TEACHER READINESS IN DIGITAL EDUCATION TRANSFORMATION: ANALYSIS LITERATURE ABOUT COMPETENCIES, CHALLENGES, AND SUPPORT SYSTEM

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Abstract: *Transformation digital education places teachers as actor key in integrate technology in a way pedagogical and sustainable. This article aim for analyze teacher readiness in transformation digital education through synthesis literature about digital competence, challenges implementation, and form support effective systemic research this use method studies literature with approach systematic narrative review to article journal international reputable and documents global policies issued in ten years last. Analysis results show that digital competence of teachers is construct multidimensional which includes aspect technical, pedagogical, social-emotional, as well as ethics and data security, and not can reduced to mastery tool solely. The literature also identifies that challenge main integration technology covers obstacle external, such as infrastructure and connectivity, as well as internal barriers, including belief pedagogical, self-efficacy, and readiness designing learning as well as meaningful digital assessment. In addition, the findings confirm that training one less time effective without support systemic in the form of development professional sustainable, teacher collaboration, and policy coherent education. This study conclude that teacher readiness in transformation digital education requires approach integrated that integrates competence, challenges empirical, and support systemic for produce practice impactful and sustainable digital learning.*

Keywords: *Teacher Readiness, Transformation Digital Education, Digital Competence, Development Professional Sustainable*

Introduction

Transformation education in the digital era is multidimensional phenomenon involving change technology, pedagogy, policy, and structure organization education. Development rapidly technology start from online learning platforms, Learning Management Systems (LMS), mobile learning, to intelligence artificial and analytical data has open possibility new for personalization, collaboration, and tracking and evaluation results Study in a way real-time (Du Plooy, Casteleijn & Franzsen, 2024). However transformation the no automatic increase quality learning; its effectiveness depends heavily on the capacity human (teacher) to utilise technology in a way pedagogical and ethical. The OECD report emphasized that provision infrastructure just no enough as source power humans and patterns development professional teachers are factor determinant (Vincent-Lancrin, Cobo Romaní & Reimers, 2023).

A number of framework adopted competencies in a way international confirm demands competence multidimensional for educators in the digital era. The European Framework DigCompEdu (Redecker & Punie, 2017) details 22 competencies covering professional areas, management source digital power, teaching and learning, as well development professional; framework This useful as reference for training program designer educators. In line with that, UNESCO (ICT-CFT, 2018) also offers stages competencies and guidelines for implementation Information and Communication Technology (ICT) in training pre-service and in-service. Frameworks this emphasize that teacher competence exceeds ability technical simple: integration pedagogical (how technology enrich the learning process), issues data ethics & security, as well as ability reflective for evaluate impact technology towards the process and results study.

The COVID-19 pandemic has accelerated adoption technology education but also exposes lack real in readiness system and teachers. Phenomenon Emergency Remote Teaching (ERT) shows difference between designed online education mature and diverted emergency to learning distance far from limitations competence teacher digital pedagogical readiness curriculum and support system become clear (Rapanta, Botturi, Goodyear, Guàrdia & Koole, 2020). Study empirical during and after pandemic report that teacher's ability to designing experience study meaningful with technology varies greatly, and that part big countries face challenge in provide relevant training, support sustainable, and coherent policies (Sing Yun, 2023). In short, the pandemic become trigger at a time gauge readiness system education face digitalization.

Literature empirical and review systematic during decade final show a number of findings relevant consistency For topic teacher readiness such as opinion Revuelta-Domínguez, Guerra-Antequera, González-Pérez, Pedrera-Rodríguez & González-Fernández (2022) : (1) digital competence of teachers must be seen as construct multidimensional which includes aspect technical , pedagogical , social-emotional (e.g. management) online classes), and data ethics / security ; (2) training technical only (one- time workshop , training tools) rare produce change sustainable practices except when combined with job-embedded professional learning (coaching, mentoring, micro-credentials, learning based practice). In line with matter, Fernández-Batanero, Montenegro-Rueda, Fernández-Cerero & García-Martínez (2022) confirm the need for development programs context -sensitive, sustainable, and integrated professional with need curriculum.

Frequent obstacles appear in literature can grouped into two categories classic: first-order barriers (constraints) external like infrastructure, connectivity, devices, time) and second-order barriers (internal constraints such as belief pedagogical, self-efficacy, resistance to change) (Yeh & Tsai, 2022). Although many countries invest in devices and networks, obstacles level second often become inhibitor main adoption meaningful technology: teachers perhaps own access to tool but not yet own draft or belief pedagogical about how technology can improve the learning process. Therefore that, policy effective must overcome second type obstacle in a way simultaneous through package policies and practices: investment infrastructure, CPL (Continuing Professional Learning) design based on practice, support technical and pedagogical resources available on site work, and formation community practice professional.

Novelty and contribution studies This lies in the approach synthesis literature that combines three aspect: competence (how global mapping framework capacity required by teachers), challenges (evidence empirical about obstacle technical and cultural), as well as support systemic (policies and training models) effective sustainable development) (Bo, 2025). Although there is Lots studies that focus on one dimensions for example digital competence, or evaluation of certain programs, still relatively a little integrated study proof empirical latest (including experience pandemic) with study framework competence international and recommendations policy systemic. This article aim provide map more knowledge comprehensive for maker policy,

developer curriculum, and researchers who want to designing intervention development contextual and impactful teacher capacity.

Literature Review

Recent studies indicate that teacher readiness for the digital transformation of education has shifted from technical understanding to a more comprehensive professional capacity. Teacher readiness is now understood as pedagogical, reflective, and adaptive capabilities in designing technology-based learning experiences that align with learning objectives and institutional contexts (Falloon, 2020). Within this framework, teachers are positioned as designers of digital learning, not simply users of technology, so technology integration must be oriented towards improving the quality of learning processes and outcomes.

Accordingly, teacher digital competence is viewed as a multidimensional construct encompassing technical, pedagogical, and professional aspects, as well as ethics and data security. International frameworks such as DigCompEdu emphasize the importance of technology integration in learning design, digital assessment, and reflection on teaching practice. However, various studies indicate that research is still dominated by self-assessment-based measurements, while exploration of the application of digital competence in concrete pedagogical practices and meaningful assessments is still limited (Redecker, 2017; Revuelta-Domínguez et al., 2022).

In addition to competency issues, research also identifies external and internal challenges to technology integration. Barriers such as limited infrastructure often overlap with internal factors, including teachers' pedagogical beliefs and self-efficacy. The experience of emergency remote teaching during the pandemic highlighted this gap, as many teachers were technically capable of using technology but struggled to design meaningful collaborative learning and online assessments. Therefore, ongoing professional development supported by coherent policies, mentoring, and professional collaboration is key to strengthening teacher readiness and sustaining the digital education transformation (Bo, 2025).

Method

Study This use method studies literature with systematic narrative review approach to analyze teacher readiness in transformation digital education through synthesis study empirical, review systematic, as well as document policy international. Search literature conducted on reputable databases. Selected literature analyzed in a way thematic with grouping findings to in three focus main, namely teacher competence (dimensions technical, pedagogical, social-emotional, as well as ethics and data security), challenges (obstacles external and internal in integration technology), and support systemic (policy education and development models professional sustainable). For strengthen validity synthesis, analysis done through triangulation sources and uses framework competence international as lens interpretive, so that produce understanding comprehensive and integrated relevant for development policies and practices improvement teacher capacity in the digital era.

Result and Discussion

Digital Competence of Teachers as Construct Multidimensional

Teachers' digital competence is not just control tools and technology, but rather is construct multidimensional which includes various interconnected components related. In a systematic review published in sustainabilit, Revuelta-Domínguez et al. (2022) showed that study literature about Digital Teaching Competence (DTC) involves diverse dimensions teacher competency, starting from mastery technical digital tools, design teaching based technology, up to integration

supportive pedagogical learning meaningful in class. They find variety of models and dimensions competencies used in global research, but There is consensus that digital competencies include knowledge, skills, and aspects pedagogical as well as ability evaluate readiness implementation in context education. This is reflect that teacher competency must be seen as more from just skills technical, but must covers understanding method technology can enrich the learning process in a way pedagogical.

More continued, according to Smestad, Hatlevik, Johannesen & Øgrim (2023) in review systematically map characterization teachers' digital competence with analyze more from 100 articles academic before and during COVID-19 pandemic. Findings they show that study no only covers knowledge and skills technical, but also attitudes and dimensions transdisciplinary digital competence of teachers including aspect pedagogical and creative in designing experience learning. findings This confirm that digital competence does not only the question of " using " tools", but also the teacher's ability to design, modify, and evaluate practice effective and relevant digital learning for student.

In addition, the study by Revuelta-Domínguez et al. (2022) noted that teachers' digital competence is often associated with framework international which has lots dimensions, such as management source digital power, design learning, collaboration professional, and understanding ethics use technology. This reviews show that development digital competence must consider variation context education, level education (school) base until college high), and needs pedagogical specific, not only just assessment technical solely.

Approach multidimensional this in line with more findings wide that teachers' digital competencies include knowledge, skills, and attitude towards use technology, including understanding about how technology can assembled to in task pedagogical like management digital class, assessment students, and reflection professional to practice learning (Aydin, Yildirim & Kus, 2024).

Variation Empirical Competencies and Challenges During the Pandemic

Study empirical international during the COVID-19 pandemic shows that teacher's ability in utilize and integrate technology education varies in a way significant between individuals and contexts, as well as that challenges that arise no only nature technical but also pedagogical. Study of Teachers' Digital Competencies before, during, and after the COVID-19 pandemic reveal that pandemic show disparity teacher readiness in online learning, with many teachers who initially not yet used to teach digitally forced develop ICT skills only through experience practical during learning distance far away, while challenge like teaching and assessment based technology still difficult overcome (Ivanov, Radonjić, Krčadinac, Đokić & Đokić, 2025). This findings show that although skills digital base increases during crisis, preparedness pedagogical and mastery of online teaching strategies are still diverse among teachers, highlighting difference level high adaptability between teacher group.

Other findings in study literature wide about dimensions digital competence also strengthens description variation teacher readiness during pandemic. A review by Smestad et al. (2023) emphasized that Lots research using self-reported data shows the digital competency status of teachers who combine knowledge, skills, and attitudes, but the role of teachers tends to be more focus on function technical than design pedagogical before and during pandemic, which reflects need training more sustainable strong for support adaptation pedagogical to online context.

In addition, a number of studies empirical in context national and cross-country shows that challenges faced by teachers during pandemic not only question access to device or the internet, but also related with readiness for designing material digital learning and online assessment effective. For example, the research reported Sudrajat & Saefi (2021) show that even though

teachers can use digital tools for convey material, they often experience difficulty moment designing activity learning online collaborative or assessment meaningful formative, thing this indicates that mastery tool technical not yet of course in line with ability in-depth pedagogical during the closing period school.

Other research as published in Frontiers in Education also highlights experience global academic where power educators at universities must move in a way fast to learning distance way back in the beginning pandemic. Respondents state that they must develop skills new with fast for convey content online, even though many feel not yet ready in a way pedagogical for optimize use technology in context more instructional complex (Myyry, Kallunki, Katajavuori, Repo, Tuononen, Anttila & Pyörälä, 2022). This findings confirm that unpreparedness pedagogical still become obstacle significant in various level education during period pandemic.

In a way overall, evidence empirical from various context show that the COVID-19 pandemic accelerates adoption technology education at a time reveal inequality in teachers' digital readiness: some teachers are successful develop skills technology in a way fast for maintain learning, while others still experience limitations in matter design pedagogical, assessment based technology and utilization full potential digital tools for interaction and personalization learning. This describes that digital transformation of education need support more professional structured and sustainable, as well as training strategies that target not only aspect technical, but also aspects pedagogical and design digital instructional.

The Role of Training and Support Sustainable in Development Competence

Formulation repeat role teacher training in the digital education era emphasizes that approach training of a nature sustainable and integrated far more effective compared to training one time nature sporadic. In systematic review most recently, researchers confirm that the Teacher Professional Development (TPD) program pays attention to individual teacher needs and provide support sustainable produce improvement digital competence as well integration more instructional in compared to approach traditional (Amemasor, Oppong, Ghansah, Benuwa & Essel, 2025). This review show that combination training with mentoring, collaboration between teachers, and reflection sustainable strengthen knowledge pedagogy and skills technical teachers, as well as help they adapt impact technology in practice real class.

In addition, the OECD Digital Education Outlook 2023 report states that continuous professional development designed for teachers' digital competence must be combined with formal standards, incentives development career, and support institutions so that teachers do not only control technology, but also capable apply it in a way creative in practice learning (Bo, 2025). This report highlight that training sustainable linked with track career and recognition digital competence helps overcome thirst training which is often happened, where the teacher felt still need learning more carry on although has follow training previously.

Support sustainable not only in the form of formal training but also mentoring intensive and mentoring. A study conducted by Budianto & Hairit (2024) show that the mentoring program includes on-the-job coaching and guidance sustainable based on the TPACK model can increase competence utilization of digital media significant that is not only in aspect technical but also in use congested creative pedagogical for increase quality learning and motivation student.

More far, research in context teacher professionalism emphasizes importance training that is not stop at one phase but nature sustainable, adaptive and relevant with need context school. According to Saragih (2025) training accompanied by support institutions and collaboration between teachers facilitating learning reflective, where teachers can each other share practice well, trial digital strategies, as well as evaluate impact use technology in learning in a way

collective. This model strengthen attitude positive attitude of teachers towards change, increase trust self, and support adoption technology in a way more deep.

Importance support sustainable is also marked in studies technology education that uses approach self-determination theory, which shows that teachers tend to develop digital self-efficacy and commitment more professional tall when training and support sustainable integrated with need motivational they (for example competent, autonomous, connected in a way social) (Chiu, Falloon, Song, Wong, Zhao & Ismailov, 2024). This matter show that support sustainable No just provide training, but also building an environment that motivates teachers to keep going learn and grow in a way professional.

In a way overall, evidence from study international underline that training must nature dynamic, relevant, and bridging theory as well as practice with mentoring, collaboration professional, evaluation reflective, as well as support consistent institutionalization for ensure that the teacher does not only control technology, but also capable integrate it in a way meaningful in teaching and learning.

The gap Integrated Research and Research Needs

Over the decades lastly, many study literature make an effort to describe development draft teacher digital competence, however Still there is gap significant research in a number of aspect crucial. Some systematic review show that existing studies often focused on measuring the digital competency status of teachers through self-assessment and reflection, while aspect pedagogical, methodological, and intervention practical not enough integrated in a way comprehensive in framework research. For example, teachers' digital competencies in higher education, a study literature systematic mapping research on digital competence of teachers in education high, find that study previously lots focus on assessment teacher self and less exploring how competence the implemented in practice involvement pedagogical and assessment concrete education (Basilotta-Gómez-Pablos, Matarranz, Casado-Aranda & Otto, 2022).

In addition, Tiwari & Magre (2025) highlight that although global literature has discuss various dimensions digital competencies, such as literacy information, creation digital content, up to digital security that is still there is emptiness real in research empirical about the effectiveness of sustainable and contextual digital training programs, in particular in measure impact real to practice classroom learning. This study also underlines need for further research strong in a way methodological and evaluative impact support institutional term long to development teacher competency.

More far, Gökdaş, Karacaoğlu & Özkaya (2024) strengthen findings this with confirm that part big study about teachers' digital competence is still emphasize condition snapshot (condition moment this) rather than longitudinal changes or connection cause and effect between training, practice pedagogical, and results learning. Sing Yun (2023) stated that although lots study has arranged for map landscape teacher competency, analysis deep to how training, support institutions and policies systemic impact on the skills required in practice class still not enough explored in a way comprehensive.

Additionally, A visual analysis of the research literature on teachers' digital literacy (2015–2024) highlight three emptiness main in study moment this: first, many studies only focus on digital literacy or one dimensions competence just without offer framework holistic that integrates aspect technical, pedagogical, and ethical; second, there are limitations longitudinal and cross-sectional research culture that can explain dynamics development competence; and third, at least studies that are systematic map trends, approaches methodological, and direction theories that are developing in the field this (Liu & Xu, 2025).

Similar gap was also found in other literature that reviews digital competence frameworks in teacher education, which shows that part study Still not enough consider practice empirical in context education real and variation contextual between countries or inter-institutional education (Rakisheva & Witt, 2023). This literature call researchers for develop framework and instruments evaluation that is not only measure teacher competency, but also guide adaptive and responsive training programs to need dynamic education.

In a way overall, consensus in literature international show need for research that is not only describe level digital competence statically, but also connecting findings empirical with practice training sustainable, adaptation pedagogical, as well as policy supportive education digital innovation. Research comprehensive, methodological follow-up more strong, and design-focused intervention practical in various context education needed to be able to enrich understanding theory as well as give recommendation applicable policies in transformation digital education.

Conclusion

Based on analysis literature, teacher readiness in transformation digital education does not can understood solely as mastery technology, but rather as a multidimensional process that includes competence pedagogical, attitude professional, and ability reflective supported by the system continuing education. Literature during one decade final show that although the COVID-19 pandemic accelerates adoption technology, gap permanent teacher readiness visible, especially in design meaningful digital learning and effective online assessment. The findings also confirm that challenge integration technology nature double, covering constraint external and internal, so that policy education not enough focused on providing infrastructure solely. Continuous, contextual, and integrated teacher training with mentoring and collaboration professional proven more effective in strengthen digital competency and adoption pedagogical technology. Therefore that, this article emphasize importance approach systemic and integrated that connects framework global competence, evidence empirical, and support institutional as foundation main in push transformation sustainable and impactful digital education.

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