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A Study on the Value, Dilemmas, and Enabling Pathways of Early Childhood Teachers' Boundary-Crossing Learning in the Digital and Intelligent Age

Jiaying Shen

Huzhou Normal University, Huzhou, China
13058929983@163.com

Abstract. In the digital and intelligent age, early childhood education is increasingly integrated with digital technologies. As a result, boundary-crossing learning has become a key pathway for the professional development of early childhood teachers. Using theoretical synthesis and logical deduction, and drawing on boundary-crossing learning theory and expansive learning theory as analytical frameworks, this study defines the meaning of boundary-crossing learning for early childhood teachers in the digital era. It analyses the core value of such learning from three perspectives: knowledge, practice, and identity. The study finds that teachers face practical difficulties, including delays in institutional evaluation and a lack of incentives, as well as cultural challenges such as rigid role perceptions and fear of difference, and technical issues such as the superficial use of technology and imitative learning. Therefore, this paper proposes targeted enabling pathways from institutional, cultural, and technical dimensions. These pathways aim to help overcome the challenges early childhood teachers face in boundary-crossing learning and to support the digital transformation of early childhood education. The study also contributes to enriching teacher education research and improving the quality of early childhood education.

Keywords: Early Childhood Teacher, Digital and Intelligent Age, Boundary-Crossing Learning, Enabling Pathways, Expansive Learning Theory

1. Introduction

With the rise of digital and intelligent technologies, early childhood education is becoming deeply integrated with artificial intelligence, big data, and other technologies. This trend demands greater cross-disciplinary competence from early childhood teachers and also provides more diverse ways for them to engage in boundary-crossing learning. The Guidelines for the Learning and Development of Children Aged 3–6 clearly emphasise the comprehensive and holistic nature of early childhood education [1]. This means that teachers must be able to integrate resources from multiple fields. Consequently, boundary-crossing learning has become an important pathway for the professional development of early childhood teachers. In the digital age, identifying the value of such learning and addressing its challenges are essential for promoting boundary-crossing learning

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among early childhood teachers. These efforts are also necessary to support the ongoing digital transformation of early childhood education. In existing research, Liu Huixuan and others have explained the value of teacher boundary-crossing learning from multiple dimensions and constructed an analytical framework for such learning in the digital age [2]. At the level of early childhood teachers, Zhang Chunying et al. have used expansive learning theory to explore the mechanisms of boundary-crossing learning and have proposed several practical suggestions [3]. Li Jing and others focused on technology empowerment, analysing the meaning, practical problems, and possible pathways of teacher boundary-crossing learning [4].

However, most current studies focus on boundary-crossing learning among primary school and university teachers, with relatively limited research on early childhood teachers. Moreover, existing studies often take a single perspective and lack a comprehensive analysis of multiple factors.

Therefore, this study employs theoretical integration and logical deduction and, drawing on boundary-crossing and expansive learning theories, explores the value and challenges of boundary-crossing learning for early childhood teachers in the digital age. It then proposes three-dimensional enabling pathways to address these difficulties, providing theoretical guidance for the professional development and digital competence enhancement of early childhood teachers in the new era.

2. Theoretical basis

2.1. The meaning of boundary-crossing learning for early childhood teachers in the digital and intelligent age

The concept of "boundary-crossing learning" emerged in the 1990s. It refers to the process in which learners from different activity systems and fields go beyond their usual work or disciplinary boundaries, interact with individuals or groups from other systems or fields, and thereby change their own knowledge structures [3]. In the digital and intelligent age, this concept has taken on new meaning. Teacher boundary-crossing learning in this era is a dynamic process in which teachers actively break through boundaries of time, space, subject, role, and technology, place themselves in diverse and heterogeneous environments, engage in meaningful communication and reshaping, and eventually generate new characteristics and cultures through the interaction of multiple elements [2].

Focusing specifically on early childhood teachers, this study defines boundary-crossing learning in the digital age as follows: In a digital and intelligent teaching environment, early childhood teachers, with child development at the centre, actively go beyond the traditional boundaries of early childhood education in terms of field, subject, role, and technology. By integrating knowledge from multiple fields, innovating in educational practices, and reshaping professional identity, they create a dynamic learning process that supports their professional growth and improves the quality of early childhood education. This definition provides a core conceptual foundation for the study's exploration of the value, difficulties, and enabling pathways of boundary-crossing learning for early childhood teachers in the digital age.

2.2. Expansive learning theory

Expansive learning theory was proposed by Yrjö Engeström in 1987. This theory defines learning as a process in which individuals and groups collaboratively identify contradictions within an activity system, cross professional boundaries, generate new practices through collaborative inquiry, and ultimately achieve systemic transformation and innovation. While expanding the conceptual boundaries of "learning" itself, this theory focuses not only on the generation of new knowledge and

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new activity patterns during the boundary-crossing process but also on the negotiation between learners and their existing environment and culture [5]. The theory starts with identifying contradictions within an activity system, encourages learners to cross professional boundaries, and ultimately helps them achieve three kinds of expansion: cognitive, practical, and identity-based.

For early childhood teachers, boundary-crossing learning is essentially an expansive process of breaking through existing professional boundaries. Digital and technological changes generate new educational demands. These new demands create contradictions with teachers' existing knowledge structures and practical logic. Through boundary-crossing learning, teachers can actively absorb new ideas and skills, reflect on and transform their practices, generate new knowledge, and ultimately achieve professional growth.

From the perspective of expansive learning, boundaries are both the starting point for boundary-crossing learning and the obstacles to be overcome. Cultural, institutional, and technical differences across activity systems create multiple barriers to individual boundary-crossing learning. The logic of actively breaking through boundaries, resolving contradictions, and renewing practices aligns well with the practical needs of early childhood teachers' self-directed development in the digital age. This theoretical perspective provides a solid foundation for analysing boundary-crossing learning among early childhood teachers.

2.3. Theoretical framework

This study uses expansive learning theory as its main analytical framework. This theory views learning as an expansive process of identifying contradictions, crossing boundaries, and generating new practices. It emphasises that learning occurs when individuals actively confront real problems. This research further establishes a three-dimensional analytical framework consisting of value, dilemma, and enabling pathway dimensions. On the value dimension, it analyses how boundary-crossing learning helps teachers expand their knowledge, practice, and identity. On the dilemmas dimension, it explores how institutional, cultural, and technical factors hinder teachers from crossing boundaries. On the enabling pathways dimension, it constructs systematic pathways to support teachers in transforming their practice.

3. Core value of boundary-crossing learning for early childhood teachers in the digital and intelligent age

3.1. Knowledge dimension: Integrating knowledge and reshaping thinking

Early childhood education is highly holistic. Children's development involves the mutual penetration and coordinated progress of five major domains. However, current pre-service and in-service training for early childhood teachers often follows a subject-based, modular logic, which cannot adequately support holistic teaching. University teacher education programmes have long faced problems such as fragmented subject areas, a gap between theory and practice, and scattered resources. As a result, early childhood teachers have limited ability to implement holistic teaching in actual practice [6].

Boundary-crossing learning in the digital age offers an opportunity to break this deadlock. Through digital platforms, early childhood teachers can collaborate across fields with AI experts, child psychologists, artists, and others, organically integrating knowledge from different areas and moving beyond the traditional boundaries of the five domains. In this process, teachers not only learn cross-disciplinary knowledge but, more importantly, develop a "holistic thinking" style. This

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way of thinking helps teachers better understand the holistic nature of child development and design more integrated educational activities in practice. Such integration across domains is a necessary condition for cultivating children's holistic competence. It also represents an expansion of teachers' cognitive role, from simple implementers to knowledge integrators.

3.2. Practice dimension: Innovating models and empowering teaching

Digital and intelligent technologies are no longer merely tools for learners. The relationship has shifted from one-way use to interactive generation, marking a new stage of intelligent learning [7]. Some studies have noted that teacher learning content is shifting from "explicit theoretical knowledge" to "tacit practical knowledge" [8]. Digital technology provides a concrete way to realise this shift. For example, with virtual reality (VR) technology, early childhood teachers can simulate real educational situations and engage in immersive learning. They can also simulate handling sudden physical conditions in children, outdoor accidents, and other practical care-related problems, and receive immediate feedback on their learning. Teachers can also use generative AI (e.g., DeepSeek) to generate lesson plan suggestions for specific topics, broadening their teaching perspectives from multiple angles and helping them think through problems comprehensively.

The "humanAI collaboration" teaching model can effectively improve teaching efficiency and integration. It also enables early childhood teachers to transform from knowledge transmitters in a single domain into designers, facilitators, and promoters of learning experiences across multiple domains. This transformation represents a practical shift, from using technology to generating new teaching practices.

3.3. Identity dimension: Reconstructing roles and achieving transformation

Boundary-crossing learning drives profound changes in teacher identity. Given the multiple forms of teacher boundary-crossing learning, teachers are required to exercise "boundary-crossing leadership" and become guides who can cross boundaries and build connections with different communities [9]. For kindergarten teachers, boundary-crossing learning requires the construction of a "decentralised" learning community. Teachers, parents, community professionals, and others are all nodes in the system, each with different knowledge, experience, and skills [3]. In such a relationship, teachers need to move from "working alone" to "team collaboration": they need to understand family education needs when communicating with parents, discover rich educational resources when working with community workers, and explore new possibilities for teaching innovation when interacting with technical experts. This identity reconstruction enables teachers to grow from passive implementers into active connectors and learners, completing the reconstruction of their professional selves through diverse interactions.

4. Real-world dilemmas of boundary-crossing learning for early childhood teachers in the digital and intelligent age

4.1. Institutional dilemma: Outdated evaluation mechanisms and lack of incentives

Current educational evaluation systems and institutional structures do not yet fully support early childhood teachers' boundary-crossing learning. Early childhood teachers work under conditions of high intensity, high emotional investment, and fragmented time. Their professional development time is often squeezed. Current workload calculations, promotion criteria, and other institutional

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measures tend to focus on traditional indicators such as teaching hours and certificates. They do not effectively recognise the learning outcomes, time, or effort teachers invest in boundary-crossing learning. For example, teachers may need to use weekends or evenings for cross-kindergarten teaching research or digital skills training. However, such time cannot be counted toward workload or compensated with time off. Flexible working hours, opportunities for cross-kindergarten exchange, and digital resources needed for boundary-crossing learning are also not systematically provided under the existing institutional framework.

Regarding incentives, the outcomes of boundary-crossing learning are rarely taken into account in promotion reviews, performance evaluations, or award selections. Consequently, teachers who exert additional effort find it difficult to secure institutional recognition or career advancement benefits. The absence of external incentives implies that boundary-crossing learning remains a marginal, peripheral activity rather than becoming a stable driver of professional development. The combination of insufficient institutional support and weak incentives diminishes teachers' extrinsic motivation to engage in boundary-crossing learning. This situation poses formidable institutional barriers and constitutes a structural obstacle for early childhood teachers seeking to cross professional boundaries.

4.2. Cultural dilemma: Traditional role perceptions and fear of differences

Cultural beliefs and psychological states also hinder early childhood teachers' boundary-crossing learning. In traditional education, teacher learning is often seen as completing external tasks, and teachers' agency has long been suppressed [8]. In early childhood education, this role perception also narrows professional identity: early childhood teachers are often viewed as "child minders", and their work is seen as simple daily care. Their professional agency is therefore not fully recognised or activated. In such a cultural environment, teachers tend to limit themselves to classroom management and routine teaching. They lack a sense of value for boundary-crossing learning or cross-domain exploration and often see it as a burden rather than a path to professional growth. Traditional role perceptions thus suppress, at the conceptual level, teachers' inner willingness to actively break through professional boundaries.

Fear of "difference" further creates cultural barriers to boundary-crossing learning. Boundaries caused by cultural differences in society can interrupt individual action or interaction [10]. From the perspective of expansive learning theory, boundaries are both the starting point of learning and the obstacle. When teachers encounter new ideas or methods that contradict their existing experience, or enter new fields that require interaction with heterogeneous groups such as researchers or technical experts, they may feel a sense of identity loss, shifting from being an "insider" to a "novice". Because early childhood teachers already have heavy daily workloads, such cognitive conflict and role change may cause discomfort. This discomfort and uncertainty may push teachers back into their familiar professional comfort zones and discourage them from taking on challenging boundary-crossing attempts. The ability to overcome fear of difference and to rebuild their professional selves in the face of uncertainty becomes a key psychological condition for effective boundary-crossing learning among early childhood teachers.

4.3. Technical dilemma: Shallow use and copycat learning

The increasing availability of digital tools and social media platforms for early childhood teachers provides a convenient way to engage in boundary- crossing learning. However, in practice, many early childhood teachers fall into formalistic, copycat patterns and struggle to achieve deep

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boundary-crossing growth. Many early childhood teachers use platforms such as Xiaohongshu (Little Red Book) to learn from peers' experiences in creating classroom environments, designing activities, and organising games. This appears to enable cross-kindergarten and cross-region sharing, but in many cases, it is simply mechanical copying. Teachers directly adopt ready-made materials and fixed patterns, rarely adapt them to their own kindergarten's context, and fail to understand the educational logic behind them. As a result, fragmented cross-boundary experiences are not internalised as professional competence.

Moreover, the misuse of technology can increase teachers' workload and weaken their capabilities [11]. Fragmented learning and additional administrative tasks further intensify this problem. Online resources are often scattered and disorganised. Teachers spend a great deal of time searching for and saving materials, leaving little time for deep reflection and integration. Digital tasks such as completing forms, uploading data, and conducting assessments take time away from deep learning and teaching research. Blindly copying online content may also lead to neglecting children's agency and the principles of play-based learning. This shallow, imitative use of technology can, to some extent, rigidify teachers' thinking and weaken their motivation to innovate, becoming an invisible barrier to deep boundary crossing.

The three dilemmas, institutional, cultural, and technical, do not exist in isolation. They are interwoven and layered, forming conceptual, instrumental, and structural barriers. Structural institutional barriers deepen teachers' doubts about the value of boundary-crossing learning. Cultural biases and fear of differences further hinder the meaningful use of technology. Shallow use of technology, in turn, reinforces the limitations of traditional institutions and culture. Collectively, these three dilemmas generate multiple contradictions within the activity system from an expansive learning perspective, thereby constraining the in-depth development and practical implementation of early childhood teachers' boundary-crossing learning.

5. Enabling pathways for boundary-crossing learning for early childhood teachers in the digital and intelligent age

5.1. Institutional enabling: Integrating boundary-crossing learning into kindergarten-based training and evaluation systems

Kindergartens should start with institutional design. They should simultaneously improve evaluation systems and incentive mechanisms for boundary-crossing learning, addressing both material and non-material dimensions.

In terms of training models, kindergartens should optimize school-based research mechanisms and leverage digital technology to break temporal and spatial constraints. For example, kindergartens can regularly invite early childhood education experts, child development psychologists, and educational technology specialists to conduct blended online and offline training sessions. Online platforms can be used to build cross-kindergarten and cross-regional learning communities that encourage exchange across different professional fields. Flexible working hours should be implemented to guarantee weekly dedicated learning time for teachers, which should be counted as part of their workload. Such measures provide institutional time guarantees and developmental space for boundary-crossing learning. Evaluation systems should be revised to incorporate indicators, including boundary-crossing learning outcomes, curriculum innovation, and cross-kindergarten collaboration, thereby boosting teachers' professional motivation.

A dual incentive system,material and non-material, should be established to strengthen external motivation. At the material level, dedicated funding should be allocated to provide performance

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rewards and learning subsidies for outstanding teachers. At the non-material level, achievements should be publicised and exclusive honours awarded. For example, boundary-crossing outcomes could serve as an important reference for selecting teaching leaders or recommending teachers for promotion. Institutional recognition can thus stimulate teachers' intrinsic motivation to continue participating in boundary-crossing learning.

5.2. Cultural enabling: Building a supportive kindergarten-based boundary-crossing learning community

To tackle rigid role stereotypes and cultural aversion to differences, kindergartens should foster an organizational atmosphere that tolerates trial and error and values individual differences. Such an atmosphere can reduce psychological barriers, activate teachers' professional agency, guide them out of their comfort zones, and support them in actively engaging in boundary-crossing exploration and developing lifelong learning abilities

Kindergartens should break down single professional boundaries and build diverse communities. For instance, they can form a kindergarten-family-community collaboration group, inviting parents with special skills and community professionals to participate in teaching research. Teachers can thus gradually reduce their anxiety about unfamiliar domains through regular, heterogeneous interactions. Regular activities, including boundary-crossing teaching, research salons, and monthly sharing sessions, offer teachers sustainable platforms for academic interaction and communication.

A risk-tolerant mechanism should be established to encourage teachers to share their confusions and mistakes in boundary-crossing practice. This helps teachers feel understood and supported during their exploration. In an atmosphere that embraces differences, teachers can move from their "comfort zone" to the "expansion zone".

5.3. Technical enabling: Reducing burdens, increasing efficiency, and transforming shallow imitation into deep practice

The key to technology-enabled empowerment lies in realizing the in-depth integration of digital technology with early childhood education practice. Such integration can genuinely reduce teacher workload, increase efficiency, deepen professional learning, and reverse the trend of mechanical, imitative teaching.

Using generative AI and other intelligent tools, teachers can complete repetitive tasks such as organising teaching research materials, recording attendance and activity reminders, and summarising children's symbolic expressions. This reduces time spent on administrative tasks. Kindergartens can offer streamlined, practical technical training to enhance teachers' digital literacy, thereby preventing technical operations from becoming an additional workload burden.

A well-structured kindergarten resource library should be built to store boundary-crossing learning outcomes in categories. This supports teachers in adapting and re-developing materials for their own contexts, discouraging blind copying. Short videos can be used to record real teaching situations and support context-based teaching research. This approach helps transform fragmented online experiences into practical skills, enabling a shift from shallow imitation to deep internalisation.

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6. Conclusion

Using boundary-crossing learning theory and expansive learning theory as analytical frameworks, this study explored the meaning of boundary-crossing learning for early childhood teachers in the digital and intelligent age. The study revealed the core value of such learning from three dimensions: knowledge, practice, and identity. It also identified three real-world dilemmas faced by early childhood teachers in boundary-crossing learning: institutional (outdated evaluation systems and weak incentives), cultural (narrow role perceptions and fear of difference), and technical (shallow use and widespread imitative learning). These three dilemmas together constrain the depth and practical transformation of boundary-crossing learning. Accordingly, this study proposed three-dimensional enabling pathways: institutional, cultural, and technical. It emphasised the need to improve both material and non-material incentives, create an organisational atmosphere that allows for trial and error, and promote deep integration between digital technology and early childhood education practice.

Nevertheless, this study has certain limitations. The research is mainly theoretical and has not yet conducted an empirical investigation. As a result, it does not fully capture the real practical contexts, individual differences, or dynamic processes of boundary-crossing learning among early childhood teachers. Because different types of kindergartens face differentiated difficulties, the generalisability of the conclusions requires further investigation. Future research could combine empirical methods, such as interviews and questionnaires, with large-scale surveys to provide a more detailed picture of boundary-crossing learning among early childhood teachers. Such studies could provide a stronger evidence base for improving the proposed pathways. Against the backdrop of the ever-evolving digital and intelligent education ecosystem, boundary-crossing learning will remain a long-term imperative for early childhood teachers to adapt to educational reforms and pursue high-quality professional development.

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