food recipes, and teachers rarely discuss and perceive valuable information or materials. They believe that more support and encouragement are needed to engage them in effectively discussing the use of technological tools.

***Yudha:** "It is true that our MGMP group contained spam which is not related to our goal to develop our skill together. However, I hope that teachers are triggered to improve their skill through group routine discussion or sharing. But, the teachers who usually discuss about materials of related contents are having a good or even better skill in digital competence, teaching materials, or the integration of technology and pedagogy."*

According to Yudha's statement, teachers who actively participate in discussions to improve their skills are more likely to possess and perceive strong digital competence compared to those who are reluctant to engage in conversations about teaching materials, methods, and technology. The rapid advancements in the industry require teachers to enhance their digital skills in order to effectively teach and incorporate industrial updates into vocational education curricula. If teachers do not engage in discussions or rely solely on their current abilities, they may struggle to implement and keep up with these industrial developments in their teaching practices.

This analysis examines the relationship between social online communities and the digital proficiency of teachers in using technology (ethics). According to the educators involved, many of their colleagues show little interest in discussing serious teaching-related topics, such as instructional tools or problem-solving, within their WhatsApp groups. Instead, those teachers who do initiate discussions tend to focus primarily on enhancing their digital competence. Conversely, some teachers are drawn to spam chats, engaging in off-topic discussions that do not pertain to their subject matter. Within these online communities, there are teachers dedicated to developing their digital skills, while others remain disengaged from such growth. They also do not concern with the ethics in digital communication within the online community.

Time challenges

Eight senior teachers who participated in FGD identified that teachers need to develop their skills in technology integration through training, courses, or even discussion. However, they also expressed frustration with teachers' administrative workloads, which sometimes hinder their learning through training or courses.

Nadia: *"We are eager to join training or a course. However, as teachers, we must fulfill many administrative tasks besides preparing teaching materials. We are already tired of our office workloads and housework, so we cannot be focused if we join training or a course."*

The teachers mentioned that they participate in training courses to comply with the regulations of the educational government. However, they also revealed that the administrative requirements imposed on them every semester are too much to handle, leaving them with inadequate time to attend training programs. Moreover, they expressed that they cannot avail themselves of any subsidies from the government for attending courses and that good courses from reputable platforms tend to be expensive.

Sufyan: *"I agree that following a training is really fundamental for us because as a vocational high school teachers, we are required to adjust our knowledge with the industrial technology development. However, our administrative tasks constrain us, which is time-consuming, so our weekends are only for rest time. Furthermore, if our administration needs a report or if it is a busy month, we will work on the weekend, too."*

According to his statement, teachers are already overwhelmed with administrative workloads, even on weekends, which leaves them exhausted and unable to fully engage with training and courses. Teachers who want to improve their digital skills perceive the challenge of limited time due to their already heavy workloads. Teachers in Indonesia have to handle teaching preparation, administration, reporting, and evaluation tasks, leaving them with little to no time to learn new things. This can make them feel exhausted and overwhelmed. Teachers affected by their workloads and stressful conditions may not be interested in taking courses and have less interaction with technology, leading to lower digital proficiency. To sum up, in time challenges, there were no positive affirmations from teachers as they feel that administration in teaching takes time. It is impacted by their time of learning digital media for teaching. Even though teachers can join a course, they will have a limited and difficult time re-learning and re-watching the materials because of time challenges (4.7).

The identified issues include online communities, deficits in self-confidence, a strong adherence to traditional pedagogical methods, age disparities among educators, and the acceptance of technology by teachers. These concerns have been previously documented in existing literature, which underscores that variables such as age, prior ICT training, and teaching experience substantially impact digital competence (Cabezas-González et al., 2021; Saripudin et al., 2021a).

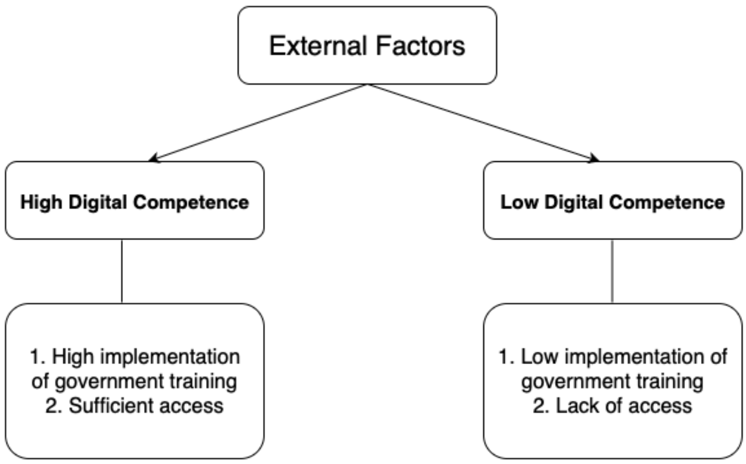


Figure 4.7 Thematic analysis of external factors

In addressing the research question: "Why do Indonesian vocational teachers exhibit low levels of digital competency?" the study examines both external and internal factors influencing digital competence. The research findings have consequently illuminated various influencing factors.

4.2.2 Internal factors of vocational teachers' digital competency

This investigation critically analyzes the impediments encountered by educators in the integration of digital technology within pedagogical practices, especially in the context of prevailing epistemological beliefs that emphasize the indispensability of technological tools in the contemporary industrial epoch. The findings reveal that numerous educators face considerable challenges in delivering online instruction and employing digital resources, often maintaining the position that traditional instructional methodologies remain superior in efficacy. Moreover, senior educators have observed a generational disparity, noting that younger teachers tend to demonstrate higher levels of digital literacy, which may consequently undermine the self-efficacy of more experienced educators in their capacity to effectively incorporate technological competencies into their instructional approaches.

Ruslan: *"In conclusion, the method of traditional teaching is still more effective/effective than dealing with technology. I feel more enjoyable teaching theory and practice through the traditional lab…. I cannot teach with advanced technology during my practical class because the laboratory equipment does not provide the newest technology development. For example, mechanical engineering students use a fueled-engine car in their current laboratory but need to do fieldwork with an electric car. So, they need to learn again because they do not get the knowledge from the school practice. I find myself thinking about how important it is to embrace technology in education. Yet, despite acknowledging its value, I often stick to traditional methods. As a result, I feel my skills stagnate because I seldom use the digital tools available to me."*

This statement elucidates that Ruslan's primary challenges are rooted in the self-motivation required for the effective integration of digital tools into educational practices. He demonstrates a preference for traditional instructional methodologies that do not incorporate industry-related technologies, thereby reflecting a greater confidence in conventional pedagogical paradigms. Nonetheless, intrinsic motivation remains a crucial factor in fostering digital competence within classroom settings. The motivation of educators has been identified as a pivotal element in enhancing their technological proficiency. Additionally, their attitudes toward technology suggest that persistent reliance on traditional methodologies is partially attributable to inadequate laboratory infrastructure, which fails to keep pace with rapidly emerging technological developments.

Candra: *"…. Many of my fresh graduate colleagues understand digital tools, and they usually integrate them into the learning activity. I learned from them because practicing technology integration is more complicated. However, I am struggling with technology implementation rather than the young teachers."*

The statement provided by Candra suggests that attaining a high level of digital competence poses significant challenges for senior educators. These teachers often lack confidence in integrating technology within the classroom setting, primarily due to insufficient technical skills. One potential approach to addressing this issue involves facilitating peer learning opportunities with younger educators, which may support senior teachers in enhancing their digital competencies.

Additionally, senior teachers often perceive younger colleagues as possessing greater proficiency in digital technologies. This perception may stem from their reliance on traditional pedagogical methods and a reluctance to incorporate emerging technological tools into their instructional practices. Moreover, limited access to adequate technological resources and equipment provided by educational institutions further hampers senior teachers' ability to experiment with and adopt unfamiliar digital tools, thereby contributing to their comparatively lower levels of digital literacy.

Younger teachers tend to demonstrate a greater propensity for proactively enhancing their digital competencies and incorporating technological tools into their pedagogical practices. Such initiatives often result in elevated levels of digital proficiency. Additionally, this dynamic creates opportunities for senior teachers to engage in knowledge-sharing and collaborative discussions, thereby fostering an environment conducive to professional development in digital literacy. Younger educators can also serve as catalysts for motivating senior colleagues to address specific challenges encountered during the teaching process, particularly regarding the integration of technology. In summary, these findings suggest that fostering collaboration between senior and junior teachers can significantly enhance the overall effectiveness and efficiency of instructional practices.

The subsequent internal factor pertains to the acceptance of technology among educators, particularly within the domain of vocational education, which is of critical significance. This importance is underscored by the rapidly changing demands of the labor market, which increasingly necessitate technological advancements driven by innovation. The findings of this study suggest that the adoption of technology by vocational teachers remains inadequate. As articulated by Nadya:

Nadya: *"Learning new technological systems can be incredibly challenging. I often find myself facing obstacles that I didn't anticipate. It's not just a matter of picking up a new skill; it requires a deep understanding of how these systems work. I know I can do it, but the process is inherently slow. I usually start by familiarizing myself with the basics on my own, but there comes a point where I hit a wall. That's when I turn to my expert friends for guidance. Their insights can make a significant difference. Engaging with new technology feels like a complex journey. It takes time, patience, and sometimes a little help from those who know more than I do. But I remind myself that every step forward is progress, and eventually, I will get there."*

The statement emphasizes that enhancing educators' digital competence represents a complex and multidimensional challenge. Additionally, it highlights that educators frequently experience discomfort when engaging with emerging technologies. This observation contrasts with the Technology Acceptance Model (TAM), which posits that users can be considered to have a high level of digital competence if they perceive the technology as useful (perceived usefulness).

Ruslan: *"You know, I've been reflecting on my journey as a teacher, and I've come to realize something quite significant. It's actually hard to possess a high level of digital competence if I rarely implement it in my practice. Throughout my teaching experience, I've noticed that I don't often integrate technology into my lessons or teaching materials. This lack of integration isn't just a missed opportunity; it's actually taking a toll on my own digital competence. It's a cycle, really: the less I use technology, the less competent I feel, and the less motivated I am to try. If I truly want to elevate my digital competence, I know I need to change this approach and start exploring new ways to incorporate technology into my teaching. It's a challenge, but I'm ready to embrace it."*

Ruslan's experience underscores the importance and advantages of integrating technology. Nevertheless, there remains a notable deficiency in acceptance and motivation regarding the perceived value of such integration, particularly in the context of the interaction between technology, work, and knowledge within vocational education and industrial settings. It is imperative for individuals to recognize the significance of technology and to work towards enhancing their digital competencies. Such development is vital for effective participation in an increasingly technology-driven society. A central theme within this internal factor pertains to teachers' acceptance of technology. Specifically, a positive attitude towards technology among educators facilitates the recognition of perceived usefulness and ease of use. Figure 4.8 illustrates various internal factors, including age-related differences, teachers' beliefs, and their acceptance of technology.

High digital competence	**Low digital competence**
Collaboration with young teachers	Unconfident and not collaborating with young teachers
Teachers start implementing technology in teaching	Traditional teaching belief
Traditional on the ease and usefulness of digital competence	Decline on the ease and usefulness of digital competence

Figure 4.8 Thematic analysis of internal factors

4.2.3 Bringing together External and internal aspects of Vocational teachers' digital competence

The interaction between external and internal aspects of digital competence within the teaching profession manifests a complex relationship characterized by access to infrastructural resources and individual motivation. A thematic analysis identified critical external determinants—including hardware availability, internet connectivity, and governmental training initiatives—categorized under the theme "Perceived Usefulness." Educators observed that deficiencies in infrastructure compelled reliance on personal devices, thereby constraining the effectiveness of digital pedagogical practices. For instance, a statement such as “Teachers strive to provide good facilities for students, but resources are limited…” exemplifies how limited access hampers the utilization of digital tools. Furthermore, participation in government-sponsored training is often perceived as driven more by certification ambitions than by a genuine intent to enhance pedagogical skills, thus exposing a disconnect between institutional support and practical pedagogical application. This gap undermines the perceived value of such training, particularly when it lacks relevance to classroom realities.

Internal factors, including self-efficacy, pedagogical beliefs, and ethics toward technology, significantly influence teachers' perceived ease of use and attitudes or ethics toward technological integration. Empirical evidence indicates that motivated educators, even in contexts challenged by infrastructural deficits, exhibit greater confidence in utilizing digital tools. For example, the statement “Learning reflects an individual’s intrinsic desire...” underscores the propensity of motivated teachers to incorporate technology into their pedagogical practices. Ultimately, while external resources can function as facilitators or obstacles, it is internal dispositions that critically determine the depth, efficacy, and sustainability of digital integration. Strong internal motivation can mitigate certain external constraints; however, optimal digital competence necessitates a congruence between internal motivation and available resources. Teachers endowed with both access and motivation tend to achieve higher levels of digital integration, whereas those lacking either are often hindered in effectively implementing technological solutions within vocational education contexts.

During the focus group discussion, educators indicated that online communication appears to influence their intentions regarding the utilization of technology in instructional settings. Interactions with colleagues, both face-to-face and online, were found to impact teachers' self-efficacy, with positive experiences serving to bolster their motivation. Participants suggested that online communities could serve as platforms for sharing ideas, addressing challenges, and exchanging knowledge, thereby supporting teachers' professional competencies and the integration of technology. However, it was also observed that these online communities often include informal content such as jokes, viral videos, and political discussions. The discussion highlighted a potential relationship between technological competence and active engagement within constructive social communities, which could function as avenues for ongoing professional development in technology use.

There was also a notable development in the association between participation in the social community and teachers' pedagogical beliefs concerning the perceived importance of technology in education, as well as their willingness to enhance their digital competence. Concerning internal factors, one educator observed that senior teachers often exhibit lower levels of digital competence attributable to a lack of confidence, motivation and ethics to adopt technological tools. Conversely, it was also noted that younger teachers can serve as support figures for their senior counterparts, fostering greater interaction and collaboration in the discussion of digital media for instructional purposes. This dynamic has the potential to build trust among senior educators and bolster their confidence in integrating technology, facilitated by mentorship and knowledge exchange with their younger colleagues. Effectively, promoting positive interactions that elevate teachers' expertise and digital skills is crucial for addressing internal barriers. In summary, the interplay between external and internal factors can precipitate substantial change, with online social communities acting as pivotal platforms that motivate teachers and bolster their capacity to develop digital competence.

The analysis delineates two principal determinants influencing the development of digital competence among vocational educators: engagement and ethics in online social communities (external factors) and collaborative interactions with younger colleagues (internal factors). Participants frequently emphasized that their involvement in WhatsApp groups and other professional digital forums—comprising educators from various regions—facilitated the exchange of ideas, resources, and innovative pedagogical practices. When such participation was active and substantive, characterized by continual knowledge sharing, practical problem-solving, and peer-to-peer learning, it markedly contributed to the enhancement of teachers' digital competencies. Conversely, engagement that was passive or superficial yielded limited benefits, thereby underscoring the pivotal role of interaction quality and intensity within these digital social spaces in fostering digital development. Based on the result of this qualitative analysis from the vocational educators, there are three important components combining the educators' need in digital competence such as management and digital collaboration, professional development, and professional ethics. Those three components will be the idea of the second analysis through the survey and FGD with experts.

4.3. Which components of Digital competence are prioritized by vocational educators and educational experts?

The digital competency components identified based on the global review in the previous stage were then adapted to the current needs of vocational education in Indonesia. The purpose of this identification was to determine which digital competency components were prioritized for current vocational education needs and which levels still needed improvement.

4.3.1 Validity and Reliability Test Results

Before conducting the survey, the questionnaire was tested for validity and reliability to ensure it was appropriate and reliable. The validity and reliability tests involved 50 respondents, consisting of vocational teachers. This instrument were dragged down from the selected framework of digital competence for educators. However, it was then adjusted with the latest results from the preliminary studies and FGD qualitative results coping three dimension including management and digital collaboration, professional development, and professional ethics**.** The results of the validity and reliability tests are shown in Table 4.4.

Table 4.4. Validity and Reliability Results

	Questions	Validity	
1	I pay attention to the management of the digital learning data that I use. **(management and digital collaboration)**	0.89100315	Valid
2	I use digital technology to collaborate and interact with fellow teachers or stakeholders. **(management and digital collaboration)**	0.86075445	Valid
3	I contribute positively and ethically to the digital world, taking into account safe and responsible digital practices (digital safety) **(professional ethics)**	0.8635323	Valid
4	I use digital technology to improve my skills professionally (taking online training, self-study, using digital devices) **(professional development)**	0.83454119	Valid
5	I participate in professional activities or training to develop digital competencies. **(professional development)**	0.73091318	Valid
6	I utilize digital learning to support learning **(professional development)**	0.74685355	Valid
7	I share digital learning materials while paying attention to the copyright of the materials. **(professional ethics)**	0.69117416	Valid
8	I encourage students to use digital technology safely so they avoid becoming addicted. **(professional development)**	0.89100315	Valid
	Reliability	0.9	

Table 4.4 shows the results of the instrument validity calculation consisting of 9 test items. The calculation results by comparing the calculated r with the table r for each item show that all items exceed the table r value, meaning all items are valid. Next, after the 9 items were declared valid, their reliability was tested. The results of the reliability test produced a value (r11 = 0.90) and were in the extremely

high reliability category. After all items were declared valid and reliable, all items were ready for use in the study.

4.3.2 Survey results

The questionnaire was distributed purposively from September 1 to 10, 2023. Data collection from that date yielded 228 respondents, representing vocational teachers. After further processing, the clean data, comprising 228 respondents from vocational teachers across Indonesia from five islands, was then analyzed. The following is a list of priority data based on respondents' opinions, as shown in Table 4.5.

Table 4.5. Descriptive Analysis of Survey Instrument

Island	Management and Collaboration	Professional Development	Professional Ethics
Bali dan Nusa Tenggara	4,96	4,87	4,82
Jawa	4,94	4,95	5,14
Kalimantan	4,72	4,88	5,06
Papua	3,67	3,60	4,00
Sulawesi	5,04	5,00	5,17

The descriptive analysis reveals that vocational education teachers in Indonesia generally demonstrate a strong digital competence across the three evaluated dimensions. The highest scores are in the Digital Learning and Ethics area, suggesting that teachers are quite confident in using technology for learning and are mindful of ethical considerations. Meanwhile, the Digital Management and Collaboration, along with Professional Development dimensions, have lower average scores, highlighting the need to enhance skills in digital data handling, online teamwork, and participation in digital competency training.

Table 4.6. ANOVA Analysis of Survey Instrument

Dimension	F-Value	p-Value
Management and Digital Collaboration	2.13	0.062
Professional Development	2.03	0.075
Professional Ethics	2.31	0..045

The regional analysis indicates that educators from Sulawesi and Java attained the highest mean scores across nearly all assessed dimensions, whereas educators from Papua consistently demonstrated the lowest performance. This pattern highlights a significant geographic disparity in digital competency mastery among vocational teachers, which is likely influenced by variations in access to technological infrastructure, professional development opportunities, and supportive digital learning environments. The statistical significance of the observed differences warrants further investigation.

A one-way ANOVA analysis indicated that only the dimension of "Professional Ethics" exhibited statistically significant differences across regions ($p = 0.045$). This suggests that levels of teacher competency in utilizing technology for pedagogical purposes and in the implementation of digital ethics vary by region, with these variations unlikely to be attributed to random chance. Conversely, the dimensions of "Digital Management and Collaboration" ($p = 0.062$) and "Professional Development" ($p = 0.075$) did not demonstrate statistically significant differences among regions, although descriptive statistics revealed some variability in mean scores. Collectively, these findings imply that the primary regional disparities pertain to the integration of technology in instructional practices and the adherence to digital ethical standards, whereas competencies related to data management and participation in digital self-development do not significantly differ across regions.

This study demonstrates that vocational education teachers in Indonesia generally possess a moderate level of digital competence, with particular strengths in facilitating technology-enhanced learning and adhering to digital ethical standards. Nonetheless, disparities in competence are evident across regions, notably with teachers in eastern Indonesia, especially Papua, exhibiting significantly lower levels of proficiency. These regional differences are statistically significant in the domains of digital learning and ethics, underscoring the necessity for targeted interventions such as specialized training programs, enhancements in digital infrastructure, and the implementation of equitable policy measures nationwide. The findings further suggest that advancing vocational teachers' digital competence necessitates not only the development of technical skills but also the cultivation of a supportive digital ecosystem and equitable access to learning opportunities across diverse regions.

4.3.3 MCDM Analysis Results

Considering the different perspectives regarding the three previously mentioned dimensions, the identification of these digital competence components was then analyzed using Fuzzy AHP, SAW, and TOPSIS to determine their priority rankings through comprehensive weighting. The data collection was from the expert panel FGD. The assigned weights reflect each component's relative significance of each component within the context of environmentally friendly competencies. The components were extracted from the basis of components from the selected frameworks. These AHP results were obtained from a survey involving experts who performed pairwise comparisons of the 11 components. The following section presents the findings of the Fuzzy AHP analysis.

1) ***Results of Creating a Digital Competency Hierarchy Structure***

The hierarchical structure of the digital competency process is built around objectives, criteria, and alternatives. The determination of criteria and alternatives refers to the results of a literature review, adopting several related articles that include the perspectives of respondents: teachers, students, and industry, as shown in Table 4.4.

Table 4.7. Criteria Determination

Criteria (Code)	Experts total	Expert
Educational expert	3	Expert 1, Expert 2, Expert 10
TVET Expert	3	Expert 7, Expert 8, Expert 9
IT Expert	4	Expert 3, Expert 4, Expert 5, Expert 6

The criteria in Table 4.7 are determined based on the level of importance of statements from experts in various fields, including education, vocational education (TVET), and the perspectives of IT experts who also involved in the education sector. Expert selection has been explained in the method, where diversity between countries is needed to ensure in-depth trustworthiness and to compare how digital competencies are applied. Expert perspectives are needed to determine the latest digital competencies that must be mastered. Next, alternatives are determined based on the digital competency components. At this stage, the alternatives compiled are information and data literacy, communication and collaboration, digital content creation, digital safety, problem solving, professional engagement, digital resources, digital teaching and learning, digital assessment, empowering learners' digital skills, and facilitating learners' digital competence (Figure 4.9).

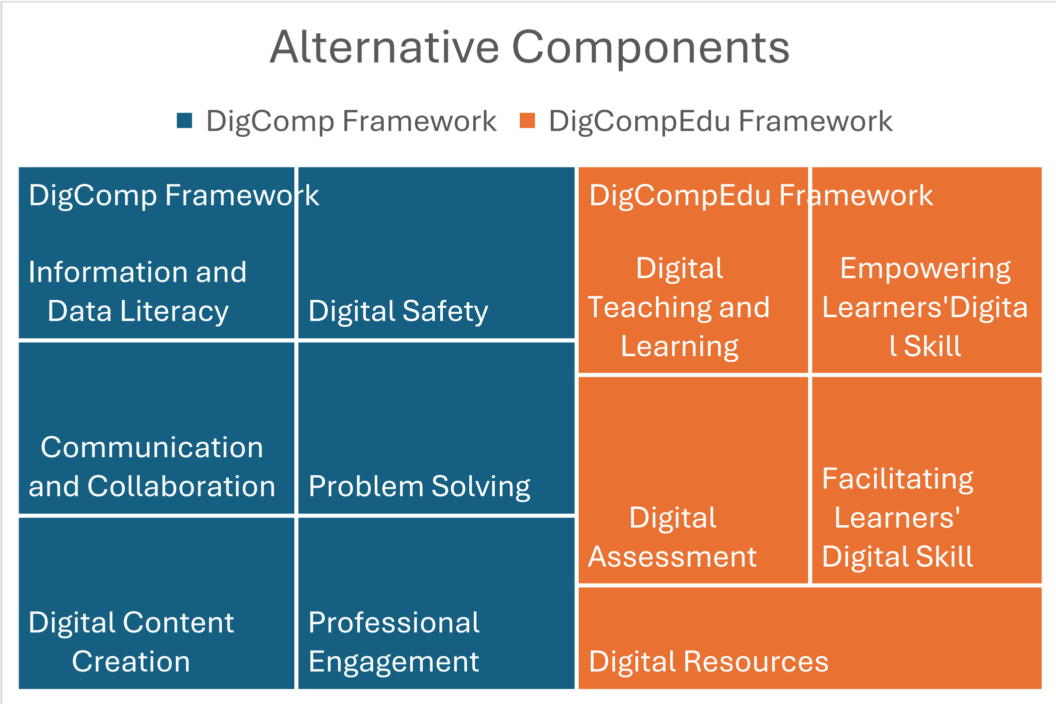


Figure 4.9 Alternative components using in pairwise survey

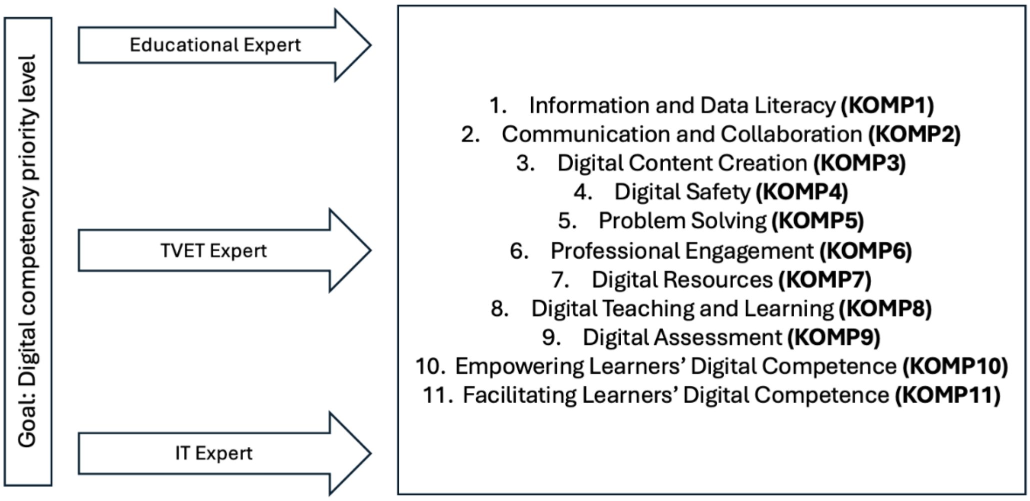


Figure 4.10 Hierarchy Process of Digital Competencies.

Figure 4.10 illustrates the hierarchical framework underlying the development of a digital competency model. This diagram comprises three principal development goals that delineate the interrelationships among the key constituent elements essential for cultivating digital competencies. At the initial tier, the primary objective is to evaluate the prioritization of digital competencies, which serve as a reference framework for enhancing teachers' digital skills in facilitating effective learning and fostering students' readiness for the professional environment. The second level delineates criteria comprising three primary elements, each derived from experts of distinct domains. Firstly, education specialists focus on expert observation of instructional practices and teachers' comprehension of digital competencies.

Secondly, TVET (Technical and Vocational Education and Training) experts observe the collaboration between educational institutions and industry sectors, particularly in the development of digital competencies aligned with labor market demands. Third, IT specialists possess in-depth knowledge of digital competency development and its critical importance, and they are actively involved in educational contexts. At the final level, an alternative framework is proposed, encompassing 11 core dimensions that signify crucial areas in the cultivation of digital competencies for educators. These dimensions include essential skills that teachers must master and implement within educational settings to ensure the successful integration of technology in curricula, thereby enhancing pedagogical effectiveness and educational outcomes.

2) Results of creating a pairwise comparison matrix *(pair-wise comparisons)*

At this stage, the researcher created a 3 x 3 pairwise comparison matrix by entering the TFN values according to equation (1). In addition to the pairwise comparisons, the fuzzy geometric mean value was also calculated according to equation (2). The calculation results can be seen in table 4.8.

Table 4.8. Results of Calculation of Fuzzy Geometric Mean Value

Criteria	EDU	IT	TVET	$(\tilde{r}_i)$
EDU	(1,1,1)	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(0.35, 0.41, 0.50)
IT	(2,3,4)	(1,1,1)	(1,1,1)	(1.26, 1.44, 1.59)

TVET	(4,5,6)	(1,1,1)	(1,1,1)	(1.59, 1.71, 1.82)

3) Fuzzy weight calculation results

The geometric mean fuzzy value has been calculated, then the weight of each criterion is calculated according to equation (3). The calculation results can be seen in table 4.9.

Table 4.9. Fuzzy Weight Calculation Results for Each Criteria

Criteria	($\tilde{r}_i$)	($\widetilde{W}_i$)
EDU	(0.35, 0.41, 0.50)	$(0.31, 0.36, 0.44) \oplus \left(\frac{1}{0.25}, \frac{1}{0.28}, \frac{1}{0.31}\right) = (0.08, 0.11, 0.15)$
IT	(1.26, 1.44, 1.59)	$(0.69, 0.84, 1.00) \oplus \left(\frac{1}{0.25}, \frac{1}{0.28}, \frac{1}{0.31}\right) = (0.32, 0.40, 0.49)$
TVET	(1.59, 1.71, 1.82)	$(0.31, 0.36, 0.44) \oplus \left(\frac{1}{0.25}, \frac{1}{0.28}, \frac{1}{0.31}\right) = (0.40, 0.48, 0.56)$

4) Defuzzification Results

Defuzzification is determined after the fuzzy weights are known, using equations (4) and (5), the results of de-fuzzification are shown in table 4.10.

Table 4.10. Crisp Weight Results after De-Fuzzification.

Criteria	($\widetilde{W}_i$)	COA	BNP	Wi
EDU	(0.08,0.11,0.15)	0.12	0.12	0.11
IT	(0.32,0.40,0.49)	0.41	0.41	0.40
TVET	(0.40,0.48,0.56)	0.49	0.49	0.47

5) Results of normalization weight calculation

The next step is to calculate the normalized weight. The total normalized value is now 1, meaning the normalized weight calculation is correct. This normalized value is used as the reference weight for ranking (Table 4.11).

Table 4.11. Results of normalization weight

Criteria	***Crips Weight*** **(W_i)**	**normalization weight**
EDU	0.12	0.12

IT	0.41	0.41
TVET	0.49	0.47
	1.02	1.00

6) Consistency Check

The final step after obtaining the normalized value weights as validation that these values can be used is to check their consistency. The pair comparison matrix is recreated in a 3 x 3 order, as shown in Table 4.12.

Table 4.12. Pair Comparison Matrix Results.

Criteria	EDU	IT	TVET
EDU	1	1/3	1/5
IT	3	1	1
TVET	5	1	1

Equations (6) and (7) are used in this stage to determine the consistency index before calculating the consistency ratio value. Table 4.13 shows the multiplication of the pairwise comparison matrix with the weight of each criterion.

Table 4.13. Pairwise Comparison Matrix Results Multiplied by Weights

Weight Criteria	0.12	0.41	0.47
Criteria	**EDU**	**IT**	**TVET**
EDU	1*0.12	0.33*0.41	0.20*0.47
IT	3*0.12	1*0.41	1*0.47
TVET	5*0.12	1*0.41	1*0.47

After completing the above steps, the next step is to calculate the ratio between the Weighted Sum Value (WSV) and Consistency Weight (CW) to determine λmax (equation 7). The calculation is shown in Table 4.14.

Table 4.14. SW and CW Ratio Calculation Results

Criteria	EDU	IT	TVET	WSV	CW	$\frac{WSV}{CV}$
EDU	0.11	0.13	0.09	0.34	0.12	2.90
IT	0.35	0.40	0.47	1.23	0.41	3.01
TVET	0.59	0.40	0.47	1.47	0.47	3.12

Once the λmax value has been determined, the CI and RI values are then determined. The RI value is determined from the total matrix, namely 3 x 3, which has a value of 0.58 based on the table from Alson and Lamata (Alonso & Lamata, 2006). Once the CI and RI values are determined, the consistency ratio value can be determined. The results of the consistency ratio calculation can be seen in Table 4.15.

Table 4.15. Results Consistency Ratio

Criteria	λ_{max}	CI	RI	CR
Total	3.01	0.008	0.58	0.014

A CR value <0.1 means that the paired matrix is consistent and the weight values can be used as considerations for decision making. The weights from the geometric mean analysis have been identified and have met the consistency value requirement, namely (0.05), meaning that the weights of each criterion and each alternative can be used for consideration.

7) Determining alternative weights

The overall alternative weights can be determined after each alternative's weight for each criterion has been determined, using steps 1 through 8 of the Fuzzy AHP process. The following describes the calculation results for each alternative weight based on each criterion.

- Alternative weight calculation results for criterion 1

The number of alternatives for all criteria is 11, so the matrix used is 11 x 11. Table 4.16 shows the pairwise comparison matrix and the results of the fuzzy geometric mean calculation for alternatives for criterion 3.

Table 4.16. Alternative Matrix Calculation Results for Criterion 1 (EDU)

	KOMP1	KOMP2	KOMP3	...	KOMP10	KOMP11	$(\tilde{r}_i)$
KOMP1	(1,1,1)	(1,1,1)	**(6,7,8)**	...	(1,1,1)	(1,1,1)	(2.15,2.22,2.38)
KOMP2	(1,1,1)	(1,1,1)	(4,5,6)	...	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(1.21,1.34,1.57)
KOMP3	$(\frac{1}{8},\frac{1}{7},\frac{1}{6})$	$(\frac{1}{6},\frac{1}{5},\frac{1}{4})$	(1,1,1)	...	$(\frac{1}{9},\frac{1}{9},\frac{1}{8})$	$(\frac{1}{9},\frac{1}{9},\frac{1}{8})$	(0.29,0.32,0.36)
⋮	⋮	⋮	⋮	⋱	⋮	⋮	⋮
KOMP10	(1,1,1)	(2,3,4)	(8,9,9)	...	(1,1,1)	(1,1,1)	(2.77,3.17,3.42)
KOMP11	(1,1,1)	(2,3,4)	(8,9,9)	...	(1,1,1)	(1,1,1)	(2.60,3.00,3.30)

After the pairwise comparison matrix and the fuzzy geometric mean value are obtained, the Crips value is calculated after De-Fuzzification to produce the normalized alternative weights for criterion 3. The results are shown in Table 4.17.

Table 4.17. Crisp Weight Results after Alternative De-Fuzzification on Alternative Weights of Criterion 1 (EDU)

	$(\widetilde{W}_i)$	COA	BNP	COA+BNP/2	WEIGHT
KOMP1	(0.13,0.14,0.17)	0.15	0.18	0.16	0.14
KOMP2	(0.07,0.09,0.11)	0.09	0.12	0.10	0.09
KOMP3	(0.02,0.02,0.03)	0.02	0.03	0.02	0.02
KOMP4	(0.01,0.02,0.02)	0.02	0.02	0.02	0.02
KOMP5	(0.12,0.14,0.17)	0.14	0.18	0.16	0.14
KOMP6	(0.02,0.03,0.03)	0.03	0.03	0.03	0.03
KOMP7	(0.07,0.09,0.12)	0.09	0.12	0.11	0.09
KOMP8	(0.04,0.05,0.06)	0.05	0.06	0.06	0.05
KOMP9	(0.02,0.03,0.04)	0.03	0.04	0.04	0.03
KOMP10	(0.16,0.20,0.25)	0.20	0.26	0.23	0.20
KOMP11	(0.15,0.19,0.24)	0.19	0.25	0.22	0.19
				1.15	1

The weighted values are then obtained to determine the consistency ratio as a requirement of Fuzzy AHP. Previously, the number of weighted values and their consistency must be known. The results of the WSV and CW ratio calculations can be seen in Table 4.18.

Table 4.18. Results of Calculation of WSV & CW Ratio on Alternative Criteria 1

Alternative KT1	KOMP1	KOMP2	KOMP3	...	KOMP10	KOMP11	WSV	CW	$\frac{WSV}{CV}$
KOMP1	0.14	0.09	0.15	...	0.20	0.19	1.65	0.14	12
KOMP2	0.14	0.09	0.10	...	0.07	0.06	1.01	0.09	11
KOMP33	0.02	0.02	0.02	...	0.02	0.02	0.23	0.02	11
⋮	⋮	⋮	⋮	⋮	⋱	⋮	⋮	⋮	⋮
KOMP10	0.14	0.27	0.19	...	0.20	0.19	2.37	0.20	12
KOMP11	0.14	0.27	0.19	...	0.20	0.19	2.22	0.19	12

The WSV and CW values are known, then determine the λmax value by adding the WSV and CW ratio values and then dividing by the number of alternatives, then the CI value can be determined using equation (6). Next, calculate the consistency ratio value using equation (8). The results can be seen in table 4.17.

Table 4.19. The results of the consistency ratio on alternative criteria 1

Criterion	λ_{max}	CI	RI	CR
Total	11	0.04	1.514	0.02

The alternative weight value in criterion 1 can be used for further needs because it meets the ratio consistency requirements, namely 0.02<0.1.

- Results of alternative weight calculations for criterion 2

In the second criterion, the steps for calculating alternative weights are the same as those for determining alternative weights in the first criterion. The results of the pairwise comparison matrix and the geometric mean fuzzy value can be seen in the following table 4.20.

Table 4.20. Results of alternative matrix calculations for criterion 2 (IT)

	KOMP 1	KOMP 2	KOMP 3	...	KOMP1 0	KOMP1 1	$(\tilde{r}_i)$
KOMP1	(1,1,1)	$(\frac{1}{8},\frac{1}{7},\frac{1}{6})$	$(\frac{1}{6},\frac{1}{5},\frac{1}{4})$	...	(1,1,1)	(1,1,1)	0.37,0.41,0.46)
KOMP2	(6,7,8)	(1,1,1)	(4,5,6)	...	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(2.12,2.46,2.70)
KOMP3	(4,5,6)	(1,1,1)	(1,1,1)	...	$(\frac{1}{9},\frac{1}{9},\frac{1}{8})$	$(\frac{1}{9},\frac{1}{9},\frac{1}{8})$	(1.42,1.60,1.78)
⋮	⋮	⋮	⋮	⋱	⋮	⋮	⋮
KOMP10	(8,9,9)	(1,1,1)	(2,3,4)	...	(6,7,8)	(1,1,1)	(2.77,3.17,3.42)
KOMP11	(1,1,1)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	...	(1,1,1)	$(\frac{1}{8},\frac{1}{7},\frac{1}{6})$	(0.62,0.72,0.85)

Furthermore, the calculation of the crips value after de-fuzzification and the weight of the second alternative criteria can be seen in table 4.20.

Table 4.21. Crisp weight results after alternative De-Fuzzification on alternative weights of criterion 2 (IT)

	$(\widetilde{W}_{i})$	COA	BNP	COA+BNP/2	WEIGHT
KOMP1	(0.02,0.03,0.04)	0.03	0.04	0.03	0.03
KOMP2	(0.13,0.16,0.22)	0.17	0.23	0.20	0.16
KOMP3	(0.09,0.10,0.14)	0.11	0.15	0.13	0.11
KOMP4	(0.14,0.19,0.26)	0.20	0.28	0.24	0.20
KOMP5	(0.02,0.02,0.03)	0.02	0.03	0.02	0.02
KOMP6	(0.03,0.04,0.05)	0.04	0.05	0.05	0.04
KOMP7	(0.05,0.07,0.09)	0.07	0.10	0.08	0.07
KOMP8	(0.02,0.02,0.03)	0.02	0.03	0.03	0.02
KOMP9	(0.07,0.09,0.13)	0.09	0.13	0.11	0.09
KOMP10	(0.16,0.24,0.27)	0.22	0.29	0.26	0.21

	$(\widetilde{W}_i)$	COA	BNP	COA+BNP/2	WEIGHT
KOMP11	(0.04,0.05,0.07)	0.05	0.07	0.06	0.05
				1.21	1

The alternative weights are known, then the consistency ratio value is calculated by calculating the WSV and CW values which can be seen in table 4.22.

Table 4.22. Results of WSV & CW ratio calculations for alternative criteria 2 (IT)

Alternative KT1	KOMP1	KOMP2	KOMP3	...	KOMP10	KOMP11	WSV	CW	$\frac{WSV}{CV}$
KOMP1	0.03	0.02	0.02	...	0.02	0.05	0.3101	0.03	11
KOMP2	0.19	0.16	0.11	...	0.21	0.15	1.8596	0.16	11
KOMP3	0.14	0.16	0.11	...	0.07	0.15	1.3602	0.11	13
⋮	⋮	⋮	⋮	⋱	⋮	⋮	⋮	⋮	⋮
KOMP10	0.25	0.16	0.32	...	0.21	0.35	2.7798	0.21	13
KOMP11	0.03	0.05	0.04	...	0.03	0.05	0.5694	0.05	11

After the WSV and CW ratios are known, the CR value can be known. The results of the ratio consistency value for alternative criteria 2 can be seen in table 4.23.

Table 4.23. Consistency ratio results for alternative criteria 2

Criteria	λ_{max}	CI	RI	CR
Total	11	0.03	1.714	0.04

Based on table 4.21, the weight of alternative criteria 2 can be used further because it meets the ratio consistency requirements, namely 0.04<0.1.

- Results of Alternative Weight Calculations for Criteria 3

In the first criterion, the calculation of alternative weights is the same as in determining alternative weights in the third criterion. Table 4.24 is the result of the calculation of the 11 x 11 pairwise comparison matrix which has been given a TFN value along with a fuzzy geometric mean value.

Table 4.24. Alternative Matrix Calculation Results for Criterion 3 (TVET)

	KOMP1	KOMP2	KOMP3	...	KOMP10	KOMP11	$(\tilde{r}_i)$
KOMP1	(1,1,1)	$(\frac{1}{8},\frac{1}{7},\frac{1}{6})$	(1,1,1)	...	$(\frac{1}{8},\frac{1}{7},\frac{1}{6})$	$(\frac{1}{6},\frac{1}{5},\frac{1}{4})$	(0.37,0.41,0.46)
KOMP2	(6,7,8)	(1,1,1)	(8,9,9)	...	(1,1,1)	(1,1,1)	(2.51,2.91,3.21)
KOMP3	(1,1,1)	$(\frac{1}{9},\frac{1}{9},\frac{1}{8})$	(1,1,1)	...	$(\frac{1}{9},\frac{1}{9},\frac{1}{8})$	$(\frac{1}{8},\frac{1}{7},\frac{1}{6})$	(0.26,0.28,0.33)
⋮	⋮	⋮	⋮	⋱	⋮	⋮	⋮
KOMP10	(6,7,8)	(1,1,1)	(8,9,9)	...	(1,1,1)	(1,1,1)	(2.15,2.46,2.70)
KOMP11	(4,5,6)	(1,1,1)	(6,7,8)	...	(1,1,1)	(1,1,1)	(1.51,1.77,2.02)

The fuzzy geometric mean value has been determined, then the crips value is determined and the alternative weight is determined in criterion 1, the calculation results are shown in table 4.25.

Table 4.2. Crisp Weight Results After Alternative De-Fuzzification on Alternative Weight Criterion 3 (TVET)

	$(\widetilde{W}_i)$	COA	BNP	COA+BNP/2	WEIGHT
KOMP1	(0.02,0.03,0.03)	0.03	0.04	0.03	0.03
KOMP2	(0.14,0.19,0.24)	0.19	0.26	0.22	0.19
KOMP3	(0.01,0.02,0.02)	0.02	0.03	0.02	0.02
KOMP4	(0.03,0.04,0.05)	0.04	0.05	0.05	0.04
KOMP5	(0.05,0.07,0.09)	0.07	0.09	0.08	0.07
KOMP6	(0.02,0.02,0.03)	0.02	0.03	0.03	0.02
KOMP7	(0.07,0.09,0.12)	0.09	0.12	0.11	0.09
KOMP8	(0.17,0.23,0.29)	0.23	0.31	0.27	0.23
KOMP9	(0.05,0.05,0.07)	0.05	0.07	0.06	0.05
KOMP10	(0.12,0.16,0.20)	0.16	0.21	0.19	0.16
KOMP11	(0.09,0.11,0.15)	0.12	0.16	0.14	0.12
				1.19	1

The weighted values in Table 4.25 are known. The next step is to calculate the consistency ratio by first calculating the WSV and CW ratios. The calculation results can be seen in Table 4.26.

Tabel 4.26. The results of the WSV & CW ratio calculation for alternative criteria 3 (TVET)

Alternative KT1	KOMP1	KOMP2	KOMP3	...	KOMP10	KOMP11	WSV	CW	$\frac{WSV}{CV}$
KOMP1	0.03	0.03	0.02	...	0.02	0.02	0.31	0.03	11
KOMP2	0.19	0.19	0.17	...	0.16	0.12	2.16	0.19	12
KOMP3	0.03	0.02	0.02	...	0.02	0.02	0.21	0.02	11
⋮	⋮	⋮	⋮	⋱	⋮	⋮	⋮	⋮	⋮
KOMP10	0.19	0.19	0.17	...	0.16	0.12	1.83	0.16	12
KOMP11	0.13	0.19	0.13	...	0.16	0.12	1.34	0.12	11

The consistency ratio value for alternative criteria 1 can be seen in table 4.27 and the results have met the requirements, namely 0.02<0.1.

Table 4.27. Consistency Ratio Results for Alternative Criteria 3

Criteria	λ_{max}	CI	RI	CR
Total	11	0.04	1.714	0.02

The weighting of each alternative for each criterion is already known, so the next step is to calculate the overall weighting of the alternatives by multiplying the weightings of the alternatives by the weightings of the criteria. The final results for the overall weighting of each alternative are shown in Table 4.28.

Table 4.28. Determination of Weight and Ranking of Alternatives

Alternative	Criteria			Weight	Ranking
	EDU	IT	TVET		
	0.12	0.47	0.41		
KOMP1	0.015	0.012	0.011	0.038	10
KOMP2	0.011	0.076	0.076	0.162	2
KOMP3	0.002	0.055	0.007	0.065	8
KOMP4	0.002	0.09	0.015	0.106	4
KOMP5	0.015	0.009	0.027	0.05	9
KOMP6	0.003	0.017	0.009	0.029	11
KOMP7	0.011	0.032	0.036	0.079	6
KOMP8	0.006	0.011	0.093	0.109	3
KOMP9	0.004	0.043	0.02	0.066	7
KOMP10	0.024	0.112	0.065	0.200	1
KOMP11	0.022	0.023	0.047	0.092	5

8) Comparison Test

The consistency ratio value is an indicator that the weighting results obtained through the Fuzzy AHP method have met the requirements for use in further analysis. However, to ensure more comprehensive results, a comparison was conducted with two other analysis methods, namely TOPSIS and SAW. This comparison aims to evaluate the reliability and accuracy of the weights generated by Fuzzy AHP in the context of multi-criteria-based decision-making. Thus, the results of the three methods can provide a more comprehensive picture of the effectiveness of the approach used. The following are the results of the ranking comparison test generated by Fuzzy AHP, TOPSIS, and SAW.

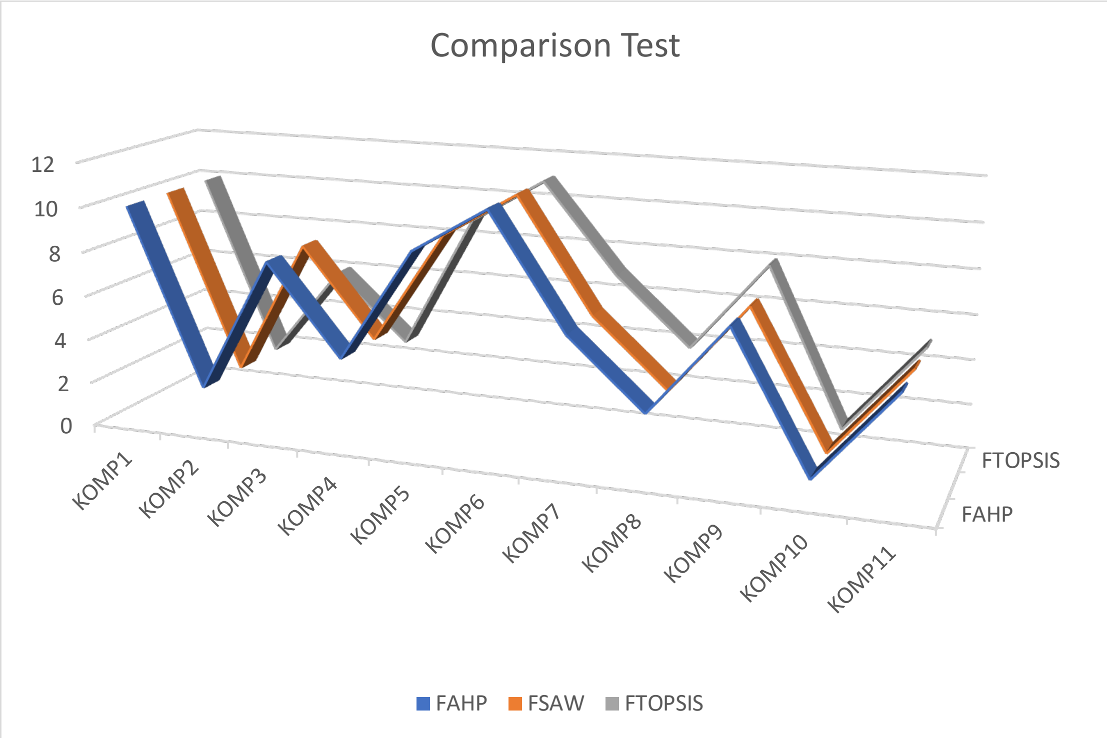


Figure 4.11. Results of the Comparison Test of Ranking of Fuzzy AHP, SAW and TOPSIS.

Figure 4.11 shows the results of the comparison test of digital competency rankings between analytical calculations using Fuzzy AHP with SAW and TOPSIS. The results obtained that the comparison between Fuzzy AHP and SAW has the same ranking order in all competencies or in percentage terms can be expressed as 100% of the number of existing alternatives. When itcompared with TOPSIS there are 8 out of 11 competencies that have the same ranking as the results of fuzzy AHP or 73% of the total number of alternatives. The 8 competencies are KOMP1, KOMP2, KOMP3, KOMP5, KOMP6, KOMP7, KOMP10, KOMP11. Furthermore, based on the overall comparison between fuzzy AHP, TOPSIS and SAW shows 73% that have the same ranking. The top 3 ranking order always shows similarities in the three methods compared, namely competencies KOMP10, KOMP2 and KOMP8. The figure 4.12 explain the detail of different rank among AHP, SAW and TOPSIS.

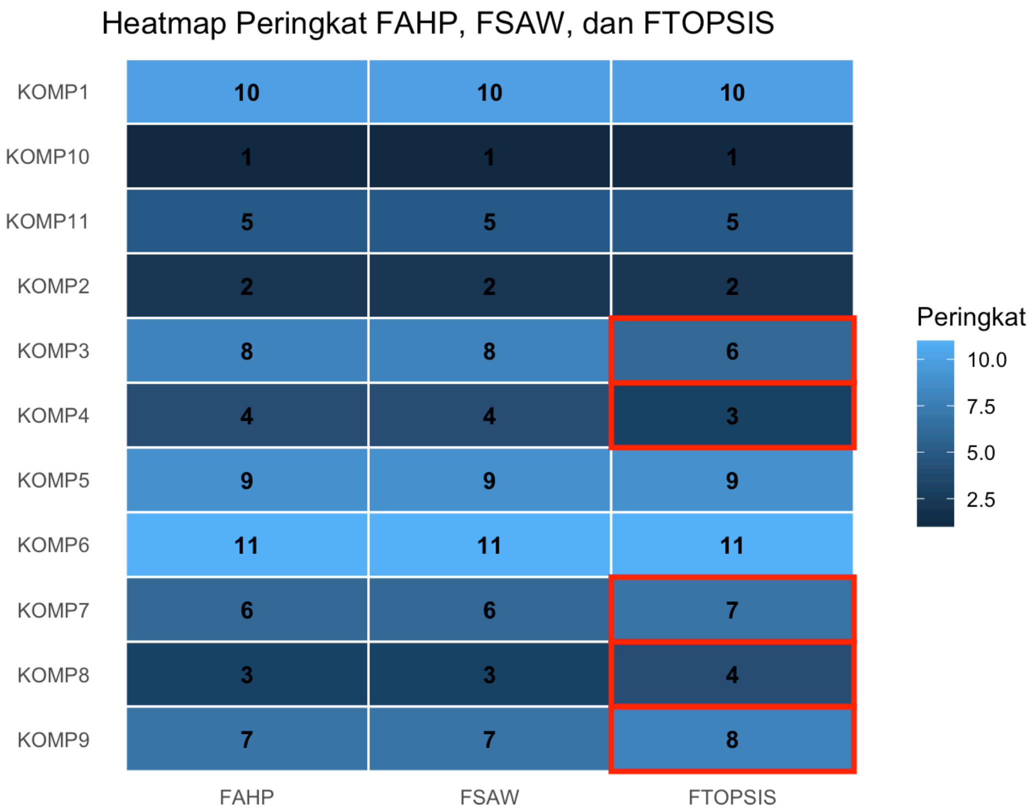


Figure 4.12. A detail rank comparison of three results

4.4 How reliable are digital competence indicator prioritization results using Fuzzy AHP, SAW, and TOPSIS under various weighting scenarios?

In a digital competency model involving criteria from three experts in different fields, sensitivity analysis serves to evaluate how changes in the weighting of each criterion affect the model's results. This is important because each group has different priorities, and changes in weighting can reflect the level of importance or influence assigned to each party. In the sensitivity test, the experiment was conducted 12 times to evaluate the effect of changes in the criteria's weightings on the analysis results. The criteria's weights were changed by increasing and decreasing them by 5% and 10%, respectively, creating a variety of scenarios to measure the stability of the resulting decisions. This test is crucial to ensure that the analysis results remain consistent despite changes in the criteria's weightings. The testing process was conducted systematically, and the results were analyzed to identify significant patterns or changes. All the experimental results are comprehensively summarized in Figure 4.13 and Table 4.29, which contain complete data on the impact of weighting changes on the analysis results.

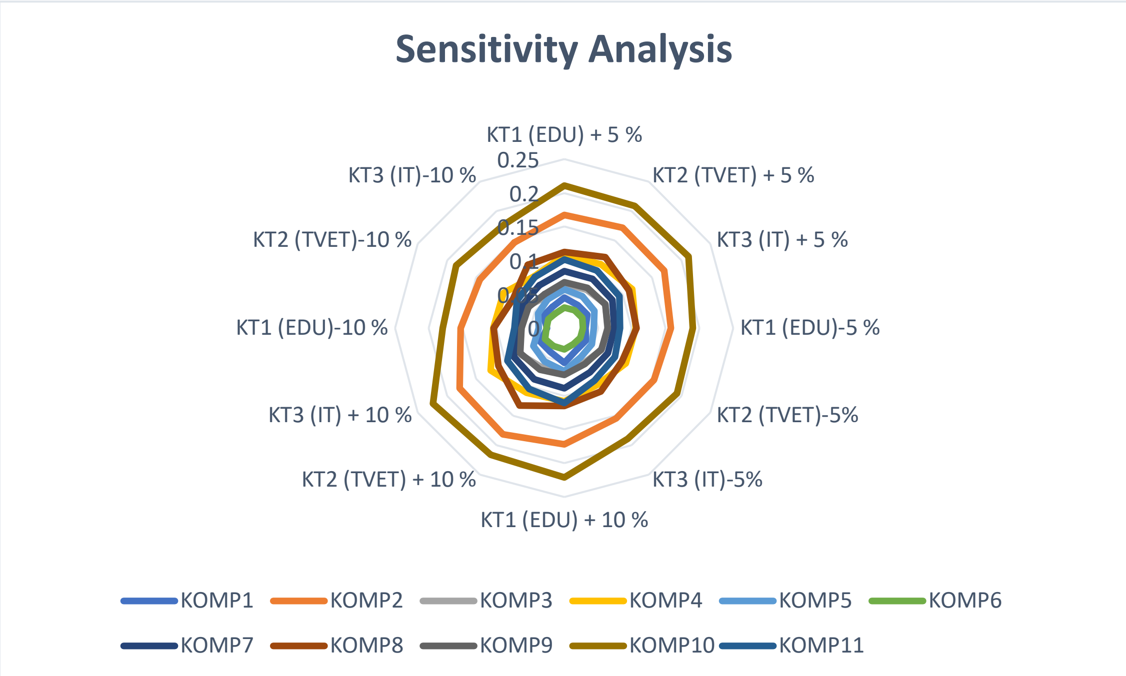


Figure 4.13 Results of the experiment on changing the criteria weights in sensitivity analysis

Figure 4.13 shows the results of 12 trials of criteria weight changes. The highest value was achieved in the seventh trial, with an +10% weighting of criterion 3, resulting in a weighting of 0.223 for alternative KOMP10. The lowest value was achieved in the 12th trial, with an -10% weighting of criterion 3, resulting in a weighting of 0.0254 for alternative KT3.

The author divides the experimental results based on the addition and subtraction of criteria weights in Figure 4.10. The results of adding 5% weights at different times to KT1, KT2, and KT3 are shown in Figure 4.14:

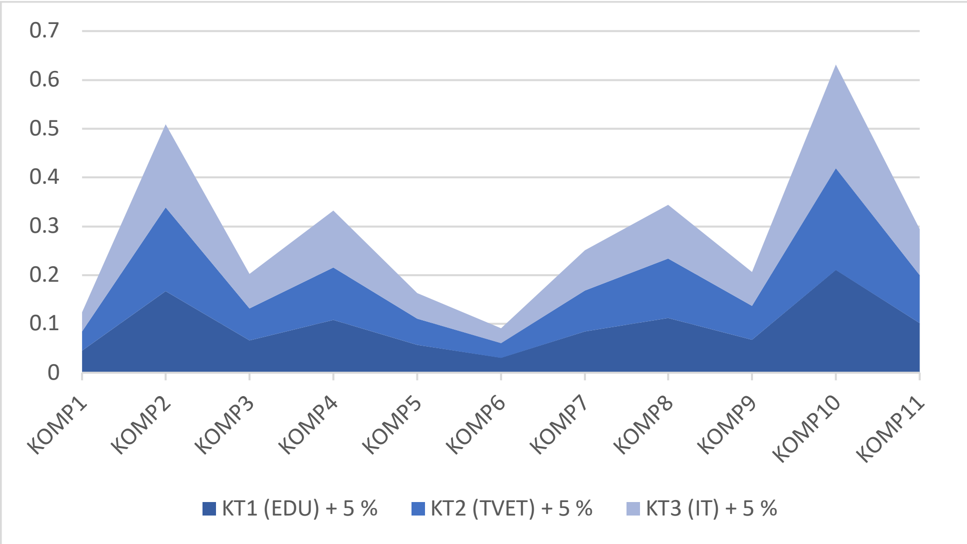


Figure 4.14 The results of the ranking changes in the sensitivity test by adding 5% to the criteria weight.

The first through third trials, as shown in Figure 4.14, were conducted by adding 5% to the criteria weights each time. The analysis results showed a change in the ranking order of the alternatives, indicating that changes in criteria weights significantly affected alternative priorities. Of all the alternatives analyzed, 54% maintained the same ranking order despite the adjustment in weights. It indicates that most alternatives are sensitive to changes in criteria weights, thus emphasizing the importance of determining accurate weights to support consistent and reliable decision-making. However, KOMP10 remained in first place in all trials. These results provide an overview when this model is used in the future and changes in the criteria in this case experts of each field do not affect the priority level and ranking order especially from the KOMP10 competency, besides that other competencies that have reliability and stability in this experiment are KOMP2, KOMP3, KOMP5, KOMP6, KOMP7, and KOMP11. Then the next experiment in the sensitivity test by reducing 5% of the criteria weight is shown in Figure 4.15.

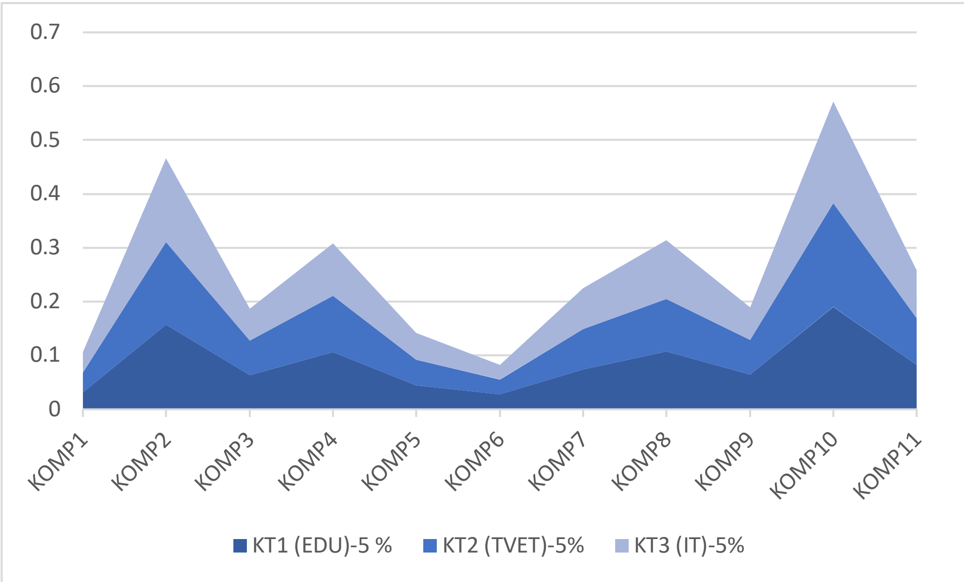


Figure 4.15. Results of Ranking Changes in Sensitivity Test by Reducing 5% in Criteria Weights

The fourth to sixth experiments were conducted by reducing the criteria weights by 5% in each iteration. This change caused the weights on the alternatives to change, which affected the final ranking results. Based on the analysis, another 54% of the total alternatives remained in the same ranking position despite the weight reduction. These results indicate that half of the alternatives have a fairly good level of stability to weight changes, while the rest show a higher sensitivity to adjustments in criteria weights. These results can be used as a reference that competencies that have stable and reliable rankings and weights when applied to changes in time and conditions and changes in criteria will not be affected. Some of the competencies that were stable and reliable in this experiment were KOMP1, KOMP2, KOMP5, KOMP6, KOMP7, and KOMP10.

Table 4.29. Ranking Change Results in Sensitivity Analysis

	Trial 1 – 3			Trial 4 – 6			Trial 7 – 9			Trial 10 - 12		
	KT1 (EDU) + 5 %	**KT2 (TVET) + 5 %**	**KT3 (IT) + 5 %**	**KT1 (EDU)-5 %**	**KT2 (TVET)-5%**	**KT3 (IT)-5%**	**KT1 (EDU) + 10 %**	**KT2 (TVET) + 10 %**	**KT3 (IT) + 10 %**	**KT1 (EDU)-10 %**	**KT2 (TVET)-10 %**	**KT3 (IT)-10 %**
KOMP1	0.04490609	0.03964702	0.03962539	0.03174386	0.03700293	0.03702456	0.0514872	0.04096906	0.0409258	0.02516275	0.03568089	0.03572415
KOMP2	0.16732084	0.17191449	0.17048298	0.15782186	0.15322821	0.15465971	0.17207033	0.18125762	0.17839462	0.15307237	0.14388508	0.14674808
KOMP3	0.06595113	0.06591938	0.07078947	0.06406509	0.06409684	0.05922675	0.06689414	0.06683064	0.07657083	0.06312208	0.06318558	0.05344539
KOMP4	0.10757509	0.10857917	0.11606793	0.10586306	0.10485899	0.09737023	0.10843111	0.11043926	0.12541678	0.10500705	0.10299889	0.08802138
KOMP5	0.05728737	0.05401868	0.05161464	0.04412515	0.04739383	0.04979788	0.06386848	0.05733111	0.05252302	0.03754403	0.04408141	0.0488895
KOMP6	0.03029137	0.03013923	0.03082489	0.02777632	0.02792845	0.0272428	0.03154889	0.03124463	0.03261594	0.0265188	0.02682306	0.02545175
KOMP7	0.084172	0.08365573	0.08250529	0.07423443	0.0747507	0.07590114	0.08914079	0.08810824	0.08580736	0.06926564	0.07029819	0.07259907
KOMP8	0.1125323	0.12118776	0.11088671	0.10699682	0.09834136	0.10864241	0.11530003	0.13261096	0.11200885	0.10422909	0.08691816	0.10752027
KOMP9	0.0677293	0.06861659	0.07058151	0.06456952	0.06368223	0.06171731	0.06930919	0.07108377	0.07501361	0.06298963	0.06121505	0.05728521
KOMP10	0.21076635	0.20846031	0.21219576	0.19021798	0.19252402	0.18878857	0.22104053	0.21642846	0.22389936	0.1799438	0.18455588	0.17708498
KOMP11	0.10146817	0.09786164	0.09442543	0.0825859	0.08619242	0.08962863	0.1109093	0.10369625	0.09682383	0.07314476	0.08035782	0.08723023

Then in the seventh, eighth and ninth experiments by adding or increasing each criteria weight by 10%, the results can be seen in Figure 4.16:

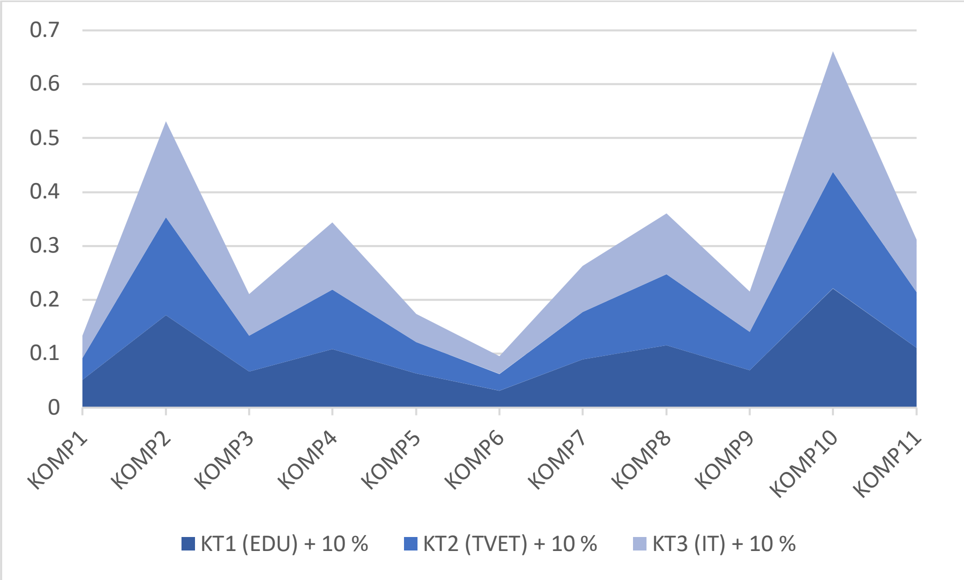


Figure 4.16. Sensitivity Test Results by Adding +10% to the Criteria Weight

In this experiment, the results of which can be seen in Figure 4.16, the criteria weights were changed by adding 10%. The analysis showed that 54% of the total alternatives still managed to maintain their same ranking positions. This percentage is very consistent with the previous experiment, indicating that the 10% weight increase did not significantly impact the ranking order of the alternatives. This finding underscores the high sensitivity of most alternatives to larger changes in criteria weights. Several competencies that were found to be stable and reliable in this experiment were KOMP1, KOMP2, KOMP5, KOMP6, KOMP7, and KOMP10. In the final experiment, the criteria weights were reduced by 10% from the resulting weights, or fixed values. The results of the analysis can be seen in Figure 4.17.

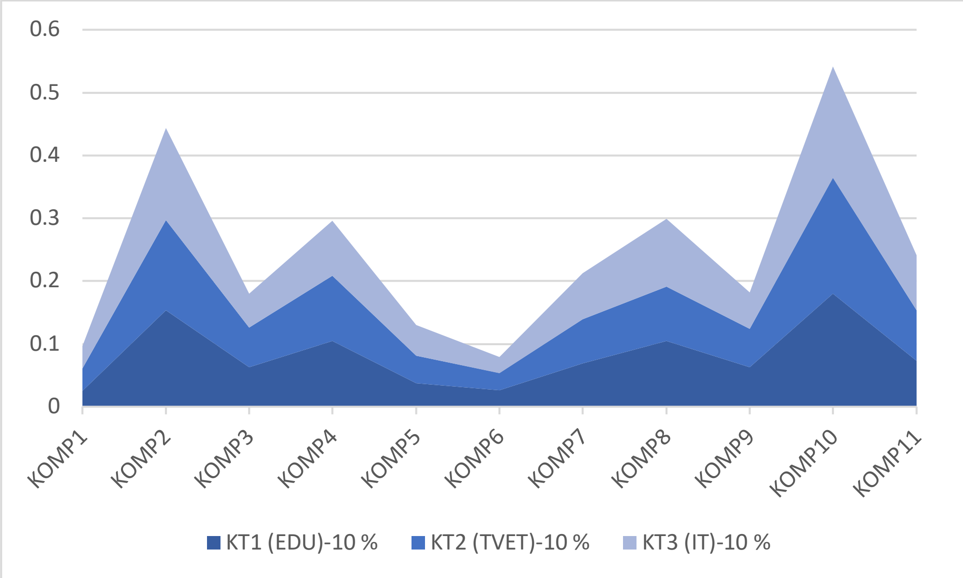


Figure 4.17. Sensitivity Test by Adding -10% to the Criteria Weight

The sensitivity test in the 10th to 12th experiments was conducted by reducing the criteria weight by 10%. The analysis results showed that 54% of the total alternatives maintained the same ranking order despite changes in the criteria weights. This percentage indicates no shift from the previous experiment, where changes in weights had no effect at all on the ranking order of the alternatives. This finding indicates that despite significant changes in the criteria weights, a number of alternatives remained relatively stable and even the same, indicating that some alternatives were less sensitive to larger weight reductions. The following are some of the stable competencies in this experiment: KOMP1, KOMP2, KOMP5, KOMP6, KOMP7, KOMP10.

These results demonstrate the stability of the designed model for future use. This demonstrates that changes in criteria from experts in education, TVET, and IT did not affect the priority level and ranking order, particularly for the KOMP10 competency, which ranked first in all trials. Therefore, this model is adaptive and remains relevant under various conditions. This analysis did not observe weight changes, but rather a reversal of rankings for the same competencies. This demonstrates that the model applied in the analysis is capable of capturing priority dynamics without compromising the accuracy of the competency weights. This indicates that despite adjustments to new needs or challenges in the field, the model maintains its focus on developing the most fundamental and impactful competencies, such as KOMP10.

Its relevance to field implementation is that this model can be relied upon as a strategic guide in educational planning, both at the level of implementing learning as a mandatory competency for educators in the curriculum and for individual and professional training. Furthermore, the model's flexibility allows stakeholders, such as teachers and digital competency experts, to adopt a more responsive approach to changing needs without having to make major revisions to the previous competency priority structure. After conducting a sensitivity test, the results show a ranking of the 11 digital competencies, from highest to lowest weight.

It provides a clear picture of the most dominant competency priorities and those requiring further attention. Table 4.30 presents the weighting and ranking of the digital competencies, sorted by dimension. This table allows for a more in-depth analysis of how the competency weighting and ranking are influenced by each relevant dimension and provides useful information for further decision-making. The overall weight results can be seen in Figure 4.18.

Table 4.30. Digital Competence Weighting and Ranking Results

	EDU	TVET	IT	WEIGHT	RANK
KOMP1	0.015	0.012	0.011	0.038	10
KOMP2	0.011	0.076	0.076	0.162	2
KOMP3	0.002	0.055	0.007	0.065	8
KOMP4	0.002	0.09	0.015	0.106	4
KOMP5	0.015	0.009	0.027	0.05	9
KOMP6	0.003	0.017	0.009	0.029	11
KOMP7	0.011	0.032	0.036	0.079	6
KOMP8	0.006	0.011	0.093	0.109	3
KOMP9	0.004	0.043	0.02	0.066	7
KOMP10	0.024	0.112	0.065	0.200	1
KOMP11	0.022	0.023	0.047	0.092	5

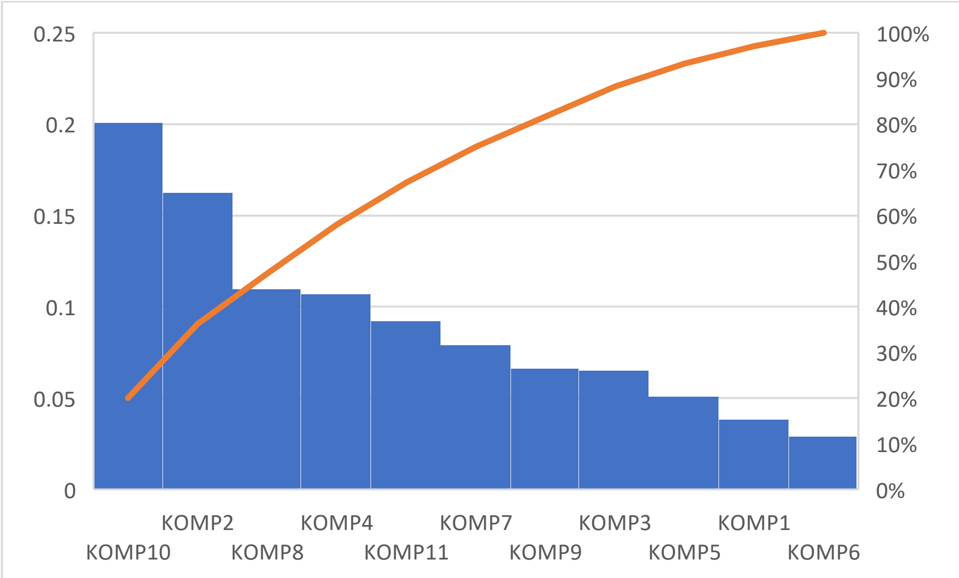


Figure 4.18. Digital Competencies Priority Order Results.

This identification process can be used as a recommendation for creating a digital competency model at the next stage.

4.5 How can digital competence's validated components and criteria be synthesized into a new framework for vocational education development?

This section explains the research objective to develop a digital competency framework as a reference for shaping vocational education that aligns with the needs of a sustainable workforce. The researcher details the results of the model design according to the following steps:

a. Definition Results of Digital Competence Components

At this stage, the components derived from the needs analysis are delineated, and each component is articulated through a formal definition. This approach facilitates a comprehensive understanding of the conceptual framework, underlying meaning, and functional role of each component. The specific definitions of the competencies discussed earlier are presented in Table 4.31:

The digital safety aims to define the importance of safeguarding digital and physical well-being through various means. It underscores the necessity of protecting devices, content, personal data, and privacy within digital environments. Furthermore, it emphasizes the need to promote physical and psychological health while fostering awareness of digital technologies as tools for enhancing teaching and technology integration. Additionally, the statement highlights the significance of understanding the social community impacts associated with digital technologies and their usage, thereby encouraging responsible and sustainable engagement with digital tools especially for teachers in their community.

Table 4.31. Definition of Digital Competence for Educators

Components	Definition
Information and data literacy	The purpose of information and data literacy is to efficiently locate and retrieve digital data, information, and content, especially related to teaching materials. It also involves evaluating the relevance of sources and their content. Additionally, it encompasses the storage, management, and organization of digital data, information, teaching materials and content.
Communication and Collaboration	This objective aims to facilitate interaction, communication, and collaboration through digital technologies, especially in teaching and learning with teacher or industrial stakeholder (for vocational educators). It emphasizes active participation in society via public and private digital services, as well as the promotion of participatory as an educator concern. Additionally, it underscores the importance of managing one's digital presence, identity, and reputation in an increasingly interconnected teaching in digital landscape.
Digital Content Creation	The competence emphasized the creation and editing of digital content and teaching materials, as well as the enhancement and integration of references within a teaching material. This process requires an understanding of copyright laws, ethics and licensing agreements in using the data for teaching materials. Additionally, it involves the ability to issue clear and comprehensible instructions to digital system and the ethics, especially in this AI era.
Digital Safety	The digital safety aims to define the importance of safeguarding digital and physical well-being through various means. It underscores the necessity of protecting devices, content, personal data, and privacy within digital environments. Furthermore, it emphasizes the need to promote physical and psychological health while fostering awareness of digital technologies as tools for enhancing

Components	Definition
	teaching and technology integration. Additionally, the statement highlights the significance of understanding the social community impacts associated with digital technologies and their usage, thereby encouraging responsible and sustainable engagement with digital tools especially for teachers in their community.
Problem Solving	The objective is to systematically identify needs and issues, as well as to address conceptual challenges and problematic situations within digital environments. Additionally, it involves leveraging digital tools for teaching to foster innovation in processes and product development. Continuous engagement with the ongoing digital evolution is also essential to maintain relevance and competence in the field. Compared to the general educators, this competence includes vocational teachers' requirements to adjust their digital competence with the advancement of technology in industry.
Professional Engagement	This competence aims to enhance digital technologies for communication, collaboration, and professional growth for educators in integrating technology into teaching and learning.
Digital Resources	A critical competency for educators is to develop a comprehensive understanding of this diversity. This entails effectively identifying resources that align with specific learning objectives, diverse learner groups, and various pedagogical styles. Additionally, educators must be able to craft rich instructional materials, establish meaningful connections, and adapt, augment, or develop their own digital resources to enhance their teaching effectiveness.
Digital Teaching and Learning	This competency refers to the design, planning, and implementation of digital technology at various stages of the learning process.
Digital Assessment	Assessment can either support or hinder innovation in education. When incorporating digital technologies into learning and teaching, it is important to consider how these tools can improve current assessment methods. Additionally, teachers should explore how digital technologies can enable new or innovative assessment techniques. Educators with digital competence should be able to effectively incorporate digital tools into assessment practices.
Empowering Learners' Digital Skill	One of the primary advantages of digital technologies in educational contexts is their capacity to support learner-centered pedagogical approaches and to enhance active learner engagement and ownership of the learning process. Consequently, digital technologies can be strategically employed to facilitate active participation, such as exploring topics in depth, experimenting with various

Components	Definition
	options or solutions, recognizing interconnections, generating innovative ideas, producing products, and engaging in reflective practices. Moreover, it also becomes essential for the vocational educators to support learners' digital skills, which emphasizes their future career.
Facilitating Learners' Digital Competence	Digital competence is a key transversal skill that educators need to develop in learners. While promoting other transversal skills depends on educators using digital technologies, the ability to guide learners in developing their digital skills is a fundamental part of educators' digital competence.

The digital competence framework for educators in both vocational and general education can be integrated into curriculum policy through several strategic steps aimed at enhancing teachers' digital skills. This involves emphasizing digital content in teaching and improving infrastructure to support digital competence development. Comprehensive training programs should be provided by the government and policy-making NGOs. Industry stakeholders must also be involved in offering regular training to vocational educators, helping them stay current with technological advancements used in industry, which can then be transferred to students. Teacher training modules should include sustainability principles to ensure effective teaching. Regulations for managing digital competence in vocational schools—especially for fields demanding high digital skills like engineering or network systems—must be established to support students' digital skill development. Policies that promote partnerships between vocational schools and industries can offer students real-world experiences. Additionally, mandatory inclusion of digital competencies in professional certification can verify that teachers and graduates possess recognized expertise in sustainable practices. Implementing these measures can fortify vocational education systems, making them more aligned with labor market demands, fostering lifelong learning, and supporting SDGs.

b. **Results of Creating the Digital Competence Model Structure for Educators**

The framework model structure includes 11 competencies outlined in the previous stage. This model is visualized in Figure 4.19.

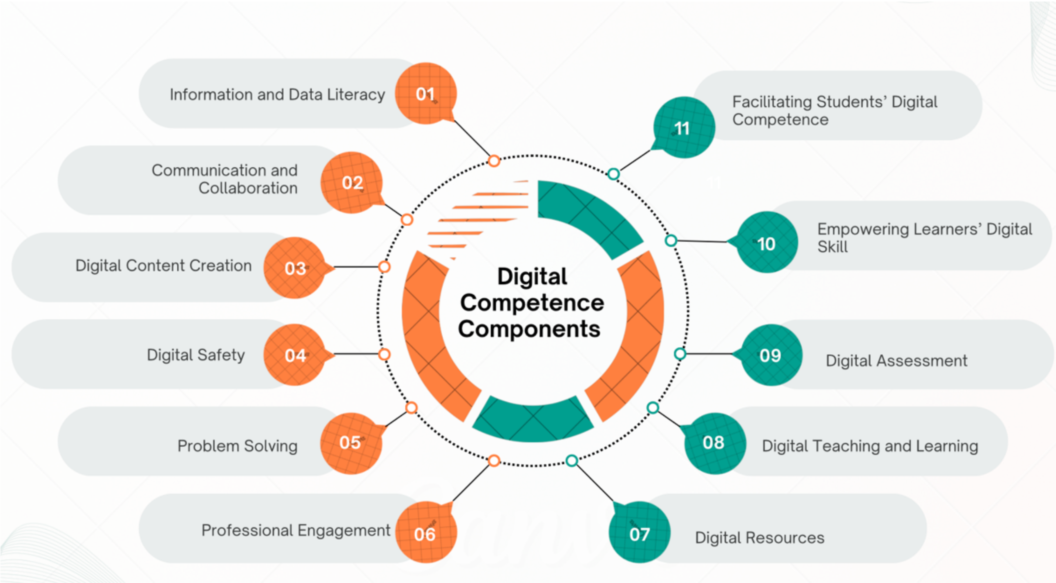


Figure 4.19. The Initial Model Digital Competencies Model Design

This research endeavour seeks to systematically examine the various dimensions of digital competence among educators, grounded in a comprehensive review of extant literature frameworks. Table 4.1 outlines the nine scholarly documents that have been carefully selected and thoroughly reviewed.

c. **Expert Panel through FGD**

This phase involves the process of input provision, model testing, and evaluation. Focus Group Discussions (FGDs) were conducted to assess the perspectives and practicality of the proposed digital competency model. The initial discussion addressed the urgency of developing the model, with insights derived from experts across relevant fields, including Education, Technical and Vocational Education and Training (TVET), and Information Technology (IT), all of which are intrinsically linked to digital competency. Curriculum specialists further examined the development of this model, considering it as an innovative approach and a necessary step to address the challenges and issues related to digital competency in the context of rapid technological advancement. The experts gave their perspective on the first question related to the urgency of digital competence for educators in the era of digital advancement especially the use of AI. The Expert 7 from TVET field stated that the high demand and development of technology commonly not really stressing for the teachers as long as there are training. It is something really new for them because it is progressively developing every day.

Expert 7: "*....AI, which for me means that the teacher not would have been decreased a bit. In some sense, it could have been increased because for some. Specific competencies they could have gained some points, but Gen. AI is again something completely* ***new for them****. They are organizing themselves. We are also offering them specific* ***courses and trainings*** *for this specific topic, but it's still in the middle, so it's still ongoing. Yeah. So actually that's interesting."*

However, the statement emphasized that technological advancements evolve rapidly and constitute something new for educators, requiring them to continuously adapt to emerging tools and methodologies. Another statement from expert 3 as IT expert stated that the needs of digital competence for teachers in the technological advancement is really crucial.

Expert 3: *"...Competencies need to be enhanced toward digital, as evidenced by policies already in place. For example, in cyber-pedagogy, teachers must possess advanced digital literacy, which must be effective in teaching and learning. Furthermore, we must be prepared for this digital era, addressing the sudden changes that occur, the development of digital capabilities, and socioeconomic changes. Therefore, we must prepare students with soft skills, including creative thinking, collaboration, and computational thinking. In conclusion, this is a crucial and urgent matter."*

Other expert in TVET, expert 8 stated that the urgency of digital competence is really high and crucial especially in vocational education.

Expert 8: *"...The enhancement of digital skills is regulated by UNESCO, with competency standards, particularly in vocational education. There are regulations/policies regarding their use in schools, including those related to financial allocation/fees. If schools can achieve this, it would be extraordinary. Students as learners and teachers as facilitators can benefit from it. How can policies be incorporated into the curriculum? For example, some teachers refuse to use AI. Does today's curriculum address the urgency of digital competency? Does the curriculum accommodate the demands of teachers who must use digital at this level? Furthermore, regarding pedagogy, teachers can develop engaging* *methods and approaches, and how can they train teachers to utilize these competencies in their pedagogy? Finally, adequate ICT infrastructure capabilities are crucial. In conclusion, this is crucial, especially to keep pace with the development of science and technology."*

The statement emphasizes the importance of developing digital competencies among educators, highlighting that such competencies are particularly complex for teachers. This complexity arises from the necessity to seamlessly integrate digital skills with pedagogical materials, teaching methodologies, and the broader implications for industry, especially in the context of vocational education. The urgency of this digital competence is aligned with the next discussion topic.

The concern of this digital competence for educators needs something new in its components, which was then guided by a question: "What are the most important digital competencies for educators to be mastered, and are there any proposed new competencies that are important to be mastered (in addition to existing competencies)?". The experts are all agreed and concerned with the digital ethics to be included in digital competence components. There are several statements agreeing digital ethics in this rapid technology changes, especially with the trends of AI and generative AI used in education. An expert from educational field stated that ethics in digital competence is the most crucial component.

Expert 1: *"...I'm highlighting important digital competencies not only at the intermediate level but also at the tertiary level. I'm focusing on digital ethics. Digital literacy has inherently improved, but ethically, this is crucial in how they use AI. One aspect of digital information is the need to be adept at evaluating information. However, digital literacy education hasn't reached that level, especially for teachers who have followers, for example, in school WhatsApp groups. If information isn't filtered, it will have an impact. Identity managers can be transferred to students…"*

The statement said that the development of digital technology is skyrocketing, yet digital ethics competence hasn't become a concern. Another statement from an IT expert, expert 4 also agreed with the idea of digital ethics but the ethical competence needs to be followed by humanity aspect and problem solving.

Expert 4: *"The focus on collaboration isn't just a competency but also a kind of leadership tool. Using Google Docs for collaboration and chat is acceptable, but ethically, in my view. The roles of teachers, educators, coaches, mentors, and digital facilitators vary depending on the type of mentor and motivator they are. Therefore, digital competencies differ based on different circumstances. Creative thinking includes two aspects: 1. Humanity and problem-solving—how teachers and educators address humanitarian needs. There should be no solutions that lack humanity."*

Furthermore, an IT expert, Expert 5, stated that digital skills teachers need to acquire are their right, and we should not evaluate them solely on what they have learned.

Expert 5: *"Regarding digital competency for teachers, while in the past, teachers were considered the sole source of knowledge, now the situation has reversed: information is available from anywhere and to everyone, making it hard to tell good information from false. As a teacher, being the primary source of information is no longer relevant. Instead, a teacher's role is to decide what to do with that information. Teachers need to be skilled at matching information to the right context. Technically, students might be more skilled at using tools, but the teacher's role is now in managing and guiding this process.…"*

An additional explanation and statement from the IT expert, expert 6 stated that a character quality is also really important and it is really stressful for the teachers.

Expert 6: *"Interested in ethics, I added that, for example, in the digital context, there's a lot of stress. This requires incorporating character qualities in dealing with environmental changes. Problem-solving, professional engagement, digital assessment, and so on, are all key areas. However, the character of teachers remains elusive."*

The complexity of digital competence for educators raises a question, as the educational system is differentiated into two systems: general education and vocational education. Questions 3 and 4 focus on the differences between digital competence in general education and vocational education. An expert from TVET, expert 9 stated that the implementation of digital competence in both general and vocational education is likely to be similar. However, vocational adaptive educators need to adjust their teaching materials in response to the advancement of industrial technology and incorporate them into their teaching and learning. Therefore, the teachers need to possess high digital competence. Here are the statements from several experts.

Expert 9: *"…A crucial distinction between general and vocational education. In vocational settings, AI is essential for practical technological applications, such as simulations in design. For example, in robotics, we usually use AI to develop programs and PLCs, which are typically assisted by AI. I view the implementation of AI in learning from the perspective of learning objectives. Vocational teachers can be categorized as normative, adaptive, or productive teachers. The use of AI varies between adaptive and normative teachers and productive teachers. Normative teachers only utilize AI, whereas productive teachers focus more on implementation. The key difference lies in the learning objectives so that's why the separation between general and vocational is actually needed"*

A statement from expert 10 also provided insight that the differences between general and vocational education lie in their learning objectives and the complexity of practical adjustments to the workforce.

Expert 10: *"The difference lies in the unique characteristics of vocational education. Vocational education focuses on practical skills and adaptive technology. Educators must keep up with these technological developments. For example, in the use of technology in vocational education, such as this internship, students' abilities are at an advanced level and they are very up to speed with technology. These practical skills and the demands of the workplace are also important…"*

Another statement from an expert in TVET also agreed that there is a need to separate the digital competence for general and vocational education.

Expert 7: *"…So digital competence is one piece of a much wider puzzle concerning technology integration. This was a kind of a side comment, but it's important for me in this respect. When you speak about differences probably it's not enough to speak about vocational versus general. Because as I said, there are many differences and important differences also within vocational education. So, if you speak about dual VET dual vocational education or vocational education, I would refer again to what I said. There is a need to a specific model. Specific pedagogical model for technology integration. We developed which requires at least partially, requires some specific competencies, digital competencies by teachers, and this is the area we we added to the DigCompEdu."*

The necessity for a specialized model in this context has highlighted two significant themes: namely, that the digital competence model must be more comprehensive to address both general and vocational education. This distinction arises from the differing objectives inherent in these educational domains.

Table 4.32 Themes from Expert Panels

Categories	Sub-categories	Anchor Examples	Theme Results
Perceived Usefulness	Digital competencies urgency	A preparation is a must for this digital era, addressing the sudden changes that occur, the development of digital capabilities, and socioeconomic changes. Therefore, we must prepare students with soft skills, including creative thinking, collaboration, and computational thinking. In conclusion, this is a crucial and urgent matter but need a more deeper explanation of ethical problem for digital competence	*Ethical issues*
Perceived ease of use	Digital competencies components	Digital ethics need to be a concern since the development of technology are really rapid yet the ethical competence is still low	*Ethical Issues*
Attitudes towards technology	The complexity of digital competencies in each area	The key differences of vocational education and general education is on its learning objectives and the complexity needs of technology integration. So, it is different with the general education.	*Digital Competence for Vocational Educators*
Perceived ease of use	The needs of specialization in digital competencies	There is a need to separate the digital competence model for vocational education and general education to have more specific competencies.	*Digital Competence for Vocational Educators*

Based on the various statements above, after reviewing all aspects, it can be concluded that, overall, both the content and construction of this model still need to be further developed and require further research regarding its components and aspects. However, several important points are noted and some suggestions for improvement, such as:

1) The need to prioritize digital ethics.
2) The division between digital competency models for vocational and general use.

d. A Revised Model

The following are the improvements suggested by experts, particularly in terms of construction. The structural results of the upgrades to the digital competency model can be seen in Figure 4.20.

The integrated digital competence framework for vocational educators emerged from a sequential, multi-source research process that combined qualitative, quantitative, and multi-criteria decision-making analyses. The process began with a focus group discussion (FGD) involving vocational educators from various regions, which identified both external and internal determinants of digital competence. External factors included engagement and ethics in online professional communities, while internal factors highlighted the value of collaboration with younger colleagues to enhance digital integration in teaching.

The national survey, distributed to 228 vocational teachers across five major island regions, revealed a generally strong self-reported competence in digital learning and ethics, but comparatively lower proficiency in digital management, collaboration, and professional development. Significant regional disparities were observed, particularly in professional ethics, with Sulawesi and Java outperforming Papua. Interestingly, while "Digital Ethics" received the highest mean score in the survey, the earlier educator FGD had revealed gaps in actual ethical practice in classrooms, reinforcing the need to embed ethics explicitly within all components of the framework. This insight was critical in ensuring that ethical considerations—covering responsible technology use, copyright compliance, learner privacy, and professional integrity—were woven into each competence definition rather than treated as an isolated skill set.

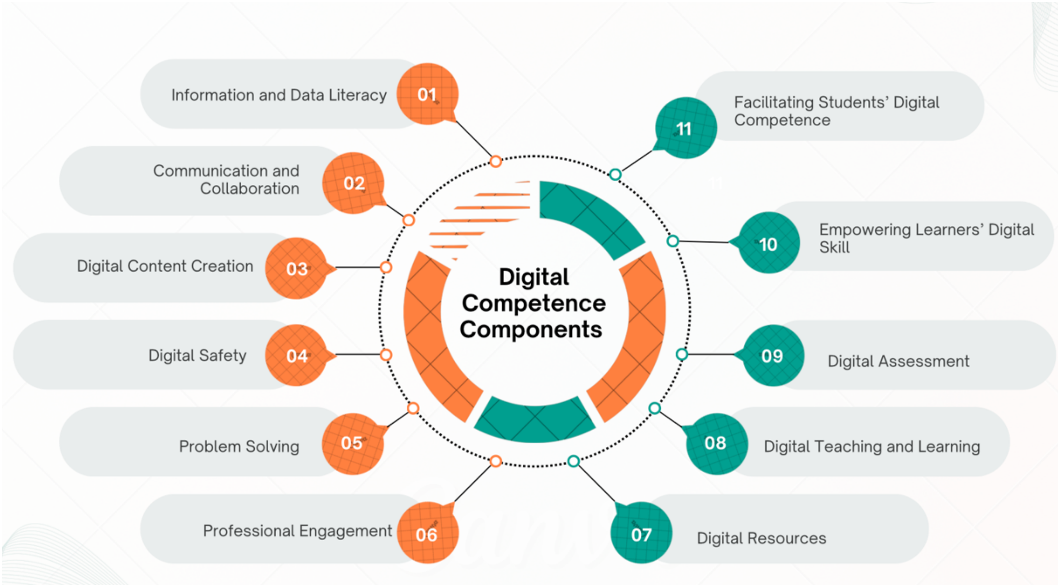


Figure 4.20. (a) A Former Digital Competencies Model.

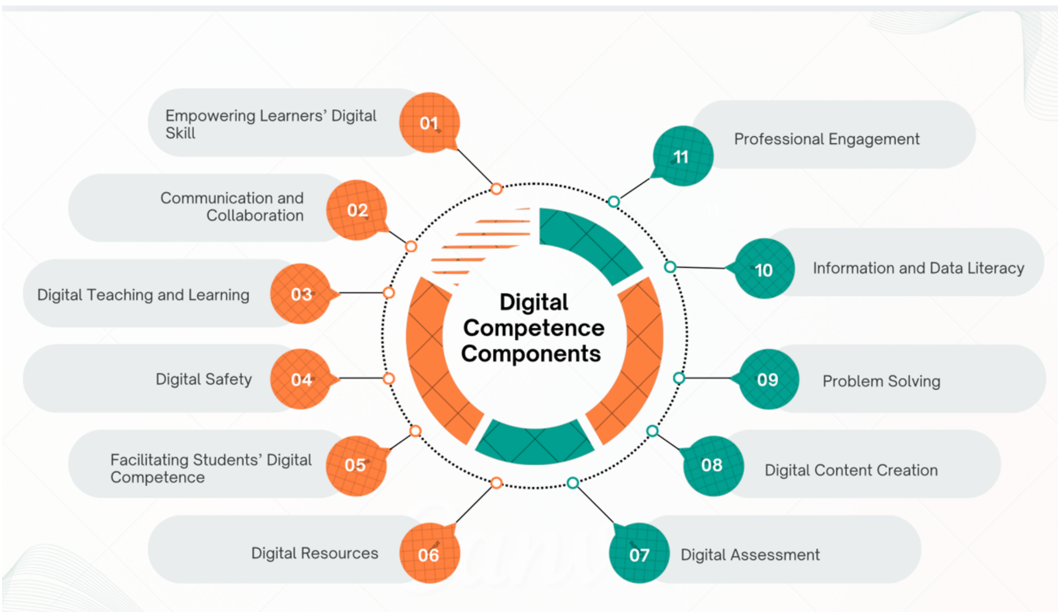


Figure 4.20. (b) A Revised Digital Competencies Model.

To establish defensible priorities for the final framework, ten international experts in education, TVET, and IT from three continents participated in further FGDs and a structured pairwise comparison exercise. Using Triangular Fuzzy Numbers and the Geometric Mean Method in Fuzzy AHP, cross-verified by SAW and TOPSIS with sensitivity analysis, the experts ranked the eleven identified components. The highest priority was assigned to *Empowering Learners' Digital Competence* (KOMP10), reflecting the urgent need for vocational educators to equip students with industry-ready digital skills.

The remaining components were ordered to reflect both pedagogical and industrial imperatives, producing a model that is industry-responsive, adaptable to technological change, and grounded in ethical practice. The final integrated framework retains the conceptual clarity of existing digital competence models while adapting definitions to align with vocational educators' needs—combining teaching content with industrial developments, ensuring relevance to emerging workplace technologies, and safeguarding ethical integrity in all digital practices. The following table (Table 4.33) is the detail of the new framework detail.

Table 4.33 DICGEVE

No	Components	Integrated definition (general + vocational educators' needs)	Ethics implementation
1	**Empowering Learners' Digital Skill**	One of the primary advantages of digital technologies in educational contexts is their capacity to support learner-centered pedagogical approaches and enhance active learner engagement and ownership of the learning process. Digital technologies can be strategically employed to facilitate active participation, such as exploring topics in depth, experimenting with various solutions, recognizing interconnections, generating innovative ideas, producing products, and engaging in reflective practices. For vocational educators, this extends to supporting learners' digital skills with a focus on future career readiness, using job-relevant tools (e.g., ERP dashboards, CAD/CAM software, industry simulations) and coaching professional digital presence.	Teach reputational risks; model ethical prompts and data handling; promote safe online communities and responsible participation; highlight the consequences of poor digital behavior in professional contexts.
2	**Communication and Collaboration**	Facilitates interaction, communication, and collaboration through digital technologies, especially in teaching and learning with fellow educators or industrial stakeholders. Promotes active participation in society via public and private digital	Respect workplace netiquette; obtain consent for recordings; safeguard identities; separate personal and professional

No	Components	Integrated definition (general + vocational educators' needs)	Ethics implementation
		services, and emphasizes managing one's digital presence, identity, and reputation. For vocational educators, this includes using industry-standard platforms (e.g., Teams, Slack, project management tools) to communicate with companies, coordinate work-integrated learning activities, and bridge academic–industry collaboration.	workspaces; be transparent about AI-assisted communications.
3	**Digital Teaching and Learning**	Refers to the design, planning, and implementation of digital technology at various stages of the learning process, enabling educators to integrate tools effectively to enhance pedagogy. For vocational educators, this involves combining physical workshop learning with simulations and virtual labs (e.g., digital twins, AR/VR for machinery), and scaffolding technology integration from tool literacy to full industry workflow application.	Ensure accessibility and inclusivity; obtain consent for data collection in technology trials; avoid intrusive surveillance in learning analytics; provide alternative methods for learners without certain devices.
4	**Digital Safety**	Focuses on safeguarding digital and physical well-being, protecting devices, content, personal data, and privacy. Promotes psychological health and raises awareness of the social impacts of digital technologies. For vocational educators, this includes addressing risks in labs, IoT devices, robotics, and industrial software; securing shared equipment; and modeling safe, sustainable technology use in industry-relevant environments.	Apply privacy-by-default; secure devices and data; avoid storing sensitive industry or student data on unsecured systems; promote healthy ergonomic practices and mental well-being in tech use.
5	**Facilitating Students' Digital Competence**	Digital competence is a key transversal skill that educators need to develop in learners, enabling them to use digital tools confidently in personal, academic, and professional contexts. For vocational educators, this means diagnosing skill gaps by trade, adapting support for both on-site and digital tasks, and embedding micro-credentials or vendor certifications that align with industry requirements.	Obtain informed consent for learning analytics; ensure equitable access to tools; prevent stigma through supportive interventions; share how collected data will be used.
6	**Digital Resources**	Entails identifying, curating, adapting, and creating digital resources aligned with specific learning objectives and learner needs. For vocational educators, it involves selecting and localizing resources to match industrial processes and equipment, ensuring version control to keep pace with industry updates, and integrating authentic technical documentation into teaching.	Respect licensing and IP; avoid sharing restricted trade materials without permission; provide accessible formats; note source provenance and update dates to prevent misinformation.
7	**Digital Assessment**	When integrating digital technologies into teaching, assessment should enhance learning and support innovative practices. Competent educators can use digital tools to design effective and authentic evaluation strategies. For vocational educators, this involves implementing authentic assessment formats such as digital job cards, e-portfolios, or vendor-based evaluation systems that reflect actual workplace performance standards.	Maintain assessment integrity; enforce plagiarism and AI disclosure rules; protect assessment data; avoid bias from automated scoring; clearly define acceptable technology use during assessments.
8	**Digital Content Creation**	Involves creating and editing digital content, integrating references, and applying copyright and licensing knowledge. Includes the ability to provide clear instructions to digital systems, especially in the AI era. For vocational educators, this extends to developing sector-specific learning content such as SOP videos, process simulations, and interactive	Attribute and license all materials properly; disclose AI-generated content; avoid deceptive or unsafe edits; ensure accessibility features (captions, alt text); respect workplace confidentiality.

No	Components	Integrated definition (general + vocational educators' needs)	Ethics implementation
		manuals, as well as translating tacit shop-floor expertise into digital learning modules.	
9	**Problem Solving**	Requires identifying needs and challenges, resolving issues in digital environments, and fostering innovation through technology. Continuous engagement with ongoing digital evolution is essential. For vocational educators, this includes using industrial software (e.g., PLC programming, CAD/CAE analysis) to solve real-world problems and maintaining agility in adapting to evolving sector-specific digital tools.	Disclose limitations of tools; avoid over-reliance on automation; ensure fairness in digital solution access; document decision processes for accountability.
10	**Information and Data Literacy**	Focuses on efficiently locating, retrieving, evaluating, and managing digital data, especially teaching-related content. For vocational educators, this means sourcing and evaluating industrial documents such as SOPs, technical manuals, and CAD files; maintaining repositories for teaching; and complying with industrial confidentiality agreements.	Cite all sources accurately; verify accuracy of AI-generated information; protect confidential industry data; anonymize personal or corporate identifiers in shared materials.
11	**Professional Engagement**	Refers to using digital technologies for professional growth, networking, and collaboration to enhance teaching practice. For vocational educators, this includes engaging in continuous upskilling with industry certifications, participating in joint projects with employers, and maintaining active membership in professional and industrial associations.	Declare conflicts of interest; avoid biased promotion of vendors; maintain professional online conduct; respect confidentiality in industry partnerships.