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Examining the Digital Technology Competencies of Preschool Teachers in Science

Okul Öncesi Öğretmenlerinin Fen Etkinliklerinde Dijital Teknolojiyi Kullanma Yeterliliklerinin İncelenmesi

Yücehan YÜCESOY

Lecturer, Karatarakli College, Anatolian Fine Arts High School, Technology, Art and Design Department, İzmir, TÜRKİYE, yucehanyucesoy235@gmail.com; 0000-0001-8171-3130

Burak DEMİR

Lecturer, Mediterranean Karpasia University, Education Faculty, Education Management, Nicosia, Turkish Republic of Northern Cyprus. burak.demir@akun.edu.tr; 0000-0001-5666-359X

Keywords

Preschool Education, Science Activities, Digital Technology, Teacher Competence, Mixed Methods

Abstract

This study examines preschool teachers' competencies in using digital technology during science activities in central and rural regions of the TRNC. The research was designed as an explanatory sequential mixed-methods study. The quantitative phase involved 250 teachers, while the qualitative phase included 20 teachers. Quantitative data were collected through a 19-item five-point Likert-type form, and qualitative data were obtained through semi-structured interviews. The findings showed that teachers' competencies were generally at a moderate-to-high level. Competence was stronger in pedagogical selection and planning, but more limited in assessment and feedback. Teachers mainly used digital technology for visualization, attracting attention, and enriching science activities. Infrastructure, technical support, time management, and classroom organization directly influenced implementation quality. The results indicate that digital technology competence in preschool science activities should be understood as a holistic construct that includes pedagogical, ethical, and contextual dimensions beyond technical skill.

Anahtar Kelimeler

Okul Öncesi Eğitim, Fen Bilimleri Etkinlikleri, Dijital Teknoloji, Öğretmen Yeterliliği, Karma Yöntemler

Öz

Bu araştırma, KKTC'de merkez ve taşra bölgelerinde görev yapan okul öncesi öğretmenlerinin fen bilimleri etkinliklerinde dijital teknolojiyi kullanma yeterliliklerini incelemektedir. Çalışma açıklayıcı sıralı karma yöntem deseniyle yürütülmüştür. Nicel aşamaya 250 öğretmen, nitel aşamaya ise 20 öğretmen katılmıştır. Nicel veriler 19 maddelik beşli Likert tipi form; nitel veriler yarı yapılandırılmış görüşmeler yoluyla toplanmıştır. Bulgular, öğretmenlerin yeterliliklerinin genel olarak orta-üst düzeyde olduğunu; pedagojik seçim ve planlama boyutunda daha güçlü, değerlendirme ve geri bildirim boyutunda ise daha sınırlı bir görünüm sergilediklerini göstermiştir. Öğretmenler dijital teknolojiyi daha çok görselleştirme, dikkat çekme ve etkinliği zenginleştirme amacıyla kullanmaktadır. Altyapı, teknik destek, zaman yönetimi ve sınıf içi düzenlemeler uygulamaların niteliğini doğrudan etkilemektedir. Sonuçlar, okul öncesi fen etkinliklerinde dijital teknoloji yeterliliğinin teknik becerinin ötesinde pedagojik, etik ve bağlamsal boyutlar içeren bütüncül bir yapı olduğunu göstermektedir.

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Introduction

Early childhood is regarded as a critical developmental stage in which the foundations of an individual's cognitive, affective, and social development are established. Experiences acquired during this period directly affect children's later learning experiences, problem-solving approaches, and the relationships they form with their environment. Science education is one of the fundamental learning areas in early childhood that enables children to explore their surroundings, make sense of natural phenomena, and establish cause-and-effect relationships. Preschool science activities foster children's sense of curiosity and develop their skills in inquiry, observation, and prediction (Van Driel, Beijaard, & Verloop, 2001).

Through science activities, children not only become familiar with scientific concepts but also develop their thinking processes. Interacting with materials and discussing the results increase the number of children's cognitive flexibility and makes learning more permanent. In this context, preschool science education should be considered not only as a content-focused teaching area but also as a learning process focused on children's active participation.

For science education to be effective in early childhood, the teacher must properly assume a guiding role. The teacher should create a learning environment that supports children's natural curiosity, encourages them to ask questions, and directs discovery processes. In this environment, science activities should be made meaningful by associating them with children's everyday life experiences. Thus, science learning moves away from the transfer of abstract information and turns into a process shaped through children's direct experiences.

Digital technologies stand out as important tools that support and enrich learning processes in educational settings. In the context of preschool education, the use of digital technologies offers various opportunities in terms of attracting children's attention, concretizing abstract concepts, and visualizing the learning process. In science activities, digital tools can be used effectively at stages such as arousing curiosity before an experiment, recording the experimental process, and comparing observations after the experiment (Caena & Redecker, 2019; Yucesoy et al., 2022). From the perspective of the Journal of Media Literacy Studies, the teacher's capacity to select, evaluate, and use digital content critically rather than merely operationally constitutes a form of media literacy that is inseparable from effective digital pedagogy. This critical-evaluative dimension is particularly relevant in science activities, where the quality and reliability of digital content directly affect the integrity of children's inquiry processes (Vuorikari et al., 2022; Zhou & Yang, 2024).

However, the potential contribution of digital technologies in science activities depends on the extent to which the teacher can relate the use of technology to pedagogical purposes. Since learning in early childhood largely occurs through hands-on experience, digital technologies should be positioned not as a substitute for physical experience but as a tool that supports it. Otherwise, technology may weaken the nature of the science activity by causing children to become passive viewers (Niess, 2012; Redecker & Punie, 2017).

The effective use of digital technologies in science activities has the potential to make children's thinking processes visible. For example, documenting children's observations during an experiment through photographs or short recordings makes it possible to evaluate learning in a process-oriented manner. Such practices help children become aware of their own learning processes and provide the teacher with concrete data to support pedagogical decisions. However, for these contributions to be realized, the duration, purpose, and content of digital technology use should be clearly planned (Law et al., 2018).

One of the most critical points in the use of digital technology in preschool science activities is maintaining pedagogical balance. Excessive or purposeless use of technology may distract children from learning objectives and make it more difficult to manage the activity process. Therefore, it is of great importance for the teacher to plan at which stage of the science activity and for how long digital technology will be used.

Pedagogical balance means using digital technology not as the center of the science activity, but as an element that supports the activity. The observation, experimentation, and discovery processes that form the basis of the science activity should be preserved, and digital tools should be regarded as supportive elements that enrich these processes. This approach contributes to sustaining children's active participation and their direct involvement in the learning process (Caena & Redecker, 2019).

1. Purpose of the Study

The main purpose of this study is to comprehensively examine the digital technology competencies of teachers working in preschool education institutions covering central and rural regions in the TRNC within the context of science activities. The study aims to determine the level and purposes for which teachers use digital technology in science activities and to reveal how these competencies are related to teacher characteristics and school context.

Accordingly, in addition to determining teachers' perceptions regarding the use of digital technology through quantitative data, the study also aims to analyze their experiences related to classroom practices in depth through qualitative data. In this way, a more holistic evaluation of teacher competencies is intended.

Problem Statement

In the context of TRNC, conditions related to the use of digital technology in preschool education institutions do not display a homogeneous structure. There are marked differences among schools in terms of technical infrastructure, in-class equipment levels, and teachers' access opportunities to digital technologies. These differences directly affect the ways in which teachers use digital technology in science activities and the quality of this use.

While some teachers use digital technologies in science activities consciously and purposefully, others benefit from these tools only to a limited extent due to technical inadequacies, classroom management concerns, or pedagogical uncertainties. This situation reveals that digital technology competencies cannot be explained solely by individual skills; rather, they should be addressed together with factors such as school context, institutional support, and professional experience.

Research Questions

The following questions were answered within the scope of the study:

- What are the levels of preschool teachers' digital technology competencies in science activities?
- How do teachers' professional experience and frequency of technology use affect their perceptions of competence?
- How do the school's digital infrastructure and institutional support affect teachers' levels of reflecting their competencies in classroom practices?
- For which pedagogical purposes do teachers use digital technology in science activities?

Significance of Study

This study offers a unique contribution to literature by addressing digital technology competencies within the context of preschool science activities. The limited number of studies conducted specifically in the Turkish Republic of Northern Cyprus (TRNC) makes this research significant in terms of local applications. The findings are important for identifying teachers' professional development needs, strengthening school-based support mechanisms, and providing data for policy-level decision-making processes. Unlike previous studies examining the use of digital technology in general education settings, this study uniquely focuses on the intersection of digital technology competence and science activities in preschool education within the TRNC context. Using an explanatory sequential mixed-methods design, it provides a more comprehensive and locally based contribution to the field by quantitatively measuring competency levels as well as revealing the contextual mechanisms shaping practice through qualitative data.

Limited Scope of the Study

This study is limited to preschool teachers' digital technology competencies in the context of science activities. It does not cover teachers' general attitudes toward technology or their use of technology in other subject areas. This limited framework made it possible to conduct an in-depth analysis specific to science activities.

2. Theoretical Framework and Literature

2.1. Theoretical Foundations of Science Learning and Digital Media Literacy in Early Childhood

The science learning process in early childhood is addressed within the framework of constructivist learning theory. According to this theory, children are not passive recipients of knowledge; rather, they are active learners who learn by interacting with their environment, experiencing, and making meaning. Science activities enable children to transform their natural curiosity toward environmental stimulus into a systematic learning process. In this process, children encounter the basic components of scientific thinking, such as observation, prediction, establishing cause-and-effect relationships, and expressing the results they obtain.

The theoretical foundations of science learning in the preschool period are also explained by Piaget's theory of cognitive development and Vygotsky's sociocultural approach. According to Piaget, children in this period are in the preoperational stage and realize their learning largely through concrete experiences. In this context, science activities require abstract concepts to be supported by concrete experiences. Vygotsky, on the other hand, emphasizes that learning takes place through social interaction and draws attention to the importance of teacher guidance and peer interaction. In science activities, the teacher's guiding questions and the structured learning environment are among the fundamental elements supporting children's cognitive development.

The main purpose of preschool science activities is not so much to transfer scientific knowledge to children as to provide the foundations of scientific thinking skills. Through these activities, it is aimed to support children's sense of curiosity, increase their awareness of the events around them, and develop an inquisitive perspective. Science activities encourage children not only to focus on results, but also to think throughout the process, conduct trials, and produce different solution paths.

One of the distinctive characteristics of these activities is that they are child centered. Science activities planned based on children's interests and daily life experiences ensure that learning is meaningful and lasting. In addition, making mistakes, trying again, and discovering are regarded as natural parts of learning in these activities. This approach contributes to children's development of self-confidence and positive attitudes toward learning.

At the same time, the scientific nature of early childhood activities intersects directly with digital media safety. Preschool science learning depends on observation, hands-on exploration, and teacher-guided discussion; therefore, digital media should be used only when it protects the exploratory character of the activity and does not replace direct experience. For young children, age-appropriate content, privacy protection, limited screen exposure, and the reliability of visual materials become part of the scientific learning environment itself. In this respect, teachers' digital media literacy functions not only as a technical competence but also as a protective and pedagogical responsibility that supports safe inquiry (Vuorikari et al., 2022; OECD, 2023; Zhou & Yang, 2024).

2.2. Digital Technology in Education: Theoretical Bases, Media Literacy, and Classroom Applications

Theoretical approaches regarding the use of digital technology in education provide important frameworks for how technology should be integrated into the learning process. In this context, the effectiveness of technology in the instructional process depends on its being used in a manner compatible with pedagogical purposes. Technology should not be regarded as an element that enables learning on its own, but as a tool that supports and enriches the learning process.

Teachers' and pre-service teachers' attitudes toward technology and their readiness for technology integration play a decisive role in the effective use of digital technology in instructional processes. Technology provides teachers with an important basis in terms of selecting tools suitable for instructional practices, following new trends, and integrating technology with pedagogical purposes (Birkollu et al., 2017).

This approach argues that technology should support the active participation of learners rather than strengthening teacher-centered transmission processes. Especially in early childhood, it is important that digital technologies be structured in a way that supports children's experiential learning. Otherwise, technology may weaken the nature of learning by pushing children into the position of passive viewers. The European Digital Competence Framework for Educators (DigCompEdu) conceptualizes this balance by situating pedagogical competencies at the core of digital practice, encompassing dimensions of content selection, learner engagement, and assessment all of which are directly relevant to the science activity context examined in the present study (Redecker, 2017; Caena & Redecker, 2019). More recent scholarship has further emphasized that digital competence in early childhood must be understood through a media literacy lens: teachers who are able to critically evaluate digital content, recognize its affordances and limitations, and guide children's media encounters are engaged in a fundamentally educative act (Vuorikari et al., 2022; Hunze et al., 2024; OECD, 2023).

In preschool education, digital technologies can be used for various purposes such as storytelling, game-based learning, visualization, and supporting discovery processes. In the context of science activities, digital tools make it possible to visualize processes that cannot be directly observed, record the stages of experiments, and enable children to express their thoughts.

Teacher education programs and in-service development processes are expected to strengthen teachers' capacity in terms of accessible digital content, gamified learning environments, and child-centered use of technology. The use of technology in preschool education should be regarded as a holistic field of competence that is not limited to knowledge of tools only, but also includes pedagogical design, accessibility, and sustainable practice dimensions (Yucesoy et al., 2022; Birkollu et al., 2017).

These tools can facilitate children's focus on the learning process by supporting their attention spans. However, the nature, duration, and content of use are shaped by the teacher's pedagogical decisions. Therefore, the role of digital technologies in education gains meaning through teacher guidance.

2.3. Digital Technology Competence: Definition, Dimensions, and Media Literacy Perspectives

Digital technology competence refers to an individual's capacity to use digital tools consciously, purposefully, and safely. In the educational context, this competence covers the teacher's skills in selecting, implementing, and evaluating technology in line with pedagogical goals. For preschool teachers, digital competence is directly related to dimensions such as child development, classroom management, and safety. The most widely adopted reference framework for this conceptualization is the European DigComp framework, the latest iteration of which (DigComp 3.0) emphasizes five interrelated competence areas: information and data literacy, communication and collaboration, digital content creation, safety, and problem-solving (Vuorikari et al., 2022). In the context of early childhood science education, this framework intersects with media literacy in a distinctive way: teachers must not only master the technical dimension of tool use, but also exercise the kind of critical media awareness that enables them to model responsible and discerning digital practice for young children (Hunze et al., 2024; OECD, 2023). This intersection between digital competence as pedagogical skill and media literacy as critical citizenship capacity represents the conceptual core of the present study's relevance to the Journal of Media Literacy Studies.

This competence should be addressed not as a static set of skills, but as a dynamic structure that continuously develops through the teacher's experiences and professional development processes.

Preschool teachers' digital technology competencies display a complex structure involving multiple dimensions. Among these dimensions, technology selection, activity planning, supporting the learning process, providing assessment and feedback, and safety and ethical responsibilities stand out. The teacher's level of competence in these dimensions determines the extent to which digital technology can be meaningfully integrated into science activities.

Especially in science activities, it is important that the teacher be able to structure technology in a way that supports children's active participation. This situation brings to the fore the interaction between the teacher's pedagogical knowledge and the skill of using digital tools.

2.4. Pedagogical Use of Digital Technology in Science Activities

The pedagogical use of digital technology in science activities covers the stage at which and the purpose for which technology is used. Digital tools can be used to arouse curiosity at the beginning of the activity, to provide observation and recording throughout the process, or to enable reflection at the end of the activity. However, for this use to carry pedagogical value, it must be aligned with the teacher's activity goals.

Pedagogically effective use of technology supports children's thinking processes and deepens science learning. In this context, the teacher's guidance plays a decisive role in enabling digital technology to contribute to the learning process. In preschool science activities, assessment is approached with a process-oriented understanding. Digital technologies make it possible to document children's learning processes, compare observations, and provide feedback.

However, for these processes to be effective, the teacher must clearly determine the purposes of assessment and use digital tools in service of those purposes.

The use of digital technologies in preschool education gives rise to special responsibilities in terms of children's safety and privacy. Teachers' selecting reliable content, protecting personal data, and ensuring age-appropriate use form important components of digital competence.

This dimension is regarded as an integral component of digital technology competence. Safety and ethical awareness directly affect the teacher's ability to use technology responsibly. Teachers' digital technology competencies are closely related to professional development processes. In-service training, professional learning communities, and peer sharing support the development of teachers' digital competencies.

When professional development opportunities are limited, teachers' use of digital technology may remain superficial. Therefore, the sustainability of professional development support is important. School context plays a decisive role in teachers' ability to reflect their digital technology competencies in classroom practices. Infrastructure, technical support, managerial encouragement, and the resources offered by the school directly affect technology integration.

When the literature is examined, it is seen that studies on preschool teachers' digital technology competencies are mostly conducted in the general education context. Studies focusing specifically on science activities are limited. This study is positioned to fill this gap in literature.

3. Method

Since this study aims to examine preschool teachers' digital technology competencies in science activities in a multidimensional way, it was designed according to the mixed-method research approach.

3.1. Research Design and Participants

In addition to describing teachers' competency levels regarding digital technology, this model also makes it possible to reveal how these competencies are reflected in classroom practices and which contextual factors are related to them.

In the first stage of the study, quantitative data were collected and teachers' perceptions of competence regarding digital technology in science activities were described in general terms.

The research process was carried out in three main stages. In the first stage, a literature review was conducted, and the theoretical framework of the study was established. In the second stage, quantitative data were collected and analyzed. In the third stage, qualitative data were collected to explain the quantitative findings in depth.

This structure ensured that the research progressed in a systematic and consistent manner and enabled each stage to contribute to the next stage in terms of data and meaning.

The population of the study consists of preschool teachers working in official and private preschool education institutions affiliated with the Ministry of National Education throughout the Turkish Republic of Northern Cyprus, including central and rural regions.

Preschool education institutions in the TRNC display different characteristics in terms of infrastructure, equipment, and institutional support. This diversity has made it possible to consider teachers' digital technology competencies in a multidimensional way.

The sample of the study was determined from the population in line with the purposive sampling approach. Purposive sampling is a method that makes it possible to select information-rich cases appropriate to the purpose of the study.

Diversifying the sample in this way made it possible to evaluate digital technology competencies not only through individual characteristics, but also in relation to school context and environmental conditions.

3.2. Data Collection and Analysis

The study group consisted of 250 preschool teachers in the quantitative stage and 20 preschool teachers in the qualitative stage. Participants represented different age groups, levels of professional seniority, school types, and levels of technology use.

For the qualitative stage, participants were selected using maximum variation criteria in order to reflect different institution types, professional seniority groups, technology-use frequencies, and central-rural school contexts. Participation was voluntary, and teachers who had direct experience of conducting science activities with digital tools were prioritized.

The characteristics of the study group provided a contextual framework for interpreting the findings and showed that teacher competencies do not display a one-dimensional structure. The data collection process was carried out systematically in line with the determined research plan. Quantitative data were collected through a measurement tool developed to determine teachers' competencies regarding digital technology in science activities.

In the qualitative data collection process, more detailed data were obtained through semi-structured interviews conducted with 20 teachers.

Quantitative data were analyzed using descriptive statistics (frequency, percentage, mean, and standard deviation) and comparative tests. High-frequency response rates (4-5 scores) and NA rates were also examined to identify strong and weak competency areas. Independent-samples t-tests were used for comparisons by institution type, and one-way analysis of variance (ANOVA) was used for comparisons by professional seniority. The significance level was accepted as $p < .05$.

The qualitative data collection process was carried out to examine in depth the experiences related to the quantitative findings. Interviews were conducted through a semi-structured form. The qualitative data collection process enabled the acquisition of contextual information regarding teachers' practices and contributed to explaining the quantitative findings.

Qualitative data were analyzed through thematic content analysis. Interview notes and transcripts were first read repeatedly; then open codes were generated, grouped into sub-themes, and organized under main themes consistent with the research questions. To strengthen trustworthiness, coding decisions were reviewed iteratively, representative teacher statements were used to support themes, and qualitative findings were compared with quantitative patterns during integration.

The joint interpretation of quantitative and qualitative data was regarded as an important element that increased the validity and explanatory power of the study.

Validity and reliability strategies were also considered in both phases of the research. In the quantitative phase, content validity was supported through expert review of the items and alignment with digital competence dimensions, and internal consistency was checked before the dimension means were interpreted. In the qualitative phase, credibility was supported through transparent coding, direct quotations, and comparison of qualitative explanations with quantitative results. These procedures strengthened the coherence and explanatory power of the mixed-method design.

3.3. Ethical Procedures

Ethical principles were meticulously followed throughout the research process. Participants were clearly informed about the purpose and scope of the study, voluntary participation was ensured, and informed consent was obtained before data collection. Participants were informed that they could withdraw from the study at any stage without any negative consequence. Personal identifiers were not included in the data set; interview excerpts were anonymized, and findings were reported only in aggregate or through non-identifying quotations. Ethical approval for this study was obtained from University of Mediterranean Karpasia Ethics Committee on November 3, 2025.

4. Findings

The findings regarding preschool teachers' digital technology competencies in science activities throughout the TRNC are presented below in an integrated structure based on quantitative and qualitative evidence.

4.1. Participant Profile and Contextual Characteristics

A total of N=250 teachers working in official and private preschool institutions in the TRNC participated in the study. Of the participants, 212 were female and 38 were male.

Table 1. Demographic characteristics of the participants (N=250)

Variable	Category	N	(%)
Gender	Female	212	84,8
	Male	38	15,2
Age	<25	45	18,0
	25–34	110	44,0
	35–44	60	24,0
	≥45	35	14,0
Institution Type	Official	175	70,0
	Private	75	30,0
Professional Seniority	0-5 years	102	40,8
	6-10 years	88	35,2
	≥11 years	60	24,0

This profile shows that digital technology competencies are related not only to individual skills but also to school type, seniority, age, and institutional practices.

4.2. Digital Infrastructure, Access, and Frequency of Use in Science Activities

Teachers' ability to use digital technology in science activities is closely related to in-class infrastructure and access opportunities. Participants' reports indicate that access conditions directly affect classroom practices.

Table 2. Digital access and usage patterns in science activities (N=250)

Indicators	Category	N	(%)
Access to basic devices in the classroom	Available	196	78,4
	Not available	54	21,6
Internet continuity	Mostly sufficient	142	56,8
	Frequent interruptions	108	43,2
Frequency of use in science activities	3+ per week	58	23,2
	1-2 per week	124	49,6
	1-2 per month	50	20,0
	Very rarely	18	7,2

Perception of technical support	Sufficient	74	29,6
	Partially	96	38,4
	Insufficient	80	32,0

Table 2 shows that factors such as internet interruption and insufficient technical support can shape digital practices in science activities not only in terms of "frequency" but also in terms of "continuity" and "quality."

4.3. Regional Differences in Central and Rural Contexts

When the findings are read in relation to the central-rural distinction, regional differences are most visible in the continuity and quality of implementation rather than in the general willingness to use digital technology. Teachers in central contexts reported more stable access to devices, internet continuity, and technical support, whereas teachers in rural contexts emphasized interruptions, limited support, and the need to reorganize activities when technological conditions did not work as planned. Thus, regional context appears to operate as an enabling or constraining condition that shapes whether digital competence can be translated into consistent classroom practice.

This distinction is particularly important for science activities because interruptions in access or support do not merely reduce frequency of use; they also limit process documentation, instant feedback, and opportunities to revisit children's observations. Therefore, the regional pattern supports the interpretation that digital competence should be evaluated together with infrastructure and institutional support.

4.4. Descriptive Findings at the Item Level

This subsection presents teachers' responses to 19 statements at the item level. The statements cover topics such as selecting appropriate digital technology, supporting creativity, evaluation, and reliability.

Descriptive Statistics for Items 1-10 and Items 11-19

Table 3. Means, standard deviations, NA, and high-frequency (4-5) rates for the 19 items

No	Statement (abbreviated)	Mean	SD	NA %	(4-5) %
1	Selecting digital technology appropriate to the topic	4,05	0,72	1,2	71,0
2	Use that develops creative thinking	3,70	0,83	1,6	52,4
3	Providing information about copyright	2,95	0,98	4,0	28,1
4	Creating an environment suitable for individual differences	3,45	0,90	2,0	44,0
5	Learning to use new technologies	3,60	0,84	2,4	48,3
6	Participation in social network communities	2,60	1,05	8,0	20,2
7	Self-assessment of the learning process with digital tools	2,85	1,00	6,0	27,4
8	Developing digitally enriched materials	3,10	0,95	3,2	35,0
9	Creating a rich learning environment	3,80	0,78	1,2	58,6
10	Using different digital technologies in harmony	3,55	0,82	1,6	47,1
11	Evaluating the process with e-portfolio/Excel, etc.	2,70	1,02	7,2	22,0
12	Closely following new technologies	3,65	0,80	2,0	50,0
13	Evaluating source reliability	3,95	0,74	1,2	66,1

14	Considering learning outcomes in selection	4,10	0,70	0,8	74,2
15	Use that ensures active participation	3,85	0,76	1,2	61,4
16	Considering individual differences in selection	3,90	0,75	1,6	64,0
17	Including digital use in the lesson plan	3,75	0,82	1,2	55,2
18	Instant feedback during the lesson process	3,05	0,98	5,2	34,0
19	Using it to encourage collaboration	3,20	0,92	2,8	38,2

Table 3 presents the item-level descriptive statistics of teachers' responses to the 19 statements.

4.5. Aggregated Quantitative Findings Across Thematic Dimensions

This subsection presents the combined means of the 19 items under analytical dimensions. Thus, teachers' digital technology competencies can be evaluated within broader pedagogical domains.

Table 4. Dimension means (range 1-5)

Dimension (analytical)	Included items	Mean	SD
Pedagogical selection and planning	1, 14, 16, 17	3,95	0,61
Enriching the learning environment and participation	2, 4, 9, 10, 15, 19	3,59	0,64
Production and tracking of innovation	5, 8, 12, 6	3,24	0,71
Assessment and feedback	7, 11, 18	2,87	0,80
Reliability and copyright awareness	3, 13	3,45	0,77
Overall mean	19 items	3,43	0,58

Dimension means that the strongest area for teachers is pedagogical selection and planning, while the weakest area is assessment and feedback.

4.6. Differentiation by Type of Institution

Comparisons by institution type show that teachers working in private institutions display higher mean scores in some dimensions.

Table 5. Comparisons of dimensions by institution type

Dimension	Official (n=175) Mean±SD	Private (n=75) Mean±SD	t	p
Pedagogical selection and planning	3,91±0,62	4,03±0,58	-1,52	0,13
Enrichment and participation	3,54±0,64	3,71±0,61	-2,05	0,04
Production and tracking of innovation	3,16±0,72	3,43±0,67	-2,84	0,005
Assessment and feedback	2,83±0,81	2,95±0,78	-1,14	0,26
Reliability and copyright	3,41±0,79	3,56±0,72	-1,48	0,14

4.7. Differentiation by Professional Seniority

When the findings are examined by professional seniority, teachers with 0-5 years of experience appear to have higher mean scores in the "production and tracking of innovation" dimension.

Table 6. Dimension means by professional seniority (ANOVA)

Dimension	0-5 years (n=102)	6-10 years (n=88)	**≥11 yıl (n=60)**	**F**	**p**
Pedagogical selection and planning	3,90	3,97	4,00	0,88	0,41
Enrichment and participation	3,61	3,57	3,58	0,19	0,83
Production and tracking of innovation	3,35	3,22	3,08	4,02	0,02
Assessment and feedback	2,92	2,85	2,81	0,72	0,49

The seniority variable diverges most in the dimension of production and innovation tracking. However, the fact that the assessment and feedback dimension remains low across all seniority groups is noteworthy.

4.8. Awareness Gaps Indicated by NA (Not Applicable) Responses

When the items with higher rates of NA (not applicable) responses are examined, some areas stand out particularly, such as participation in communities on social networks (Item 6), self-assessment, and process monitoring.

4.9. Qualitative Findings

Qualitative findings provide a strong background that explains the quantitative patterns. Teachers' narratives show that digital technology in science activities is mostly used for visualization, attracting attention, and making the process visible.

Table 7. Qualitative themes, sub-themes, and sample narratives (n=20)

Theme	Sub-themes	Representative teacher narratives (abridged)
Purposes of use	Visualization, arousing curiosity, process recording	"First, I arouse curiosity with a 1–2 minute video; then we conduct the experiment at the table."
Pedagogical design	Station work, small group, inquiry	"When I set up stations, I can use the device like a 'station,' and the children come one by one."
Assessment and feedback	Collecting evidence, instant feedback, monitoring	"I want to provide instant feedback, but it is difficult to manage the class at the same time."
Barriers	Time, technical disruptions, finding content	"When the connection drops, the flow is disrupted; the plan changes that day."
Reliability and copyright	Selecting appropriate content, limits of sharing	"I do not open everything I see; I choose from reliable sources."
Institutional conditions	Support, infrastructure, administrative approach	"If there is support, I try more comfortably; otherwise, I do not want to take risks."

The area of assessment and feedback is affected more by classroom management, time, and technical conditions. Participation in professional networks (Item 6) remains weak because it is outside routine classroom flow.

4.10. Quantitative-Qualitative Integration: A Joint Reading of the Findings

While quantitative findings show "which areas are strong/weak," qualitative findings provide an explanatory framework for the question of "why." For example, the relative weakness in assessment and feedback becomes more understandable in relation to classroom flow, child age, and infrastructure limitations. This pattern is consistent with broader findings in the literature on early childhood digital pedagogy, which identify assessment and documentation as the competency area most constrained by contextual and logistical factors (Zhou & Yang, 2024; OECD, 2023).

The findings indicate that preschool teachers' digital technology competencies in science activities in the TRNC generally follow a medium-high level, but there are imbalances across dimensions.

5. Discussion, Conclusion, and Recommendations

In this section, quantitative and qualitative findings are interpreted together, and it is discussed through which pedagogical functions teachers use digital technology in science activities, in which areas they are strong, and which contextual variables shape this structure.

5.1. Competency Patterns: Strengths, Weaknesses, and Media Literacy Dimensions

The findings show that preschool teachers' competencies in using digital technology in science activities in the TRNC are generally at a medium-high level. However, this general picture does not mean that all competency areas are equally strong. This medium-high general level is broadly consistent with findings from comparable national and international contexts: studies applying the DigCompEdu framework in Turkey have similarly reported integrator-level competence on average among in-service teachers, with notable variation across dimensions related to assessment and professional networking (Frontiers, 2025; Springer, 2024). From a media literacy standpoint, the dimension of "reliability and copyright awareness" detected in the present study maps directly onto what the DigComp 3.0 framework defines as "information and data literacy" a competence area that is especially formative when teachers mediate children's first encounters with digital content (Vuorikari et al., 2022).

This imbalance may also be explained by the specific instructional conditions of the early childhood context. In preschool, science activities proceed through short attention cycles, movement, hands-on participation, and the need for instant classroom management. One of the strongest areas in the findings is teachers' ability to select digital technology appropriate to the topic of the science activity and to place it in the activity plan by considering learning outcomes.

This result suggests that digital technology is positioned in science activities as a support serving learning outcomes. Especially in preschool education, the fact that teachers approach technology not as an end but as a supportive element is pedagogically meaningful.

Teachers' relatively high mean scores on indicators related to "creating a rich learning environment" and "supporting active participation" can be associated with the ability of digital tools to visualize science processes, attract attention, and concretize abstract content. In contrast, the relatively lower means in areas requiring more complex in-class organization, such as using technology to encourage collaboration, show that collaborative use is more difficult to implement in the early childhood context.

While indicators of learning and closely following new technologies are at a medium-high level in the findings, the indicator of participation in communities on social networks remains at a lower level. Qualitative findings also show that teachers mostly access information through quick searches and ready-made content, whereas systematic community participation is weaker.

5.2. Contextual and Institutional Factors Shaping Digital Practices

In the quantitative results, the lowest means are seen in the areas of "monitoring with process assessment tools," "supporting self-assessment," and "instant feedback. "This pattern indicates that teachers' digital competence is shaped not only by knowledge and skill, but also by the physical arrangement of the classroom, the continuity of infrastructure, and institutional support.

This finding offers an important practical implication: in early childhood science activities, digital assessment and feedback processes should not be designed as "heavy" systems, but as practical routines that can fit classroom flow. The fact that the indicator of "evaluating source reliability" is high while the indicator of "informing about copyright" is relatively low shows that teachers are more careful in content selection than in explicitly explaining ethical issues.

This result emphasizes that digital literacy should be addressed not only through access and use, but also through ethical, legal, and security dimensions. In comparisons between official and private institutions, the fact that private institutions show higher mean scores in some dimensions may be associated with the quality of digital practices being related not only to teacher willingness but also to the school's resources and organizational flexibility. Nevertheless, the relatively high level of pedagogical selection and planning in both institution types indicates that teachers' basic pedagogical decisions are more robust than contextual limitations.

Within this contextual frame, the central-rural distinction also helps interpret why similar pedagogical intentions may lead to different classroom practices. Central settings tend to provide more stable conditions for continuous use, whereas rural settings make teachers more dependent on contingency planning, low-tech alternatives, and institutional support. Therefore, regional context should not be read simply as a geographical variable; it functions as a practical ecology that affects assessment, feedback, documentation, and sustained use.

Findings by seniority show that teachers with lower seniority appear higher in areas such as production and tracking of innovation, whereas teachers with higher seniority appear relatively stronger in pedagogical selection and classroom adaptation. This result suggests that teachers' conceptualizations of technology are shaped over time by teacher education, professional experience, and previous practice experiences.

The increase in NA rates in some statements (especially in areas related to participation in professional communities and assessment-feedback) indicates that some dimensions are not sufficiently reflected in teachers' daily practices. This finding shows that to support the development of digital competence, not only technology introduction but also instructional design, assessment literacy, and context-sensitive support models are needed.

Qualitative findings make the mechanisms behind quantitative patterns visible. Especially in the relatively weak area of assessment and feedback, it is seen that teachers avoid more complex digital processes due to time limitations, classroom flow, and technical risks. In addition, teachers' emphasis that they use digital technology mostly to arouse curiosity and for visualization purposes is consistent with the pedagogical nature of preschool science activities.

5.3. Implications for Policy, Teacher Development, and Sustainable Digital Media Education

The problems of internet continuity and insufficient technical support shown by the findings indicate that sustainability is a critical issue in the integration of digital technology into science activities. The OECD Digital Education Outlook (2023) highlights that infrastructure continuity, and minimum device standards are preconditions for any meaningful development of teachers' digital competencies; without these conditions, highly motivated teachers are constrained in translating competence into sustained classroom practice. The implications for media literacy education are similarly structural: teachers who lack reliable access to digital tools cannot systematically model critical media engagement, source evaluation, or copyright-aware content use all of which are essential components of a pedagogy that prepares children for life in a media-saturated environment (OECD, 2023; Vuorikari et al., 2022).

In this context, teacher competencies should be considered not only as personal skills, but also together with the school's capacity to function as a learning organization and its culture of institutional support. Since science activities in early childhood progress based on "discovery, observation, and experimentation," the role of digital technology is often not to replace the experiment, but to frame it, make it visible, or support reflection.

In contrast, the limitation in assessment and feedback may make it difficult to make process skills visible in science learning. Therefore, digital routines that produce minimal but meaningful evidence should be strengthened. When all findings are evaluated together, it is seen that teachers effectively use digital technology in science activities for selection and enrichment purposes, but there are more limited practices in areas such as assessment, feedback, collaboration, and participation in professional networks.

Conclusion

In conclusion, the discussion section shows that preschool teachers' digital technology competencies in science activities in the TRNC context display a pedagogically meaningful but contextually constrained structure. In this study, the pattern of preschool teachers' digital technology competencies in science activities was examined through quantitative findings based on 19 statements, qualitative themes explaining this structure, and an integrated interpretation of these two data sets.

General findings show that teachers' digital technology competencies in science activities are at a medium-high level. However, this level is not distributed homogeneously across all dimensions. This picture is also compatible with the instructional conditions of early childhood. In preschool, science activities proceed through short attention cycles, safety sensitivity, movement, direct experience, and instant classroom management requirements.

One of the strong outputs of the study is that teachers can select digital technology appropriate to learning outcomes in science activities and integrate it pedagogically into the activity plan. In addition, the high level of evaluating source reliability shows that sensitivity related to safety and appropriateness in early childhood education are reflected in teachers' digital preferences.

A critical aspect of the findings is that the assessment and feedback dimension appears lower compared to the other dimensions. Producing evidence throughout the process, supporting self-assessment, and giving instant feedback are more difficult to sustain in the flow of preschool classrooms. Moreover, although teachers' tendency to follow innovations appears at a medium-high level, participation in professional digital communities is relatively low. This indicates a more individualized rather than network-based pattern of professional learning.

In comparisons by institution type, the fact that private institutions can show higher mean scores in some dimensions reveals that teacher competencies are shaped not only by pedagogical knowledge but also by resource diversity, technical support, and organizational flexibility. Findings by seniority show that although the low-seniority group appears higher on indicators related to production and tracking of innovation, the pedagogical selection and planning dimension is more balanced across all groups.

While quantitative findings clearly reveal strong and weak areas, qualitative findings explain the mechanisms behind this pattern. The dimensions of assessment and feedback, collaboration, participation in professional communities, and ethical informing are shaped not only by teacher competence but also by time, classroom management, technological continuity, and institutional support conditions.

The overall implication of the study is that teachers mostly use digital technology in science activities effectively on the axis of selection-planning-enrichment; however, more contextual, sustainable, and practice-oriented support is needed in areas such as assessment-feedback, collaboration, ethics, and professional networking.

Recommendations

In this section, recommendations are presented under the headings of system and policy, school and administration, teacher education and in-service development, and classroom practice design.

Recommendations on the System and Policy Level

Continuity of infrastructure and minimum standards: Internet access and the continuity of devices are among the fundamental conditions that determine the usability of digital technology in science activities. Therefore, schools should guarantee minimum standards in terms of connection, technical functioning, and basic hardware.

Institutionalization of the technical support mechanism: One of the main reasons teachers give up on digital practices is the absence of a support structure that can quickly solve problems. For this reason, a school-based or regionally accessible technical support mechanism should be institutionalized.

Digital practice packages embedded in early childhood science: Teachers should be provided not only with tool introductions, but also with sample practice sets embedded in the stages of science activities. Such packages can facilitate the transformation of competence into practice.

Recommendations at the School and Administration Level

A school-based reliable content pool: The fact that teachers appear strong in selecting reliable content is an advantage that can be institutionalized.

Station and rotational use design: When the number of devices is limited, structuring the use of digital technology like a station can both facilitate classroom management and support children's active participation. A culture of in-school sharing and micro-communities: The apparently low participation in professional digital communities can be balanced through in-school micro-communities.

Recommendations for Teacher Education and In-Service Development

Science activity-based digital pedagogical training: Training content should focus not so much on the question of which tool is used how, but on how digital technology can be positioned within science activity design in a pedagogically meaningful way.

Assessment-feedback-focused micro-modules: Short and practical modules are recommended for the weakest areas. These modules can increase teachers' assessment capacity without increasing workload.

- Short evidence collection: one photograph, one short audio recording,
- Reflection: a mini card with two questions,
- Feedback: one sentence of observation + one sentence of the next step,
- Simple checklist: a minimal template for process monitoring. These micro-practices can increase teachers' assessment capacity without adding burden.

Transforming the ethics and copyright dimension into a classroom routine: Since the copyright information indicator is relatively low, this area should be converted into age-appropriate routines at the early childhood level.

Recommendations for Classroom Practice Design, Monitoring, and Assessment

A three-stage digital placement approach: For each science activity, the role of digital technology can be planned through one of three purposes:

1. Arousing curiosity and visualization,
2. Supporting and making discovery visible,
3. Producing evidence, reflection, and feedback.

This approach strengthens pedagogical alignment by providing the teacher with decision steps.

Low-cost productions that support creativity: Small productions that enable children to express their observations (photo collage, short audio explanation, simple digital drawing) can be used.

Adaptation strategies for individual differences: Digital content can be used to provide differentiated options: shorter instructions, more visual support, repetition opportunities, and alternative expression channels.

Micro-evidence + micro-feedback routine: The strongest solution proposed for the area of assessment-feedback is classroom-flow-compatible micro-routines. The teacher can routinely use:

- 10 seconds of evidence (photo/audio),
- 2 reflection questions,
- 2 feedback sentences. When this routine becomes sustainable, it can provide a visible improvement in assessment capacity (Caena & Redecker, 2019).

Role-based design for collaboration: Device scarcity does not have to reduce collaboration. In small groups, roles such as observer, recorder, narrator, and organizer can support collaboration.

- short classroom observations,
- teacher reflective notes,
- short video clips,
- children's products and explanations

The effectiveness of these recommendations can be monitored through evidence such as short classroom observations, teacher reflective notes, short video clips, children's products, and their explanations.

Limitations and Recommendations for Future Research

- This study provides important and multi-layered findings regarding preschool teachers' digital technology competencies in science activities in the TRNC context; however, it also has some limitations that should be considered in the interpretation of the findings.
- First, the fact that the quantitative data are based on teachers' self-reports may bring the effect of social desirability and the possibility of a gap between perceived competence and actual classroom practice.
- Second, the cross-sectional collection of data does not allow monitoring changes in competence over time. Since digital competence is a dynamic structure, longitudinal studies are needed to observe development processes.
- Third, although a sample targeting the whole TRNC was designed, access conditions (institutions' willingness to participate in the study, teachers' availability, and regional opportunities) may have limited representation power.
- Fourth, since the qualitative section was conducted with a limited number of participants, the aim of the findings is not to represent the experiences of all teachers, but rather to explain the patterns observed in the quantitative stage in depth.

Finally, although contextual factors such as infrastructure and technical support were reported in the study, these factors were not measured in detail (e.g., the school's device inventory, connection speed, frequency of technical support).

Future research should be designed in a way that allows a deeper and more multidimensional understanding of teachers' digital technology practices in science activities.

- First, studies that directly observe classroom practice are important. Short natural classroom observations can provide stronger evidence about how the teacher positions digital technology within the flow of the activity.
- Longitudinal studies that monitor change over time are recommended. For example, the developmental course of teachers' assessment-feedback practices can be tracked after an educational intervention.
- Multivariate models in which variables such as institution type, seniority, class size, and the school's level of digital infrastructure are examined together can reveal more clearly which factors are more determinant.
- Intervention studies testing the effects of micro-assessment and micro-feedback routines specific to the early childhood science context are recommended. Such studies may provide stronger evidence about the sustainability of digital competence in practice.

Finally, school-based models aimed at increasing teachers' participation in professional digital communities should be tested; for example, structures such as in-school micro-communities, peer mentoring, and shared content production can be examined.

Author Declarations

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Author/Authors: Yücehan YÜCESOY, Ph.D., Technology Teaching Education Department, Faculty of Education; Burak DEMİR Öğretim Görevlisi, Akdeniz Karpaz Üniversitesi,Eğitim Fakültesi

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