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Original Paper

A Systematic Review on Teacher Digital Literacy in Higher Education

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Abstract

In order to conduct a conceptual review, and to discover the topics and categories of research, this study firstly searches the Google Scholar database, and then conducts a specific analysis of the 17 publications, hoping to explore the overall research that constitutes the topic of digital literacy for teachers in the university setting, to understand whether the concept needs to be continuously defined. The relative theoretical framework and key components to guide teacher digital literacy in the context of higher education have not yet been formed. It is necessary to continue to review the concept and key components of digital literacy for teachers in higher education in the future, providing a perspective for digital transformation research in higher education institutions.

Keywords

teacher digital literacy, higher education, literature review, influential factors

1. Introduction

Digital literacy can be described as a person's ability to process information, to channel effectively, to understand when and how to achieve goals in digital form (Widana et al., 2020), it can also be seen as a concept, based on the universal logarithm tool and the basic practice and intellectual ability of a kind of information society (Tejedor et al., 2020; Potyrała & Tomczyk, 2021). Given the high importance of the concept of digital literacy, the problem remains: How education institutions and educators should conceptualize teacher digital literacy. Since the definition of digital literacy in 1997, the framework of

digital literacy and capacity model have mostly concentrated at the national and international levels, and more focused on measuring the quality of teaching value research, rather than the ability to start with the education skills, which leads to the fact that the existing theoretical literature on the education level less pay attention to teacher digital literacy (Esteve et al., 2020).

However, Ayyildiz et al. (2021) reported that digital literacy is a genre, format and tool rather than a concept. Given the strong emphasis placed on the concept of digital literacy, the question remains as to how higher educational institution and educators should conceptualize teacher digital literacy. For one thing, the concept of digital literacy has been generally accepting since Glister defined it in 1997, although it has appeared in higher education not for a long time (Tejedor et al., 2020). On the other hand, the existing frameworks of digital literacy model and digital competency model at the national and international levels are mostly focused below the university level and more on accreditation systems that measure the quality of teaching value research rather than teaching skills. As a result, the conceptualization research on digital literacy of teacher at the level of higher education derived from the existing theoretical literature is not highly referable (Esteve et al., 2020), and there are not many references in practice.

For these reasons, teacher digital literacy can be considered as part of the structure of higher education. However, the challenges in higher education regarding how to conceptualize digital literacy for teachers have been widely recognized in much of the literature. It is difficult to distinguish between digital literacy and digital competence because scholars either believe that the concepts of digital literacy and digital competence in higher education are interchangeable or that the concept of digital literacy itself is dynamic and loose. This brings cognitive difficulties and challenges to the conceptualization of teacher digital literacy in higher education, of which dimensions depend on and which specific influencing factors are included. For example, Ilomakiz et al. (2016) agreed that digital literacy, digital competence and technological competence can be inter-used in certain contexts. Van et al. (2017) commented that skills in the 21st century are an organic integration of digital skills or digital literacy at multiple perspectives. Based on the development theory of new organisms, Skantz-Aberg et al. (2022) concluded that digital ability and digital literacy are difficult to be distinguished from each other in micro, meso and macro aspects. Of course, there are also scholars in the practical application of digital literacy and digital ability that believe these concepts are the relationship between inclusion and inclusion. Martin and Grudziecki (2006), for example, argued that digital competence is underpinned by digital literacy. Dong et al. (2021) put forward the opposite opinion when analyzing the Digital Education Action Plan (2021-2027) proposed by the European Union that digital literacy is included in digital competence. With the development of digital technology from teaching aids to in-depth application, it can be seen that the various methods used to classify digital literacy and digital

competence are currently either overlapping or non-exhaustive, or have conceptual ambiguity (Van Deursen et al., 2015).

However, the lack of consensus on the definition of digital literacy for teachers in higher education shows that the concept is currently confused. Although people have tried to establish their own understanding of teacher digital literacy, there is still no unified understanding of what the connotation of it is and what factors are the main indicators affecting it. For example, Tinmaz et al. (2022), based on digital literacy differences formed by different regions, believe that the topic of studying teacher digital literacy will become more important in the future. Spante et al. (2018) further suggested from the perspective of practical application that the concept of digital literacy should be redefined in the future based on critical perspective, development perspective, compatibility, and legitimate policy research. It can be seen that although the concept of teacher digital literacy has increasingly become common in public discourse, due to the differences in national conditions and cultures, the research questions, models and gaps on it are quite complex and diverse. So far, there has not been an unified universal definition.

From the search of Baidu Encyclopedia, the term of digital literacy was first drawn from the five digital literacy frameworks by the Israeli scholar, Yoram Eshet-Alkalai, after analyzing relevant literature and conducting experimental research in 1994. In 1997, Paul Gilster simplified the term digital literacy and described it as the use and understanding of information in the digital age. Since then, digital literacy has gradually evolved into a basic survival skill for citizens in the digital age (Xu et al., 2021), especially the research on digital literacy in the field of education has attracted more and more attention from scholars. The reason why the research on teacher digital literacy has gained a strong position in the context of education (Pozos & Tejada, 2018) is that, on the one hand, for future digital citizens, qualifications for digital access, digital communication and cooperation, digital etiquette, digital governance, and digital security and confidentiality are extremely important (Milenkova & Lendzhova, 2021). On the other hand, the extent to which the political, economic, cultural, professional and other aspects of citizenship can be digitized depends on the effective and appropriate use of information and communication technologies. An important prerequisite for these qualifications is that people have the corresponding digital literacy and ability.

Therefore, in the following research, the understanding of the specific characteristics and key components of teacher digital literacy in different backgrounds should be explored firstly, which can provide a more comprehensive basis for clarifying the concept of digital literacy in the new situation, because scholars have been trying to find ways to define teacher digital literacy in higher education. For example, Widana et al. (2020) put forward the view that teacher digital literacy has a direct positive impact on creativity in higher education. Zhao et al. (2021) further argued that demographic factors such as gender and teaching years also have an impact on teacher digital literacy in higher education.

However, up to now, there is still little theory that can comprehensively explain the digital literacy of teachers in higher education from the perspective of ecological development. The lack of unified understanding of the definition of teacher digital literacy in higher education also shows that it is more necessary to form a clear norm and standard in higher education with the increasing attention paid to the research of digital literacy in practice. To this end, based on the overall research on the conceptualization of teacher digital literacy in higher education in the past 15 years (1997-2022), this study will conduct an in-depth assessment of the emerging research topics of digital literacy along the development path of the concept of digital literacy, and discuss the following issues:

1) What is the annual total number of publications (every three years), growth rate (every three years), regional distribution, citation rate, and the number of publications related to teacher digital literacy?

2) What are the research topics, levels, categories, methods and objects of papers related to teacher digital literacy?

3) What are the key components of teacher digital literacy?

2. Research Aim

This literature overview focuses on the changes of teacher digital literacy in higher education brought about by educational transformation in the digital era, and traces and clarifies the concepts of teacher digital literacy and digital competence in the global literature. On the basis of summarizing the concept of change, this study further discusses the characteristics and main components of teacher digital literacy in contemporary higher education. More specifically, the purpose of this study is to explore the development direction of teacher digital literacy in higher education in the digital environment based on different analytical dimensions and through selected literature, so as to provide a theoretical basis for improving the digital literacy of university teachers in higher education in the future.

3. Methodology

This literature overview is based on the research method proposed by Gough (2007) for literature review, and then selected by the search procedure in a specific database and analyzed through six steps. 1) Formulate review issues and specific plans; 2) Review and elaborate the research literature through abstracts and keywords; 3) Define inclusion and exclusion criteria and describe specific research paths; 4) Further review the objectives and scope of the study subjects; 5) Re-screened publications based on inclusion and exclusion criteria; 6) Extract and code data, evaluate quality and relevance, and explore questions to be answered.

3.1 Database Selection and Search Terms

The reason why Google Scholar was chosen as the main search tool in this study is that it can cover all kinds of publications related to the topic to the maximum extent due to its language coverage, the

keywords allowed in each search and the wide range of journals covered. Since this study hopes to make statistics by time segment so as to make it easier to observe the trend and change of research, three years is specially selected as a period of search period. Since this study only hopes to see a general development trend, no screening calculation including relevant concepts and excluding other fields was done for the first round data results when extracting the results. In order to gain an initial understanding of the research on the conceptualization of teachers' use of digital tools and skills in higher education, and to observe the research hots and concerns of scholars, this study used the following keyword combinations to manually exclude duplicate papers.

(i) "ICT" OR "digital literacy" OR "higher education"OR"digital competence" OR "professional digital competence" OR "digital education"

(ii) "ICT" AND "digital literacy" OR "ICT" AND "higher education" OR "digital literacy" AND "higher education"

(iii) "ICT" AND "digital literacy" AND "in University Settings"

3.2 Inclusion and Exclusion Criteria for Publication Selection

In line with research expectations, this study developed a criteria for inclusion in the corpus. That is, to meet concerns about the digital age, to examine conceptualization of terms, to consider factors that influence teacher digital literacy, and to obtain authoritative peer review. The specific search procedure is to set a time range to search for abstracts and keywords to exclude those publications that are not related to the research topic firstly. Then, the inclusion and exclusion method was used to delete the publications that have not been cited or have not appeared in the journal partition table of Literature and Information Center of Chinese Academy of Sciences (updated in December 2021) or have not been authorized to publish and be included in the latest LetPub website. Then the full text was read again. The final 17 publications included in the corpus were those that contained citations, peer-reviewed journal publications, and published in the world's top authoritative journals.

3.3 Reviewing and Coding Process

In order to organize the publications more systematically, this study adopted a scheme of conceptual understanding, research level and research objectives, as well as review and coding of research design and objects. Finally, the annual growth of research digital literacy literature, the country distribution of authors, the number of citations, the definition of research topic, research level and objective, research methods and objects were extracted from the 17 publications and marked in the form of Excel.

3.4 Data Analysis

After obtaining the basic research data, this study made a list of 17 publications that were finally included in the corpus. A table containing the publication's author information, country distribution, research design, and description of digital literacy terms and conceptualization was then created, and the questions were framed in the following six areas: 1) Technical ability; 2) Teaching ability and

professional development; 3) Cultural and ethical awareness; 4) Digital context; 5) Training opportunities and lifelong learning; 6) critical thinking and innovation.

4. Results

In this part, 17 publications included in the corpus are analyzed in depth. Firstly, the general research status of the concept of teacher digital literacy in higher education has been rethought. Secondly, the main themes, categories and key components of higher education related to digital literacy of teachers have been discussed.

4.1 The Necessity and General Situation of Concept Research

In the review process of this study, we found that although most of the publications contains various relevant concepts in the abstract or keywords, after two-round checking, 120 publications (176 publications in total) were found to be excluded, accounting for 68% of the total publications. Therefore, the scarcity of conceptualization became apparent, further to analyze the concept of teacher digital literacy in higher education will be necessary.

4.2 Description of the Key Components that Affect the Concept

To further explore whether the concept of teacher digital literacy in the context of higher education is constantly changing due to time, region, policy, culture, methodology and level of analysis, this study poses the first question:

1) ***What is the annual total number of publications (every three years), growth rate (every three years), regional distribution, citation rate, and the number of publications related to teachers' digital literacy?***

Without considering literature duplication, this study found that from year of 2021 to now, the literature on digital literacy is the most by single item search of literature keywords (Table 1). In terms of annual growth, the literature on the combination of digital literacy, information and communication technology and higher education showed a rapid rise (Table 1).In addition, according to the publication dates of the 17 selected publications in the corpus, it can be seen that the publication year of 14 publications is concentrated from the year of 2020 to 2022 (Table 2). From the geographical distribution of publications, most of them are concentrated in Europe and Asia. In particular, there are 12 publications from Europe. Among the 12 publications, 7 of them were from Nordic countries. In terms of country distribution, Norway, Sweden and the Netherlands each contributed two publications. There were five literature studies in Asia, including two from China and a total of four from other countries (Table 2). In terms of the number of cited, the most cited documents also belong to the five European countries, among which the Netherlands has two publications with a large number of citations, followed by Sweden (Table 3).

In order to better understand whether the connotation and key components of teacher digital literacy in higher education are related to individuals, schools, culture, local policies and theoretical guidance, etc and weather there is relationship and crossover between systems, this study raises a second question:

2) What are the categories, perspectives, research objectives, levels, methods, and objects of papers related to digital literacy?

In the analysis of the research categories (Table 4), this study firstly found some concepts related to digital literacy and competence that appeared in the corpus of 17 publications, such as digital competence, digital literacy, digital literacy and digital competence, digital skills, professional digital literacy and professional digital competence. In terms of research objectives, among the 17 publications, 15 were on the topic of technical ability and teaching ability, 12 were on the topic of cultural awareness, 8 were on lifelong learning, 7 were on situational support, 6 were on professional participation, 4 were on critical thinking, and 1 was on innovation. From the research level, among the 17 publications, 7 publications explored teacher digital literacy from the meso level and the micro level, and 3 publications from the macro level (Table 5). In these conceptual statements, 6 of the 17 papers were conceptually explained through literature research, 2 were discussed under the framework theory, 1 was produced from the study of related policy documents, 1 was formed by both literature research and document interpretation, another paper based on other theories.

In terms of research methods, 8 of the 17 publications adopted survey method; the basic research method of 5 publications was literature research. Two papers were carried out through cases; one used interviews; 1 is done through policy explanation. From the perspective of research objects, among the 17 publications, 7 were about university teachers, 5 studied through literature review, 2 were about students, 1 was about both teachers and students, 1 was about policy documents, and 1 was about research experts and digital citizens.

4.3 Related Concepts Components

In order to further clarify the basic research situation of digital literacy of university teachers and reflect on the general research situation and trend with the diffusion of information and communication technology, this study forms a third question:

3) What are the key components of digital literacy of teachers?

Through the analysis of 17 corpus publications, it is found that there are many factors affecting the digital literacy of teachers in higher education, such as the technical ability of teachers due to the use and learning of information and communication technology outside teaching; Teachers' ability to deal with electronic materials, evaluate teaching ability, develop specialization and solve problems in teaching; Digital privacy and security issues arising from culture, ethics, ideas, awareness, etc; Virtual teaching situation brought by digital interconnection; Teachers' critical thinking and creativity; And the opportunities for teacher training and the need for lifelong learning created by digital education. It can

be said that the reason why the current concept of teacher digital literacy has not been achieved is the result of the joint influence of many factors. Therefore, the clear definition of this concept should be considered in an all-round way and discussed in a long-term manner.

5. Discussion

According to the publication year, annual growth, regional distribution and citation rate of papers related to digital literacy, the research on digital literacy in the context of higher education is on the rise. As can be seen from the regional differences in the use of these terms in this study, most of the publications defining digital literacy are from Europe and Asia. Both continents are putting more emphasis on the use of digital literacy as a whole. According to the number of citations, European countries are significantly higher than other countries and regions in terms of both the number of citations and the national distribution, especially the Netherlands and Sweden, which are countries with advanced research and present a few and concentrated state. It is fair to say that although this is a passive form, the COVID-19 pandemic has really played a big role in promoting the research of teacher digital literacy (Sanchez-Cruzado et al., 2021). Secondly, both in terms of the number of citations and the distribution of countries, the ranking of European countries is significantly higher than that of other countries and regions, especially the Netherlands and Sweden, which are countries with advanced research, indicating that European countries are in the leading position in both digital education and the framework research of digital literacy and ability. Such research results are inseparable from the fact that digital education in Europe has been attached great importance by national policies and have a unified digital competence framework or skill framework to guide development. For example, the Digital Competence Framework for European citizens proposed by the EU in 2013, the Professional Digital Competence Framework for Teachers proposed by Norway in 2017, the Universal Digital Competence Framework for teachers issued by Spain in 2017, and the Digital Strategy implemented by Sweden in 2017.

From the analysis of the main categories, perspectives, research objectives, levels, methods and objects of papers related to digital literacy, it can be seen that scholars mainly study digital literacy as the main category. Trying to give a conceptual explanation through literature or without reference to any source is the main entry point of scholars. The main research goal of scholars is to explore the technical ability, teaching ability and professional development direction. From the perspective of research level, it is the mainstream of current research to discuss from the meso-level and micro-level. Most scholars take quantitative research as their main research method; the subjects of the study are teachers. It can also be seen that, based on theoretical and practical needs, it is still the focus of the future research on the conceptualization of digital literacy in higher education. Especially in the digital transformation, scholars have not yet given a specific and comprehensive concept, no feasible standard for reference at

the national policy level either, it is of great significance to identify the concept as soon as possible and form key components that can guide the improvement of digital literacy of university teachers in practice. From the perspective of research objectives and research, proximal processes are the driving force behind human development as a pipeline of synergistic interactions between human characteristics and their environment, however, what exactly is the successful development result varies from one culture to another and from subculture to subculture (Navarro & Tudge, 2022). Therefore, through the process-human-environment-time (PPCT) model of neo-ecological theory to analyze the interaction of teacher digital literacy at micro and meso level, and to explore the mutual relationship between various factors, are the key competencies and responsibilities that future university teachers will need to be able to more successfully navigate new educational paradigms in an environment of ever-changing technology, and to lead students to acquire the skills and responsibilities they need to fully integrate as citizens of the digital world.

From the analysis of the key components of teacher digital literacy in higher education, based on the theory that personal characteristics, background and time are interdependent, and all elements are multi-directional interaction and collaborative development (Navarro & Tudge, 2022), this study finds that technical competence, teaching competence and professional development, cultural and moral awareness, moral and cultural awareness, digital context, training opportunities and lifelong learning, critical thinking and innovation are the main components of the research.

5.1 Technical Competence

According to Bronfenbrenner & Morris (2006), in the theory of biological ecology, human characteristics will appear twice over time. That is, individual characteristics can be an indirect producer, but also can be the inevitable product of development to a certain stage (Navarro & Tudge, 2022). Among the 17 articles in the corpus of this study, 16 articles explored technical competence. It shows that the use and learning of information technology tools are the means and prerequisite for the cultivation of technical competence of university teachers, and also the premise and foundation for the improvement of digital literacy and lifelong learning and the realization of sustainable development. For example, Van et al. (2017) proposed that skills in the 21st century are an organic integration of digital skills or digital literacy in terms of the relationship between digital skills and information and communication technologies. The remaining 15 articles also affirm that technical ability plays an irreplaceable role in improving teachers' literacy, but Tejedor et al. (2020) laid more emphasis on the ability of individuals to comprehensively develop in the information society and the improvement of individuals' comprehensive functional literacy under the time system.

In view of the fact that most of the literature explores teacher digital literacy in combination with technological capabilities, it is still a research topic to explore information and communication technology from the micro perspective for many years. Moreover, the majority of studies agree that

information and communication technologies will play a greater role in the 21st century (Van Deursen & Van Dijk, 2010a). However, how to stimulate the motivation of teachers, how to shorten the difference of digital literacy among individual teachers and the low state of overall literacy, continuous measures to improve need to be taken. In terms of how to concretize this technological ability so that teachers have the ability to perceive digital resources as useful and easy to use, except for relevant policy support, teachers themselves need to be interested in and motivated to use information tools and learn because people's characteristics, background and time are interdependent, and these elements are the result of multi-directional mutual relations and synergies (Navarro & Tudge, 2022).

5.2 Teaching Ability and Professional Development

In the development of digital transformation, all teachers, especially those whose professional autonomy will be affected due to their low level of knowledge and technology (Tatto, 2019), regardless of their professional research interests, should consider how the digital environment can inject people with the results they are interested in. As Navarro & Tudge (2022) stated, it is the core of school system development to examine teachers' information teaching ability from the perspective of professional development because the low level of technology or professional knowledge effectively limits teachers' professional autonomy. Another example is that Li and Yu (2022) proposed that the better the development of teacher digital literacy, the stronger their educational ability. In terms of the relationship between teacher digital literacy and professional development, Zhao et al. (2021) believed that college teachers are positive in information and data literacy, communication and collaboration, security and problem solving, but negative in self-evaluation of digital content creation.

From the above analysis, it is found that the problem of teachers' inability to navigate freely in the digital world is related to the lack of better development of teachers' teaching ability and professionalism. In view of the higher requirements for the teaching ability of university teachers in the pandemic and post-pandemic era (Li & Yu, 2022), how to help cultivate the digital identity of teachers in the future and promote the development of teachers as learners and the learning of students (Engeness, 2021) needs to be further discussed. However, how to improve the digital literacy of teachers in higher education depends on the support of academic environment, the preparation of teachers themselves and the cooperation of students to a greater extent. In addition, how to increase teachers' self-efficacy is the focus of promoting individual creativity and professional development. In the future, it is suggested to explore and develop certain design principles through the learning and design of digital environment, so that teachers and students can reposition themselves as active subjects of knowledge practice, so as to cultivate the digital identity of teachers (Engeness, 2021).

5.3 Cultural Moral Consciousness

Bronfenbrenner (1989) believed that human beings are a product of the alternating effect of creating culture and being created by culture. Problems such as the further widening of the digital divide caused

by the physical barrier of COVID-19, the greater imbalance of educational resources, the leakage of user privacy, and the excessive involvement of non-educational institutions etc., are inseparable from the cultural and ethical impacts of society. As (Navarro & Tudge, 2022) pointed out when elaborating the process-human-context-time model in the new ecological theory, proximal process is the driving force behind constituting human development. In this study, 10 articles explored cultural awareness, and most of them discussed ethical privacy issues caused by the use and learning of digital technologies, especially a series of values and social justice issues generated through digital media. For example, Skantz-Aberg et al. (2022) believed that the digital ability of teachers is the collection of individual system and social system. The ability to interact with peers from the collective has a great impact on teacher digital literacy. Potyrała and Tomczyk (2021) analyzed the impact of information protection and gender fixation on digital security technology from the micro level.

Our systematic review of the literature shows that secrecy and ethics are increasingly important factors influencing teacher digital literacy and their ability to teach students. Information and communication technology has inevitably eroded other values of higher education while improving university teaching results and promoting new market forces, leading to over-digitalization of education and non-professionalization of teaching, and further affecting the cultural and ethical level of teachers and students. In addition, although the cultivation of ethics and morals is a spirit embodiment of multi-dimensional integration, from the perspective of external system, ethical privacy and cultural atmosphere will inevitably affect the digital literacy of college teachers, and then exert moral and knowledge influence on students. For example, Potyrała and Tomczyk (2021) provided evidence that it is the focus of current research to explore the issues of information security and cyber-bullying brought about by individuals using and learning information and communication technologies from a micro perspective. Skantz-Aberg et al., (2022) analyzed the relationship between external systems and micro systems, and conclude that the cross-border interaction between systems is one of the important factors affecting teacher digital literacy. In short, the research focuses on the copyright privacy of digital resources, the reliability assessment of online information, the interdependence between personal characteristics, background and time factors, and the interactive support of cultural atmosphere to explore the influencing factors of teacher digital literacy.

5.4 Digital Situation

With the popularization of digital technology, various social networks, MOOCs, Facebook, Blogs and other media resources have filled the entire network environment. However, due to their individual differences, teachers showed diversified abilities from the aspects of digital literacy level in learning and using information and communication technology, and mastering the knowledge and skills of digital security connection. In this study, a total of 7 publications explore the field of digital environment. Most of these literatures believe that the digital environment is not only influenced by the

country, culture, teaching management and other aspects, but also restricted by the external system communication and cooperation. For example, Tejedor et al. (2020) proposed that blended teaching under special circumstances is a kind of "Crisis Learning" in view of the COVID-19 epidemic environment, and firmly believe that there are significant differences in digital environment between different countries. Dong et al. (2021) further pointed out that digital capabilities include communication and collaboration in different environments. In addition, Sanchez-Cruzado et al. (2021) discussed the online collaboration and interaction between teachers and other peers and students, and online communities and social networks from the perspective of shared resources.

Through this study, it is found that the policy support from the macro level, the strong provision of teaching resources and training opportunities at the meso level, and the appearance supportive atmosphere at the social level are the important influencing factors for the cultivation of university teacher digital literacy from the perspective of digital environment. Therefore, the exploration of teacher digital literacy can not only be considered from the perspective of digital citizenship literacy, but also should be discussed through multi-interaction in virtual microsystem, and comprehensive and multi-view collective support atmosphere. The influence of different levels of digital technology and local political, economic and cultural aspects among countries should be treated differently and developed differently. In other words, the improvement of teachers' individual digital literacy is the result of the joint efforts of many parties. Just as Bronfenbrenner (1989) put forward, individual behavior is determined by the internal and external characteristics of the interaction between individuals or groups and the environment.

5.5 Training Opportunities and Lifelong Learning

Digital technology has derived a new form of education and realized the precise connection between the supply and demand of education. However, university teachers are generally at a low level in the field of digital literacy (Pozos & Tejada, 2018), and even if teachers have enough professional knowledge in a certain field, they still cannot guarantee a high level of competence in other fields of digital literacy (Potyrała & Tomczyk, 2021). In this study, through eight studies on digital training and lifelong learning, it is found that in-depth exploration of teachers' ability to participate in digital literacy training and have lifelong learning is one of the current research cores. For example, the influence of teacher training on teacher literacy is explored by the researchers such as Anthonysamy et al. Tejedor et al.(2020) held firmly that it is impossible to improve the teaching outcomes of university teachers and students by only introducing new educational technologies without specific training and long-term systematic learning, and lifelong learning must be carried out in combination with the time system. Sanchez-cruzado et al. (2021) took specific training as the starting point and explore the training objectives and directions that university teachers and training institutions jointly face from the micro level.

Through the analysis of the literature on training opportunities and lifelong learning, it is found that teacher digital literacy training opportunities are an important factor to improve teacher digital literacy, and lifelong learning will be an inevitable requirement under the future digital education. In the specific training, it is necessary to consider the specific background from the outer system, the information and communication technology capability of the meso system itself and the professionalism of teachers, as well as the individual differences of university teachers in the micro system and the factors such as cognitive knowledge, resource management and motivational beliefs behind the formation of such differences (Anthonysamy et al., 2020). As Tejedor et al. (2020) put it, in the digital age, digital literacy refers to a set of interrelated skills or abilities that are necessary for an individual to succeed in the ecological development system.

5.6 Critical Thinking and Innovation

Critical thinking and creativity are the key to effective learning in and out of higher education. However, there are 4 publications exploring the impact of critical thinking on the digital literacy of teachers in higher education and only 1 paper explores the digital literacy of teachers from the perspective of innovation. Although there are few scholars exploring the research field, just as Zakharov et al. (2021) concluded from the evaluation and analysis of the literacy index, teachers' attitude towards technological innovation is one of the five literacy indicators, which is considered as one of the key skills in the learner toolkit of the 21st century. As for critical thinking, Polizzi (2020) explored the importance of critical thinking to media literacy from a macro perspective. Zhao et al. (2021) studied the critical and creative ways to solve technology, information, multimedia and other problems from a micro perspective, which are crucial to the future learning process and participation. On this basis, Ayyildiz et al. (2021) further analyzed the reasons for the lack of flexible digital literacy at the present stage from the perspective of future development needs, and put forward the supporting view that teachers should have the necessary critical thinking skills and abilities in practice in the future, regardless of the deep form.

According to this study, although digital literacy, motivation and higher-order thinking ability have an impact on teachers' creativity (Widana et al., 2020), the academic community has not reached a consensus on the key aspects of creativity development in higher education up to now (Egan et al., 2017). In addition, more and more attention has been paid to the exploration of teacher digital literacy from the perspective of critical thinking. The reasons are as follows: on the one hand, because critical thinking involves a wide range of disciplines and abilities, educators must master the basic knowledge of the concept of critical thinking and require themselves to be continuous learners and applicators of critical thinking, able to continuously strengthen professional learning and self-reflection (Li et al., 2022). On the other hand, although the critical thinking and a high level of creativity is a kind of thinking skills upgrading, more emphasis on at every stage of thinking development between

inheritance, interrupt, differentiation and integration, based on the motivation, both inside and outside factors that affect digital literacy, teaching team characteristic variables, such as dealing with different ecological dimension of the impact on education practice shall be considered.

6. Research Limitation

Although based on the research corpus, this study concludes that it is necessary to form a stereoscopic pluralism theory or framework that includes all aspects in the future. However, as mentioned above, due to the dynamic, open and loose nature of this concept, few scholars have conceptualized teacher digital literacy from the perspective of higher education, and research and data sorting will be needed in the future. Secondly, since the research started from 1997 to analyze the publications of other scholars, it is inevitable to miss the predictive and pioneering research of other scholars. Therefore, this study suggests that in conceptualizing teacher digital literacy later, the skills required by college teachers to utilize digital resources out of the classroom and the comprehensive ability to monitor student learning performance should be considered in different contexts and methodologies firstly. Furthermore, the development perspective should be used to consider how teachers, as digital citizens, use information management systems, innovate and develop, use and share knowledge outside of teaching.

7. Conclusion

Overall, this study suggests the scholars under the higher education of teachers research of digital literacy of key five components including microsystem, mesosystem, macrosystem, excosystem and time system. Every factor is interrelated each other, which further verifies the Bronfenbrenner's bioecological theory can be used as the theoretical support of this study in digital age. In this study, through the analysis of 17 publications on the conceptualization or measurement of digital literacy of college and university teachers in the digital era, it is found that concerns about the lack of empirical evidence in this area are acknowledged. For this reason, the premise of this study is that in the future, it is necessary to put forward the comprehensive, three-dimensional and diversified extension concept of teacher digital literacy in higher education in the digital era, as well as the key components of this concept, as a strong support for theoretical and practical guidance. In addition, it is concluded from literature review that it is still the focus of current research for scholars to explore their digital literacy from the perspective of theory. In practice, there are still specific frameworks or key components for measuring teacher digital literacy from the perspective of higher education. More research will focus on the key components that influence the digital literacy of college teachers. Specific speaking, from the technical ability, teaching ability and professional development, culture, moral consciousness, the digital situation, training opportunities and lifelong learning, critical thinking and innovation to delve

into the university teachers in teaching reflection, the key component of literacy formed in teaching reform is the first step in identifying and possibly quantifying current and expected needs. Just as Zakharov et al. (2021) described that digital transformation at replacement and improvement level, can be introduced in the process of teaching and learning in the future, colleges and universities and teachers, who are in the vanguard of promoting educational change, will surely realize that improving digital literacy is no longer an option, but a real necessity. It is the core of changing the traditional teaching area.

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Table 1. Keyword Search Growth Rate Comparison Table (every three years)

Index/Comparison growth	1997-20002001-2004	2001-20042005-2008	2005-20082009-2012	2009-20122013-2016	2013-20162017-2020	2017-20202021-
ICT	62.22%	52.99%	56.02%	42.37%	-72.02%	24.67%
digital literacy	37.44%	54.42%	51.65%	49.26%	-54.96%	78.66%
higher education	20.26%	-8.95%	8.71%	-28.39%	28.00%	-368.40%
ICT; digital literacy	85.71%	57.00%	23.08%	15.95%	-4.04%	38.40%
ICT; higher education	53.40%	43.71%	44.52%	31.04%	-27.07%	-67.56%
higher education; digital literacy	40.18%	20.29%	48.51%	24.86%	-31.13%	7.27%
ICT; digital literacy; higher education	84.54%	54.22%	6.67%	-1.23%	2.98%	50.30%

Table 2. Year of Publication, Citations, Country and Continent Statistics

	Year of publication	Cited number	Rank by country	Continent
1	2017	1205	Netherlands	Europe
2	2018	336	Sweden	Europe
3	2020	141	Netherlands	Europe
4	2020	110	Spain	Europe
5	2020	73	England	Europe
6	2021	67	Spain	Europe
7	2020	49	Malaysia	Asia
8	2020	40	Fiji	Asia
9	2021	37	Norway	Europe
10	2019	21	Norway	Europe
11	2021	10	Poland	Europe
12	2021	8	Turkey	Asia
13	2021	5	China	Asia
14	2022	4	England	Europe
15	2022	3	Russia	Europe
16	2022	3	Sweden	Europe
17	2021	3	China	Asia

Table 3. Country Citation Ranking

Author and year of publication	Name of literature	Cited number	Rank by country
Van et al., 2017	The relation between 21st-century skills and digital skills: A systematic literature review	1205	Netherland
Spante et al., 2018	Digital competence and digital literacy in higher education research: Systematic review of concept use	336	Sweden
Van et al., 2020	Teachers' online teaching expectations and experiences during the Covid19-pandemic in the Netherlands	141	Netherland
Tejedoret al., 2020	Digital Literacy and Higher Education during COVID-19 Lockdown: Spain, Italy, and Ecuador	110	Spain
Polizzi, 2020	Digital literacy and the national curriculum for England: Learning from how the experts engage with and evaluate online content	73	England

Table 4. Understanding of the Concept of Digital Literacy

	Term	Definition
1	Digital Competence	Helleve et al. (2020) It is the sum total of the qualifications a person needs to act in a professional manner. Teachers should develop a sense of self-understanding and develop knowledge, skills and general abilities in several areas.
2	Digital Literacy	Polizzi (2020) It is often used as a variant of media literacy. In addition, functional digital literacy is understood to include a general orientation to the Internet.
3	Digital Literacy	Reddy (2020) It refers to an individual's ability to discover and evaluate information, use it effectively, create new content, and share and communicate this newly created information through appropriate digital technologies.
4	Digital Literacy	Van et al. (2020) It is closely related to personal characteristics, online teaching expectations and experience, stress, information overload, digital teaching skills, educational quality, social emotion and so on.
5	Digita Literacy; Digital Competence	Zhao et al. (2021) Digital Literacy includes three parts: digital consumption, digital capability and digital security, but there is no special explanation of digital literacy in the field of education. Digital Competence includes issues related to technology, information, multimedia and communication.

6	Digital Competence	Engeness (2021) Teacher digitization ability is a dual framework. It is developed in social, cultural and professional environments and intrinsically related to their professional identities.
7	Digital Literacy	Ayyildiz et al. (2021) It is a “loose” and ill-defined concept, meaning different according to users of different methods. So accept digital literacy as a type, format and tool, not a concept.
8	Digital Literacy	Li and Yu (2022) It is the potential ability to realize teachers’ professional development in the e-learning community. In terms of its relationship with educational ability, the better the development of teachers’ digital literacy, the stronger their educational ability.
9	Digital Literacy; Digital Competence	Spante et al. (2018) Digital literacy is a combination of three concepts :1) skills-based approach to the operation of expertise; 2) emphasizes the non-generality and multi-situational nature of concepts; 3) Critical digital literacy in the reflexes approach to “interrogating the world”. Digital competence includes a wide range of competencies, especially those related to values and ethics.
10	Digital Literacy	Tejedor et al. (2020) It is the acquisition of technical competence in the use of information and communication technologies.
11	Digital Skills	Van et al. (2017) 21st century skills are broader than digital skills. But there are currently fewer operational components available to provide a digital skills framework.
12	Digital Competence	Sánchez-Cruzado et al. (2021) It refers to the process in which teachers are qualified to guide students’ learning and use digital tools now and in the future in a digital environment and reflects ICT competence and information literacy skills.
13	Digital Literacy	Zakharov et al. (2021) It is based on the assessment of five indicators of information, computer, communication and media literacy and attitudes towards technological innovation.
14	Professional Digital Literacy	Potyrała & Tomczyk (2021) It is a concept created based on a universal and unquestionable knowledge of digital tools and is an ability to function in an information society.
15	Digital Competence	Skantz-Åberg et al. (2022) It is usually indistinguishable from and often confused with the more general term digital competence and is the most widely used defining concept. It includes seven parts.
16	Digital Competence	Dong et al. (2021) It is a general term for the knowledge, skills and attitudes related to digital technology. In relation to digital literacy, digital literacy is a part of digital competence.

17	Digital Literacy	Anthonysamy et al. (2020) It is the ability to adapt to the knowledge society, including knowledge, skills, effective use of digital technology, information management, digital skills, ethical awareness, etc.

Table 5. Research Levels and Objectives

		Level of research			Aim of research							
	authors	Macro	Meso	Micro	TC1	TC2	CC	CT	C	DSC	PP	LS
1	Engeness (2021) Norway		√		x		x	x	x			x
2	Ayyildiz et al. (2021) Turkey			√		x			x	x	x	x
3	Zhao et al. (2021) China			√				x	x	x	x	x
4	Li and Yu (2022) England			√				x	x			
5	Helleve et al. (2020) Norway		√		x			x	x	x		x
6	Polizzi (2020) England		√				x		x		x	x
7	Reddy (2020) Fiji		√			x	x	x	x		x	x
8	Van et al. (2020) Netherland		√					x	x	x		x
9	Spante et al. (2018) Sweden	√						x	x	x	x	x
10	Tejedor et al. (2020) Spain and Ecuador		√					x	x		x	
11	Van et al. (2017) Netherland			√							x	
12	Sánchez-Cruzado et al. (2021) Spain			√			x	x	x		x	
13	Zakharov et al. (2021) Russia		√					x	x	x		

14	Potyrała & Tomczyk (2021) Poland		√		x	x	x	x		
15	Skantz-Åberg et al. (2022) Sweden	√				x	x		x	
16	Dong et al. (2021) China	√		x	x	x	x	x		
17	Anthonysamy et al. (2020) Malaysia		√		x	x	x	x		

Abbreviated: technical competence=TC1; teaching competence=TC2; cultural consciousness=CC; critical thinking=CT; C=creativity; digital setting support=DSC; Professional participation=PP; lifelong study=LS

Table 6. Research Methods, Perspectives and Objects

	author	study design	study object	research angle	object		People			
					publication	policy	teacher	student	citizenship	expert
1	Engeness (2021) Norway	case study	teacher and student	theory			1	1		
2	Ayyildiz et al. (2021) Turkey	quantitative design survey	teacher	literature research			1			
3	Zhao et al. (2021) China	survey	teacher	Conceptualization without reference			1			
4	Li and Yu (2022) England	literature review	publication	Conceptualization without reference	1					
5	Helleve et al. (2020) Norway	case study	teacher	document			1			
6	Polizzi (2020) England	interviews	expert and digital citizenship	literature research					1	1
7	Reddy (2020) Fiji	literature review	publication	Conceptualization without reference and frame	1					
8	Van et al. (2020)	survey	teacher	Conceptualizati			1			

	Netherland			on without reference						
9	Spante et al. (2018) Sweden	literature review	publication	literature research	1					
10	Tejedor et al. (2020) Spain and Ecuador	survey	student	literature research				1		
11	Van et al. (2017) Netherland	literature review	publication	Conceptualization without reference	1					
12	Sánchez-Cruzado et al. (2021) Spain	survey	teacher	policy,document,model			1			
13	Zakharov et al. (2021) Russia	survey	teacher	frame			1			
14	Potyrała & Tomczyk (2021) Poland	survey	teacher	literature research			1			
15	Skantz-Åberg et al. (2022) Sweden	literature review	publication	literature research	1					
16	Dong et al. (2021) China	policy interpretation	document	frame		1				
17	Anthonysamy et al. (2020) Malaysia	survey	student	Conceptualization without reference				1		
					5	1	8	3	1	1