EDeR

Educational Design Research

Volume 10 | Issue 2 | 2026 | Article 102

Contribution Academic Article

Title **Co-Designing Inclusive Digital Learning Environments: A Design-Based Approach for Varied-Level Anchors for Participation**

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Abstract Today, schools face the dual challenge of integrating a great variety of textual and linguistic practices while ensuring inclusive participation for all learners. Digital storytelling has emerged as a promising approach for enabling students with different abilities and backgrounds to explore academic content through their own voices (Wu & Chen, 2020). This paper presents findings from a design-based research project (McKenney & Reeves, 2018) conducted across primary schools in Italy, Germany, and Portugal, which leveraged digital storytelling to promote inclusive practices around narrative thinking (Bruner, 1991; Herman, 2003). The research addresses two critical questions: how to extract transferable design principles from context-specific inclusive practices, and what conditions enable peer support and collaboration in diverse learning settings. From this inquiry emerged the concept of Varied-Level Anchors for Participation (VAPs), a design framework that creates multiple entry points into learning activities, enabling learners with different abilities, languages, and ages to contribute meaningfully. Through interaction analysis of 41 recorded sessions and additional qualitative data analysis, the study identifies specific design features that facilitate inclusive engagement. VAPs help

identify design principles and reconceptualize participation not as individual access but as interdependent contribution, where different abilities become essential to collective outcomes. The study advances the field of inclusive education by offering concrete strategies for designing learning environments where differences enhance rather than hinder collaboration, and by illustrating how DBR can bridge theory and practice through participatory innovation.

Keywords Inclusive education, design-based research, digital storytelling, universal design, participatory design, mixed-age, Varied-Level Anchors for Participation (VAPs)

DOI https://doi.org/10.15460/qw66jy79

Citation Schlauch, M. (2026). Co-Designing Inclusive Digital Learning Environments: A Design-Based Approach for Varied-Level Anchors for Participation**.** *EDeR – Educational Design Research,* 10(2), 1-23.

https://doi.org/10.15460/qw66jy79

Co-Designing Inclusive Digital Learning Environments: A Design-Based Approach for Varied-Level Anchors for Participation

Michael Schlauch

1.0 Introduction

In a primary school classroom in Europe, a six-year-old who cannot yet read sits beside an eleven-year-old crafting complex narratives. Together with their peers, they navigate a digital storytelling tool, seamlessly switching between German and Italian, supporting each other across age, ability, and language differences. This scene exemplifies what Papert (1980) envisioned when he imagined computers as "objects to think with". Yet achieving such inclusive collaboration requires understanding specific conditions that make this engagement possible, conditions that often escape scientific observation or the plans of curriculum designers and edtech developers. Educational technology frequently privileges those already advantaged while further marginalizing vulnerable learners (Reich, 2020; Selwyn, 2023). This paradox demands urgent attention: How can digital learning environments be designed to genuinely include rather than exclude?

Although Design-Based Research (DBR) explicitly addresses the theory-practice divide through iterative, collaborative innovation processes (McKenney & Reeves, 2018), its application to inclusive education, a field particularly challenged by implementation gaps, remains limited. Recent scholarship has begun to advocate for greater application of DBR approaches to inclusive education challenges (Schroeder & Reh, 2023). This gap is particularly striking given the natural alignment between DBR's participatory principles and inclusion's collaborative ethos, as both emphasize the involvement of all learners and stakeholders, iterative improvement, and context-responsive solutions (Anderson & Shattuck, 2012; Booth & Ainscow, 2017).

Meanwhile, teachers and schools struggle to translate inclusive education theories into practice across their varied contexts. Frameworks like Universal Design for Learning (UDL) offer principles for accessible curriculum design (CAST, 2024), while Communities of Practice emphasize collaborative knowledge construction (Lave & Wenger, 1991; Wenger-Trayner et al., 2023). Additionally, concepts like scaffolding (Wood et al., 1976), rooted in Vygotsky's Zone of Proximal Development, have long guided the practice of tutoring through gradually increasing difficulty. However, translating these theoretical insights into practical, scalable innovations remains challenging. The Index for Inclusion (Booth & Ainscow, 2017) provides assessment tools, yet the journey from evaluation to transformation requires contextualized design work, precisely what DBR offers.

Digital storytelling represents a particularly promising avenue for this work, drawing on Bruner's recognition that narrative serves as a vehicle for collaborative meaning-making in educational settings, allowing learners to share and negotiate diverse perspectives (Bruner, 2004), as it naturally integrates multiple inclusive education principles while providing a concrete design context for the DBR methodology (Smeda et al., 2014).

The challenge of moving from specific inclusive adaptations to transferable design principles has been a persistent issue in inclusive education research, where solutions often remain tied to particular contexts and established traditions (Haug, 2017). This represents both a methodological and a practical opportunity for DBR approaches. This study positions the development of a digital storytelling environment as a vehicle for systemic change that can reveal transferable principles for inclusive innovation. This article addresses this theory-practice gap through two research questions:

- RQ1: How can researchers move from context-specific inclusive learning practices to transferable design principles when conducting DBR with diverse learners?
- RQ2: What conditions and design features promote peer support and collaborative learning in inclusive digital environments?

To address these questions, this study develops the concept of Varied-Level Anchors for Participation (VAPs). This framework enables researchers and practitioners to systematically move from context-specific adaptations to application of design principles for inclusive learning environments. The analysis draws on a three-year design-based research project that developed a digital storytelling tool with learners across Italy, Germany and Portugal, where children aged 6-13 served as co-designers throughout iterative development cycles, as well as subsequent classroom implementations.

This article makes two key contributions to the emerging field of design-based inclusion research. First, it addresses the methodological challenge of how participatory DBR can turn context-specific inclusive practices into transferable design principles. Second, it identifies and validates specific design principles for inclusive digital environments that promote peer support and collaborative learning with the example of digital storytelling, demonstrating how diversity in abilities, languages, and ages can enhance rather than hinder collective outcomes.

2.0 Theoretical Framework

Digital learning environments encompass technology-mediated spaces where learners interact with content, peers, and teachers through digital tools. These environments extend beyond software to include the social practices, pedagogical approaches, and collaborative dynamics they enable (Amiel & Reeves, 2008). Designing such environments inclusively requires attention to the intersection of design

methodology, inclusive pedagogy, and digital practice. In this context, cooperative design processes play a central role in shaping educational arrangements, understood as assemblages of tools, activities, social relations, and pedagogical structures that constitute learning environments.

2.1 Design-Based Research Meets Inclusive Education

As initially noted, DBR can be conceived of as an innovation strategy for inclusive education (Schroeder & Reh, 2023), recognizing its potential to generate context-sensitive solutions through iterative refinement. However, few empirical studies demonstrate how DBR's cycles can actively involve diverse learners as co-designers rather than merely as end users or research subjects.

Norwich's "fox perspective" on inclusive education provides crucial theoretical grounding for addressing tensions through ongoing negotiation rather than seeking unitary solutions (Norwich, 2023). His approach recognizes "dilemmas of difference", which describe tensions between enabling individual learners through differentiation and avoiding stigmatization through commonality. Rather than viewing inclusion as fixed, he conceptualizes it as continuous negotiation of plural values that can conflict. This processual understanding aligns with DBR's iterative approach, where each design cycle renegotiates competing demands, such as individual needs versus collective participation, specialized support versus mainstream inclusion. This sets us up for systematically designing dynamic learning environments that acknowledge inevitable trade-offs.

The Index for Inclusion (Booth & Ainscow, 2017) provides a comprehensive framework for school development through inclusive values, guiding institutions in building cultures, policies, and practices that increase participation and reduce barriers for all learners. While the Index offers rich insights into what makes environments inclusive, translating these insights into concrete design decisions remains challenging. This research explores how the Index's dimensions might inform inclusive design in digital learning environments. Rather than using the Index retrospectively to evaluate existing practices, this study examines how its principles can inform design decisions, shifting the focus from identifying barriers after they emerge to considering multiple ways learners might engage and support each other.

While Design-Based Research provides the methodology for iterative innovation, cooperative inquiry offers specific techniques for partnering with children as co-designers (Druin, 1999). However, applying these methods in school contexts where learners vary significantly in abilities and communication styles requires additional measures to bridge participatory ideals with the practical demands of supporting diverse learners.

This study addresses this gap by developing what I term "Varied-Level Anchors for Participation" (VAP) - a framework that enables children with diverse abilities to contribute meaningfully to digitally enhanced

learning environments. The concept of VAP aims for participation on multiple levels, offering multiple entry points and contribution modes.

2.2 Digital Storytelling as Inclusive Practice

Bruner (1991, 2004) argues that humans naturally organize their experiences and memories through narrative structures, with stories serving as both a conventional cultural form and a universal cognitive tool. This narrative thinking extends across diverse contexts, from interpreting literature and engaging in conversation to making sense of news, demonstrating stories' power as a basic mechanism for human understanding (Herman, 2003). This cognitive universality makes storytelling naturally inclusive, as all children, regardless of ability or background, engage with stories as a way of understanding their world.

In the book "Grammatica della fantasia" ("grammar of fantasy"), Rodari (1973) outlines how narrative creation can be made accessible to all children through playful linguistic techniques like the "binomio fantastico" (combining unrelated elements) and "ipotesi fantastiche" (hypothetical questions). These techniques show that storytelling, whether traditional or digital, can be approached through structured yet imaginative methods that lower barriers to creative expression.

Wu and Chen's (2020) systematic review of 57 educational digital storytelling studies reveals significant untapped potential in the field. While most implementations use an appropriative orientation where students create stories to understand predetermined concepts, the authors advocate for expanding toward more sophisticated approaches: agentive orientations that give students autonomy over their learning choices, reflexive orientations that focus on identity formation and self-exploration, and particularly reconstructive orientations that engage students in critically examining and challenging established concepts or stereotypes. This shift from content delivery to student agency, identity development, and critical engagement could better support inclusive education by allowing diverse learners to engage with the curriculum through their own experiences and perspectives. Smeda et al. (2014) also identify digital storytelling as especially effective for fostering collaboration among students with diverse abilities.

The Agentic Personalization Framework, grounded in previous empirical work by Kucirkova (2019), reveals how open-ended digital storytelling supports children's agency through multi-level participation. When digital storytelling apps are designed with open-ended features rather than predefined templates, they enable increased peer collaboration, as children negotiate content choices through multiple modes of expression. Such designs allow younger children to engage through basic functions while complex tasks naturally invite support from peers or adults. This scaffolded functionality demonstrates how digital storytelling tools can create multiple entry points for participation, transforming differences in

age and ability into opportunities for both collaborative engagement and individual agency.

2.3 Inclusive Learning through Varied-Level Anchors for Participation

The frameworks mentioned above converge in viewing diversity as a resource rather than a deficit, which Varied-Level Anchors for Participation (VAPs) operationalize through specific design features. The concept of VAPs synthesizes key insights from educational theory and inclusive pedagogy to create a practical framework for inclusive design. The purpose of VAPs is to transform activities so that diverse abilities become complementary resources for collective learning.

This transformation begins by extending Universal Design for Learning principles into concrete design features. While UDL provides flexible pathways tailored to individual needs (CAST, 2024), VAPs go further by integrating these paths into shared activities where learners rely on each other's differing strengths. For instance, a single storytelling activity could engage children regardless of their preferred learning modality, whether they learn best through visual, auditory, or hands-on manipulation, by creating interdependent roles where diverse skills become necessary for collective success.

Central to this approach is how VAPs help reimagine participation itself. Drawing on Lave and Wenger's concept of legitimate peripheral participation (Lave & Wenger, 1991), VAPs create multiple, simultaneous peripheries; that is, various valid starting points and trajectories within the same activity. Rather than a single path from novice to expert, inclusive digital learning environments offer various entry points that constitute valid forms of participation. In the case of digital storytelling, a child who cannot yet write but guides narrative through image selection participates as fully as one who types text. This variety ensures every learner finds their "anchor" for meaningful contribution. Moreover, these diverse entry points can generate patterns of mutual support that work in the opposite direction: for example, when younger children's visual choices and creative interpretations guide older children's narratives.

Underpinning this participatory framework is a fundamental reconceptualization of communication modes. Building on Kress's recognition that communication is inherently multimodal (Kress, 2010), VAPs reframe multiple modes not as enrichment but as essential accessibility infrastructure. When children can anchor their participation through images, sounds, gestures, or words interchangeably, traditional literacy barriers dissolve. This shift fundamentally changes how we design learning environments; from privileging text to creating genuinely multimodal activities where each mode carries equal value.

Taken together, Varied-Level Anchors for Participation represent design features that enable meaningful participation through learners' strongest modalities, create interdependence where different abilities complement each other, and generate peer support

organically through the structure of activities. Through the application of VAPs, attention shifts from adapting existing activities for diverse learners to designing activities that require diversity to function. The following sections demonstrate how this theoretical concept can be applied to concrete design decisions and classroom practices.

3.0 Methods

This study employed Design-Based Research (DBR) to develop and evaluate inclusive digital storytelling environments through participatory design with children. Following McKenney and Reeves' generic model (McKenney & Reeves, 2018), the research progressed through iterative cycles of analysis, design, and evaluation, with each phase informing subsequent iterations. DBR is characterized by seeking both theoretical understanding and practical solutions. While the development of the digital storytelling web application was completed between 2020 and 2022, the subsequent research phase of this study focused on testing and evaluating design principles across various contexts, with inclusive education as a central lens. This methodological approach aligns with inclusive education's processual nature, enabling continuous refinement based on diverse stakeholder input. Specifically, this article presents a re-analysis of data collected during the entire DBR process, with specific focus on inclusive participation patterns and their implications for design principles.

Rigor was ensured by following Plomp's quality criteria for DBR (Plomp, 2013). Relevance was ensured by addressing authentic classroom needs identified by teachers alongside the demand for inclusive digital learning environments. Consistency was reflected in the systematic development of design principles grounded in theory. The successful implementation of the intervention across varied educational settings, from Montessori environments to public school classrooms, serves as an indication for the quality criteria of practicality, while effectiveness emerged through peer support and collaborative storytelling practices that appeared to benefit classroom learning. Finally, triangulation of children's artifacts, teacher interviews, and video observations supported the formulation of design principles through the conceptualization of the VAP framework.

3.1 Research Timeline and Phases

The research unfolded through iterative DBR cycles spanning four years (2020-2024). Initial tool development began in 2020, yielding a functional prototype that underwent extensive testing with children as co-designers throughout 2021-2022. During this phase, 41 video-recorded collaborative storytelling sessions were conducted, documenting children's interactions with evolving prototypes. These co-operative inquiry sessions proved transformative for the design, as children's direct feedback revealed critical accessibility barriers, in-

cluding small text labels and unintuitive navigation. In response to these insights, the second iteration incorporated specific accessibility features such as text-to-speech functionality and multilingual interface options, directly addressing the diverse communication needs identified during testing. The refined tool was published as an open-source web app, after which it entered practical use as a network of teachers across Europe integrated it into their regular classroom practice. This adoption phase provided validity for understanding inclusive participation patterns beyond researcher-facilitated sessions. The current study represents a secondary, retrospective analysis, systematically examining the collected data through the theoretical lens of inclusive design principles to extract transferable insights about how digital environments can support diverse learners' collaborative storytelling.

3.2 Participants and Context

The initial design phase engaged 37 children, aged 6-13, from a German-speaking school in South Tyrol. This bilingual context, where children navigate between German and Italian daily, provided a natural setting for exploring multilingual digital storytelling. Participants represented mixed age groups, ranging in age by seven years, and varying prior experiences with digital tools. In this Montessori school setting, participation was voluntary, with children choosing whether to engage in design sessions, reflecting the institution's pedagogical philosophy of child-led learning. Following initial development, extensive experimentation occurred in Portugal with two complete classes (n=45), testing the tool's transferability to different educational contexts. During the subsequent naturalistic adoption phase, teachers from various settings integrated the storytelling environment into their regular practice with ongoing consultation.

The data corpus for this secondary analysis comprised 41 video-recorded sessions from the design and testing phases capturing collaborative storytelling interactions, semi-structured interviews with five teachers, exploring their pedagogical integration of the tool, and digital story artifacts produced during the sessions. These multiple data sources enabled triangulation of participation patterns across different educational contexts, languages, and pedagogical approaches.

3.3 Design Process

The development followed an iterative, participatory design process, grounded in both theoretical frameworks and children's direct input. The initial design principles emerged from synthesizing literature on digital storytelling, inclusive education, and child-computer interaction. Five core objectives guided the development: (1) multimodal expression supporting diverse communication preferences, (2) scaf-

folding creative freedom, (3) collaborative learning, (4) cultural responsiveness through customizable content, and (5) critical engagement encouraging children to interrogate technology design itself. The tool's conceptual foundation drew from Rodari's "binomio fantastico" (Rodari, 1973), a creative writing technique combining disparate elements to spark imagination. This approach shaped the storytelling tool's core mechanism: presenting children with diverse story elements from different categories to combine into narratives. However, unlike Rodari's random word pairs, the storytelling tool enables children to actively shape their narrative resources by contributing their own drawn elements, thus transforming it from a closed system into an open, evolving narrative environment.

Technical implementation prioritised accessibility and adaptability through iterative refinement with children as co-designers. Early prototype testing with children revealed critical barriers: small text labels challenged emerging readers, mouse-click sensitivity frustrated younger users, and a cluttered layout confused some participants. Children's direct feedback led to enlarged high-contrast labels, enlarged touch/click areas, and clearer visual separation, while maintaining aesthetic appeal. The interface evolved to present story elements through an interactive sequence: children click on a magic hat, which reveals three text labels from different categories, following Rodari's principle of combining disparate elements. After selecting one label, it transforms into a visual representation of that story element, and a new magic hat appears to the right. This process continues until eight images form a complete storyboard. The constraint of showing three options at a time emerged through iterative testing to reduce cognitive load while maintaining creative possibilities.

The participatory process continually shaped technical decisions. When multilingual children began creating story elements labeled in multiple languages, the system was adapted to support multilingual labels rather than enforcing monolingual conventions. This responsiveness to emergent use patterns exemplified how children's innovations drove the design process.

Built as a web-based application using open-source technologies, the tool runs on standard school computers without special software installation, reflecting commitment to inclusive access beyond the immediate research context.

Technology choices embodied broader methodological commitments. The export function produces standard PDFs, ensuring that stories can be shared regardless of families' technology access. Avoiding proprietary formats or cloud dependencies respects data privacy and enables offline installation, crucial for schools with limited connectivity. The decision to build the storytelling app as an open-source web-based application ensures research benefits remain accessible to all participating communities and enables other educators to adapt the tool for their contexts.

Through this iterative development process, the storytelling tool served as both a research context and a proof-of-concept for Varied-Level Anchors for Participation. Its specific features revealed generalizable principles applicable to other inclusive digital environments, demonstrating how participatory design with diverse learners can inform broader theoretical development.

3.4 Data Collection

Central to the methodology was an adapted version of the cooperative inquiry approach developed by Druin (1999), modified to accommodate naturalistic school settings and workshop structures integrated into regular classroom activities. In the initial design phase, work proceeded with voluntary participation in mixed-age groups within multilingual settings. For the implementation studies, multimodal data collection methods were employed. Visual methods included children's drawings of proposed story elements to include in the digital storytelling environment. Verbal data encompassed think-aloud protocols and recorded group discussions. Textual outputs consisted of story transcripts, written narratives, and systematic observational data captured through field notes. Contextual inquiry (Druin, 1999) guided observation protocols, focusing on how children navigated the tool in naturalistic classroom settings. Digital data logs tracked usage patterns and made it possible to retrace collaboration dynamics. Video recording procedures for the 41 sessions followed established guidelines for interaction analysis (Jordan & Henderson, 1995), with laptop cameras positioned to capture both screen activity and participant interactions. Using the inbuilt webcam was prioritized to provide consistent coverage while minimizing intrusion. Ethical protocols included parental consent with clear withdrawal options at any point without consequence as well as complete anonymization of all data using pseudonyms.

3.5 Analytical Approach

The primary analytical approach followed interaction analysis principles (Jordan & Henderson, 1995). Video recordings of 41 collaborative storytelling sessions were subjected to repeated viewing, with initial content logs documenting events indexed by time stamps. Following interaction analysis's commitment to grounded observation, analytical foci were not predetermined but emerged through iterative engagement with the recordings. These included examining event structures (particularly transitions between story segments), the temporal organization of activities, turn-taking patterns across verbal and physical actions, shifting participation frameworks, trouble and repair sequences, spatial arrangements around the digital tool, and artifact manipulation patterns. Through multiple viewings, recurring phenomena were identified, leading to the development of

collection segments where similar participation patterns could be compared. The VAP framework emerged from this systematic observation of naturally occurring interaction patterns, as repeated viewing revealed how children with diverse abilities spontaneously distributed tasks in ways that are described in the results. Not all sessions demonstrated successful collaborative patterns, even when VAPs appeared present. These failures fell into two categories: technical infrastructure problems (e.g. an unresponsive mouse) and missing prerequisite competencies (e.g. story elements in a foreign language). These negative cases helped identify the minimum conditions necessary for VAP functionality, rather than undermining the framework.

To triangulate and extend these observational findings, a qualitative content analysis (Kuckartz, 2019) was applied to complementary data sources: semi-structured interviews with participating teachers (n=5) and the digital story artifacts produced during sessions. Following Kuckartz's (2019) systematic approach, the main categories corresponding to the participation anchors identified through video analysis were used as an initial coding frame. Interview transcripts were coded for teachers' descriptions of student collaboration patterns, while story outputs were analyzed for evidence of distributed authorship. This analysis confirmed the participation patterns observed in videos, as teachers independently described collaborative behaviors that aligned with the emerging VAP categories. Additionally, QCA revealed how these patterns manifested in the final products: stories created through distributed participation showed more complex narrative structures than those created individually. The convergence of observational data, participant perspectives, and artifact analysis strengthened the confidence that these participation patterns could be understood through the concept of varied-level anchors for participation.

4.0 Results

4.1 Participation across Abilities

While space limitations preclude discussing all documented sessions, the following vignette exemplifies typical interaction patterns observed on many occasions. This description of a storytelling session conducted in a mixed-age classroom illustrates how children with diverse abilities, spanning ages 7-13 with varying literacy levels, collaboratively created a narrative through complementary forms of participation:

> Oscar (7 years old), the smallest one, controlled the mouse while the older participants Nina and Karl (both 12-13) sat beside him. Linda (8), who had reading difficulties, watched from nearby. Nina studied their story sequence - dragon, catastrophe, book, digital footprint - and began narrating how

the dragon read about an approaching catastrophe. When selection options appeared, Linda suggested an old cat but struggled to read the label due to overlapping labels (a technical bug). Karl noticed her confusion and directed Oscar to hover the mouse over the text until Linda could see the label "cat in boots" clearly. [...] Nina proposed that the grandmother could use the magic pen to stop the catastrophe. Karl affirmed this made sense, Linda nodded approvingly, and Oscar clicked to add it. They continued building collaboratively, alternating who would start a sentence based on a selected story element and who would complete it, with Oscar selecting the elements agreed upon. Karl sat back, anticipating what might appear next ("I hope the feast picture appears") while commenting on the tool's patterns. When Oscar's left-handed mouse grip caused difficulties, a selected image disappeared, but the group filled the narrative gap with another improvised story element. The session peaked when Linda's hand-drawn tree-horse appeared on screen. She called out excitedly while Nina and Oscar laughed at the fantastical creature, recognizing their peer's creation now integrated into the storytelling environment and in their collective narrative.

This single episode demonstrates several forms of participation operating simultaneously: Oscar's interface control despite being the youngest, Karl's peer support for Linda's reading challenges, Nina's narrative construction, and Linda's visual recognition of peer-created elements. Each child contributed through different channels while supporting others' participation. A systematic analysis of all documented sessions revealed several distinct participatory anchors that enabled such inclusive collaboration. Table 1 synthesizes patterns observed across all sessions.

Table 1: *VAP Specification Matrix: participatory anchors and their design characteristics in collaborative digital storytelling*

Participation Anchor	**Design Characteristic**	**Prerequisite Skills**	**Form of Contribution**
Interface navigation	Click-triggered motion of magic hat	Mouse control, visual recognition of interface elements	Navigate tool interface, click story elements chosen by group
Collaborative decision-making	Algorithmic pre-selection of three options	Ability to follow group interaction, basic communication (verbal or non-verbal)	Express agreement/disagreement, maintain activity flow
Visual decoding	Labels replaced by pictures after selection,	Visual perception, ability to associate images with meanings and communicate	Decode images, express emotional responses

	enabling modal shift	them	(surprise, delight)
Oral story construction	Open narrative structure with given pool of story elements	Verbal fluency in at least one language, narrative imagination	Create narrative additions, propose story developments
Critical narrative mapping	Visual storyboard displaying all selected story elements	Working memory, ability to track narrative sequence	Question story logic, reorder elements, identify narrative gaps and signal them
Linguistic mediation	Option to include labels in multiple languages	Functional competence in two or more languages or modes	Translate between languages, bridge communication, read out loud
Tool assistance	Simple, predictable interface patterns	Knowledge about the interface, procedural memory	Guide others through interface, share procedural knowledge

Each participatory anchor emerged from specific design characteristics built into the tool. The magic hat metaphor, the three-option limit, and the visual storyboard were deliberate features that enabled different forms of participation. By distributing technical and cognitive demands across different skill sets and roles, from mouse control to narrative imagination, these design elements and activity structures ensured that children could contribute through their existing abilities while receiving support in areas where they needed it. These anchors functioned as entry points rather than fixed roles, with the material environment supporting fluid transitions between them. For instance, the mouse often served as a "talking stick," granting narrative authority to whoever held it while ensuring eventual handoff to others.

In mixed-age classrooms, children who could not yet read fluently (aged 6-7) participated fully alongside fluent readers (aged 10-13). These emerging readers successfully handled interface navigation while peers provided linguistic mediation through reading labels aloud, demonstrating how technical operation could be decoupled from literacy requirements. The intervention facilitated creativity through modal shifts—from label to image to oral narrative to written text. Children engaged in visual decoding by reinterpreting images ("This isn't just a pen - it's a magic pen"), while those strong in critical narrative mapping would signal when story elements didn't align with the emerging narrative. In one session, a student discovered that by repeatedly clicking through the selection algorithm's three-option limit, they could systematically view all available story elements rather than just the randomized selections, demonstrating how interface knowledge provided unexpected narrative possibilities.

The linguistic mediation anchor proved particularly vital in multilingual contexts, where children not only translated between German, Italian, and English but also read story elements aloud for emerging readers. This created cascading support where a single child's bilingual competence enabled participation for multiple group members. Importantly, these participatory anchors were non-hierarchical. Children excelling in visual decoding might require support for interface navigation, while those demonstrating strong collaborative decision-making might seek help with oral story construction. This complementarity meant that diverse abilities became resources for collective storytelling.

4.2 Enabling Peer Support

The participatory anchors identified in Table 1 did not function in isolation, but rather formed an interdependent network where each anchor enabled others. This functional alignment created multiple legitimate pathways into the storytelling activity. The anchors exhibited cascading relationships, where one form of participation naturally led to others, as displayed in the interdependency wheel (Figure 1).

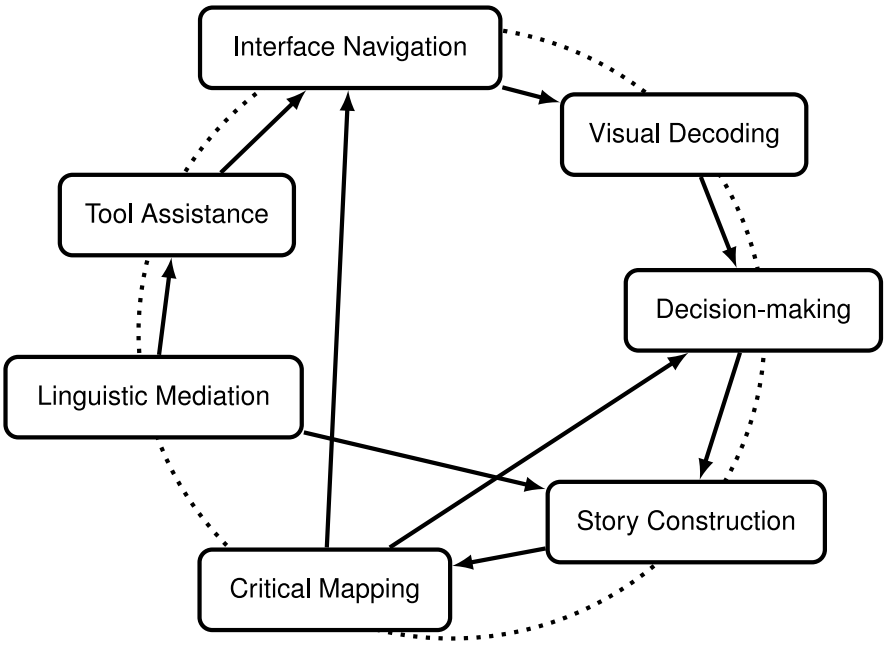

Figure 1: *Interdependency Wheel - with relations of mutual support*

Interface navigation enabled visual decoding by clicking revealed images, which in turn supported collaborative decision-making through shared visual references. These decisions fed into oral story construction, which benefited from critical narrative mapping to maintain coherence. When linguistic differences arose, those with narrative oversight could guide linguistic mediation. Tool assistance

functioned as a meta-anchor, enabling smoother operation across all other forms of participation. As this depiction is not exhaustive, other classroom uses of the storytelling environment yet to be observed may reveal additional VAP anchors and relationships.

This interdependence meant that children could enter through any anchor and access others through flexible pathways. For example, a child might begin with visual decoding, move to collaborative decision-making, then progress to oral construction; or follow an entirely different trajectory based on their strengths and the group's needs. Each competency remained valuable in itself while opening doors to other forms of participation. When groups were smaller or certain anchors were absent, children tended to expand their participation. In two-child configurations, each child typically engaged with three or four anchors rather than specializing in one. When working alone, children cycled through multiple anchors themselves, by clicking, viewing, deciding, and narrating in rapid succession. This flexibility demonstrated how this particular VAP framework supported both collaborative and individual engagement patterns. In multilingual contexts, language diversity became a generative resource. Children assembled linguistic repertoires across German, Italian, and English, with the visual-first design ensuring that language differences didn't block participation. Images served as shared reference points while children negotiated meaning through multiple communicative channels. Child-created story elements further reinforced collective investment in the storytelling process. When children recognized peers' drawings in the digital library, they showed heightened interest and selected these elements more frequently. This can lead to interesting phenomena, such as the emergence of recurring narrative helpers. The "magic pen", drawn by multiple children, acquired a consistent identity as a benevolent helper across stories. This became a shared symbol that connected individual contributions to an emerging story world. The design's structural features enabled groups to self-regulate through material constraints. The three-option limit created natural pause points for negotiation, while the visual storyboard provided persistent reference points when disagreements arose. These features supported recovery from collaboration breakdowns without requiring adult intervention. These interconnected anchors demonstrate that it is possible to plan and prepare for the conditions where diverse abilities become interdependent resources. Seen from the VAP framework developed in this contribution, we can retrace how varied competencies became mutually reinforcing elements of collective achievement.

5.0 Discussion

This study demonstrates how Design-Based Research with children can generate transferable principles for inclusive digital environments. The Varied-Level Anchors for Participation (VAPs) framework addresses both research questions by providing a systematic ap-

proach to moving from context-specific observations to design principles (RQ1), and to identifying conditions that promote peer support through interdependence (RQ2).

As previously mentioned, Norwich (2023) identifies a central tension between specialized support (risking stigmatization) and common provision (potentially inadequate for diverse needs). VAPs navigate this dilemma by reframing difference as a collective resource. For instance, Linda, a beginning reader, contributed to visual storytelling in ways that complemented her peers' strengths. Unlike traditional peer tutoring, VAP-structured activities showed no consistent helper-helped relationships, as all participants required support in some domain, normalizing assistance-seeking.

While the Index for Inclusion (Booth & Ainscow, 2017) provides aspirational goals, VAPs offer one approach to concrete operationalization. Building inclusive cultures can be supported through design features that make diversity advantageous for activity completion. Producing inclusive policies can be aided by specification matrices like Table 1, which maps design characteristics to participation opportunities. One can refine inclusive practices over time by closely observing and responding to participation patterns. The VAP framework thus provides specific tools for translating the Index's broad dimensions into design decisions.

VAPs differ in emphasis and specificity from Universal Design for Learning. While UDL often provides flexible, parallel pathways related to modes of expression and highlights collaboration (Rao & Meo, 2016), VAPs offer a tangible way to foster interdependent participation, where diverse abilities can complement one another. For example, when one child controlled the mouse, the other narrated, and a third contributed visual interpretations, their roles supported each other in a coordinated way rather than functioning separately. VAPs also diverge from scaffolding (Wood et al., 1976). Traditional scaffolding seeks to reduce the learner's freedom initially, limiting choices and complexity to make tasks manageable and then gradually increases them as learners gain independence and eventually perform tasks alone. VAPs instead help distribute task components across participants: one child might have limited narrative control but manage technical operations; another might struggle with text but excel at coming up with creative associations; a third might craft complex narratives while depending on others. Rather than aiming for individual independence as a scaffolding goal, VAPs maintain interdependence as a permanent design feature. Moreover, VAPs extend Lave and Wenger (1991) by proposing an addition to legitimate peripheral participation: rather than a single trajectory from novice to expert, VAPs create multiple, equally valid peripheries. Normally, in communities of practice, newcomers gradually move from peripheral observation toward central expertise. In VAP-structured activities, participants maintain specialized roles that are intended to avoid hierarchical progression. Each role offers a complete form of participation,

rather than serving merely as a stepping stone to “full” membership, while still providing potential for learning progression.

VAPs contribute to ongoing discussions about moving beyond accommodation models in inclusive education. While inclusion has long recognized the value of peer support and collaborative learning, VAPs offer a specific framework for designing activities where different abilities become interdependent resources. The framework shifts focus from solely ensuring individual access to learning toward also considering how diverse abilities can enhance collective outcomes. Through systematic DBR cycles, the VAP framework offers concrete design heuristics while remaining adaptable across contexts. This extends inclusion beyond adjusting for individual needs toward a systemic design effort that leverages diversity for mutual benefit.

To apply the concept of VAPs in other domains, one could follow a three-step approach. First, one can embrace the core design principle that activities should make diversity necessary for success. Second, teachers may systematically analyze any learning activity by asking: What barriers can become varied-level anchors for participation? What operations could become participation opportunities? Where can modalities of expression interconnect? What common goal motivates children to work together? What provides symbolic cohesiveness (as story elements did in our study at hand)? Third, using instruments like the VAP specification matrix and the interdependency wheel, one can structure activities to require rather than merely allow diverse contributions. For instance, while speculative, in a problem-based mathematics scenario, participation anchors might include manipulating materials, verbalizing strategies, drawing representations, and checking calculations, creating similar patterns of interdependence.

VAPs challenge existing educational structures in several ways. Assessment becomes more complex as the focus shifts from individual to collective achievement. While groups may demonstrate success through oral story retellings or critical discussion, institutions still require ways to identify individual contributions within collaborative work. Professional development must prepare teachers to recognize emergent patterns of participation, resist assigning fixed roles, and facilitate without directing. For example, teachers in this study initially struggled to hold back from suggesting story developments, learning instead to ask open-ended questions like, “What’s that character’s motive?” They expressed surprise at the inclusive potential of this approach, particularly how it created opportunities for peer recognition beyond traditional academic performance. For instance, in storytelling activities, a child with learning difficulties might produce remarkably expressive drawings, prompting admiration from peers and reshaping how ability is perceived within the group. Successful implementation also requires greater flexibility in classroom space and materials, aligning with more open-ended, creative approaches to learning. Hence, VAPs should not be adopted in isolation

but integrated into broader inclusive school development efforts. Frameworks like the Index for Inclusion offer useful points of compatibility for such integration.

Design-Based Research (DBR) and its iterative cycles proved essential for developing inclusive digital storytelling. The methodology's strength lay in its capacity to balance systematic documentation with responsive adaptation. Interaction analysis of video recordings enabled detailed, post-hoc examination of participation patterns. Involving children as co-designers allowed for flexible responses to their motivational dynamics and existing competencies. Testing the framework across diverse contexts, for example, from Montessori environments to Portuguese public schools, helped distinguish transferable principles from context-specific features. DBR proved particularly well suited to inclusive education research, not only for its design orientation but also for its ability to generate theoretical insight through practice. However, the methodology demands careful balance: advanced planning is essential to navigate tensions between iterative flexibility and school schedules. Teacher openness emerged as a prerequisite for meaningful research collaboration.

This study shows that inclusive design involves more than simply removing barriers, it requires the creation of conditions in which diverse abilities become mutually essential. The VAP framework offers both theoretical contribution and practical strategies for reconfiguring diversity as a shared resource in educational settings.

6.0 Limitations

Several limitations of this study warrant acknowledgment and point toward future research directions. While the analysis revealed patterns of inclusive participation, it did not systematically examine power dynamics between children of different abilities. Although observations showed younger children being granted decision-making power by older peers, future research should investigate how ability hierarchies may persist or transform within VAP-structured activities and whether certain participation anchors might inadvertently privilege some contributions over others.

The volunteer-based recruitment of participating children supported genuine engagement but also introduced a self-selection bias, potentially excluding those less comfortable with technology or collaborative learning. While this limitation was partially mitigated in later phases through whole-class participation, the initial design remained shaped by the perspectives of self-selected participants. This highlights a broader challenge across design-based research focused on inclusivity.

The study's focus on digital storytelling environments, while revealing rich possibilities for inclusive participation, limits the transferability of its findings. To date, VAPs have been tested only within narrative

activities, and their application in other learning contexts warrants further investigation. Different subject domains may require distinct strategies to implement the VAP concept effectively.

Institutional and systemic considerations received limited attention in this classroom-focused research. While teachers successfully implemented the tool with researcher support, the study did not examine school-level policies, professional development needs, or structural changes necessary to support inclusivity efforts at the school-wide level. Further research could explore how schools might systematically apply the VAP framework to identify opportunities for more structured and inclusive activities across their curricula.

Finally, the study documented instances of children interrogating the tool's functionality but did not systematically cultivate such critical digital engagement. How to intentionally design "higher-level" participation anchors that promote critical examination of digital systems, moving toward structured critical inquiry, remains an open question for future investigation.

7.0 Conclusion

This study demonstrates how Design-Based Research can bridge the theory-practice gap in inclusive education through authentic participation of diverse learners. By developing the Varied-Level Anchors for Participation framework through a systematic analysis of collected data, the research showed how context-specific observations can yield transferable design principles (RQ1) and identified interdependent task structures as a key condition enabling peer support in learning environments (RQ2). The VAP framework contributes to inclusive education theory by operationalizing abstract principles into design specifications. It extends beyond Norwich's dilemmas of difference by showing how supposed tensions can become productive interdependencies. Similarly, it builds on communities of practice and UDL by proposing multiple valid peripheries and designing for sustained interdependence rather than individual access paths. Most significantly, it provides empirical evidence that diversity enhances rather than complicates learning when properly designed for.

Practically, educators can apply VAPs through systematic analysis of learning activities, asking what barriers might become participation anchors and how different abilities could become mutually necessary. However, implementation requires systemic changes: assessment methods valuing collective achievement, teacher preparation and integration with broader inclusive school development frameworks. The three-step approach outlined provides a starting point for such efforts. Future research should test the viability of the VAP concept across subject domains, examining whether similar interdependence patterns emerge in mathematics, science, or other areas. Development of assessment tools that capture collective achieve-

ment while recognizing individual contributions remains crucial. Additionally, exploring VAPs at different educational levels (e.g., secondary schools settings) could reveal age-specific considerations. The six-year-old navigating digital stories alongside an eleven-year-old crafting narratives exemplifies the potential of designing for interdependence. This study contributes to emerging calls for design-based inclusion research by demonstrating how participatory design with diverse learners can generate principles that transform educational practice. The VAP framework offers one pathway for creating learning environments where diversity becomes a resource for collective achievement rather than a challenge to be managed.

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Journal Details

EDeR – Educational Design Research
An International Journal for Design-Based Research in Education
ISSN: 2511-0667
uhh.de/EDeR
#EDeRJournal (our hashtag on social media services)

Published by

Hamburg Center for University Teaching and Learning (HUL)
University of Hamburg
Schlüterstraße 51
20146 Hamburg

Germany
+49 40 42838-9640
+49 40 42838-9650 (fax)
EDeR.HUL@uni-hamburg.de
hul.uni-hamburg.de

In collaboration with

Hamburg University Press
Verlag der Staats- und Universitätsbibliothek Hamburg – Landesbetrieb
Von-Melle-Park 3
20146 Hamburg
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+49 40 42838 7146
info.hup@sub.uni-hamburg.de
hup.sub.uni-hamburg.de