Topoi
https://doi.org/10.1007/s11245-024-10155-3

Scaffolding and Individuality in Early Childhood Development

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Accepted: 9 December 2024

Abstract
Scaffolding interactions are typically portrayed optimistically within 4E frameworks of cognition. In this paper, we argue that this "dogma of harmony" has also influenced research on scaffolding interactions during development. Specifically, we show how some scaffolding interactions aimed at supporting task execution and skill acquisition in early childhood can inadvertently lead to detrimental effects on learners' wellbeing, understood in terms of what individuals are capable of achieving rather than through the resources they possess. To characterise these effects, we propose a model that highlights the manifold ways in which individual differences interact with scaffolds' features during developmental processes. Using this model, we discuss two types of maladaptive scenarios: those where the scaffolds are efficient to various degrees depending on *inter*-individual differences, and those where scaffolds' efficiency is tied to particular timeframes depending on *intra*-individual differences. The upshot of this discussion is that, to challenge the harmony dogma, more inclusive education policies should not only consider scaffolds' efficiency but also determine whether individuals can adequately transform their use into valuable opportunities for their learning across contexts and timescales.

Keywords Cognitive Scaffold · Individual Differences · Child Development · Language Acquisition · Child Wellbeing · Niche Construction

1 Introduction

Individuals rely on structured physical and social environments to efficiently carry out different tasks (Clark 2008; Hutchins 1995; Newen et al. 2018; Walter 2014; a.o.). Such environments—and the tools or artefacts they provide—are standardly referred to as "scaffolds". While different taxonomies of scaffolds have been elaborated (e.g., Brey 2005; Fasoli 2018; Coninx and Stephan 2021), these can be primarily discerned by the type of operation they support (Heersmink 2013). For instance, objects constitute cognitive scaffolds when their handling aids in executing mathematical operations (Martin and Schwartz 2005), close acquaintances constitute affective scaffolds when assisting in emotion regulation (English, John, and Gross, 2013), and personal narratives constitute social scaffolds when they structure individual identities (Fabry 2023). We can, therefore, understand scaffolding interactions as concrete manifestations of a broader process of "niche construction", wherein organisms intervene in their environment in ways that enhance their agency (Sterelny 2010; see also Kendal 2011).

Some scaffolding interactions, particularly during early childhood, are critical for learning and development. During this stage, developmental (also called "instructional") scaffolds play a crucial role in the growth of literacy skills, emotion regulation skills, and prosocial attitudes (Stotz 2010). Psychologists have observed that the tutorial interactions between the developing child and more skilful elders are a defining feature of our species (Vygotsky 1978; Wood et al. 1976). For instance, caregivers' contingent

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Published online: 29 January 2025

responsiveness—their tendency to react promptly and meaningfully to a child's behaviour—has been found to scaffold various aspects of early language development, including vocabulary growth during the first year of life (Rollins 2003). This tendency highlights that organisms not only modify their individualised niches to diminish their cognitive load but also engineer that of their offspring, thereby shaping their learning trajectories.

Although scaffolds are standardly seen as helpful resources, researchers are increasingly identifying scenarios where they have maladaptive effects in addition to or instead of adaptive ones (see, e.g., Coninx 2023; de Carvalho and Krueger 2023; Slaby 2016; Timms and Spurrett 2023). This shift in focus challenges the previously unquestioned assumption that scaffolds lead to beneficial outcomes—referred to as the "dogma of harmony" by Aagaard (2021). Such scenarios can be found across experiential domains: The use of AI writing systems has been linked to a hindrance of critical thinking abilities (Royer 2024), environments assisting in emotion regulation may unknowingly perpetuate sociocultural norms that foster prejudice (Mesquita and Albert 2007), etc. However, despite the crucial role of developmental scaffolds in children's learning trajectories, research into their potential maladaptive effects remains limited. A recent exception can be found in de Carvalho and Krueger (2023), who analysed the maladaptive influence of caregivers' ableist biases on children's scaffolding interactions.

In this paper, we contribute to this shift in focus by examining the potentially harmful effects of developmental scaffolds on individuals' wellbeing. We define wellbeing through the "capability approach"; that is, as a matter of what individuals are capable of achieving rather than the resources available to them (Sen 1974). Under this framework, any factor—whether external or internal—that improves the individual's capacity to employ a resource to achieve a valued goal enhances their wellbeing, and those that reduce such capacity are detrimental. External factors are the features of the environment in which the interaction occurs, such as customs of child-rearing, caretakers' psychology, and socio-economic conditions. Internal factors, in turn, refer to aspects of the person, such as their physical condition, language skills, and intelligence (Robeyns and Byskov 2011). We contend that, despite their multiple benefits, efficiently designed educational technologies can also have detrimental effects on an individual's wellbeing, influenced not only by external factors—such as the ableist biases examined by de Carvalho and Krueger (2023)—but also by internal ones.

To uncover scenarios where developmental scaffolds might yield detrimental effects due to internal factors, we propose a model of scaffolding processes that illustrates how individual differences interact with scaffolds' features across contexts during development. Our model integrates insights from three recent empirical studies concerning the role of technological scaffolds in children's language acquisition and early literacy development. The first study presents a systematic review and meta-analysis of contemporary research on the effects of screen time on language development, laying the groundwork for understanding the role of external factors (Madigan et al. 2020). The second and third studies focus on the interaction effects that emerge from children and scaffolds' characteristics, shedding light on the role of internal factors (Diprossimo et al. 2023; Diprossimo and Cain 2023b).

Using this model, we identify two types of detrimental scenarios: on the one hand, situations where scaffolds are efficient to various degrees depending on *inter*-individual differences and, on the other, situations where scaffolds' efficiency is indexed to particular timeframes due to *intra*-individual differences. These scenarios illustrate that concentrating solely on the quality of scaffolds, without considering the degree to which individuals can turn scaffold interactions into meaningful learning opportunities (also referred to as "conversion factor"; Sen 1992), can lead to increased marginalisation. To address these issues, we suggest that more inclusive educational policies adopt a more individualised approach to scaffolds' design, which ought to mimic the adaptive efforts of caregivers towards their children's unique needs. In this way, this paper aims to bridge recent advances in scaffolded cognition with language acquisition research in a way that can prove mutually beneficial: Philosophers investigating scaffolded cognition can use our model to test, modify or reject extant analyses of scaffolding interactions in other domains (e.g., affective scaffolding), and psychologists studying language acquisition can gain insights from philosophical frameworks to diagnose maladaptive outcomes of scaffolding interactions.

The paper is organised as follows: Sect. 2 compares perspectives on developmental scaffolding processes in philosophy and psychology. Section 3 examines recent empirical studies on the role of technological scaffolds in children's language acquisition and early literacy development. Section 4 proposes a general model of scaffolding processes applied to the study of early childhood development. Section 5 analyses two scenarios in which developmental scaffolds are maladaptive despite their efficiency and discusses ways to address them. Section 6 concludes.

2 Developmental Scaffolds: A First Approximation

2.1 Developmental Scaffolds within Philosophical Taxonomies

How can we distinguish developmental scaffolds from other types of scaffolds? Philosophers have proposed to differentiate scaffolds based on multiple criteria, such as their function (e.g., epistemic or ontic, cf. Brey 2005), ontology (e.g., representational or ecological, cf. Heersmink 2013), or the type of cognitive support provided (e.g., complementary or substitutive, cf. Fasoli 2018). To give an overall perspective, we employ Coninx and Stephan's (2021) meta-distinctions: temporal frame, direction of impact and dimensions of efficacy.

2.1.1 Temporal Frame

Scaffolding processes can unfold across different temporal scales (Griffiths and Scarantino 2009; see also Coninx 2023; Menary 2018; Varga 2016). These temporal scales allow for the characterisation of various units of analysis depending on the research question. Following Sutton (2016), we can distinguish between phylogenetic, sociogenetic, ontogenetic, and microgenetic analysis units. In phylogenetic and sociogenetic analyses, we are concerned with the activities of whole species and (sub-)populations, respectively. In contrast, in ontogenetic analyses, the focus is on an individual's idiosyncratic engagement with their environment during different life stages, leading to alterations in their phenotypical properties (Trappes et al. 2022). Finally, microgenetic analyses highlight singular environmental modifications, such as the particular interactions between infants and caregivers that allow for local social coordination (Krueger 2013; Varga and Krueger 2013). Now, even though the acquisition of new skills happens throughout life stages, it occurs primarily due to agents' successful microgenetic engagements with the environment. Hence, the study of developmental scaffolds requires working at the interface between ontogenetic and microgenetic temporal units. The studies discussed in Sect. 3 will illustrate this point.

2.1.2 Direction of Impact

Scaffolding interactions differ in terms of the type of causal relationship between the scaffold and the supported ability (also called "reciprocity"; Coninx and Stephan 2021). In unidirectional interactions, the scaffold (e.g., a white cane used by a blind person) impacts the relevant mental ability (e.g., spatial navigation) without being influenced by it. In bidirectional interactions, both the scaffold and mental ability affect each other over time. For instance, playing an instrument can be seen as bidirectional when it forms a feedback loop where the playing is shaped by the emotional experience it fosters (Saarinen 2020). In the case of developmental scaffolds, both types of causal interactions can be observed. Children's books, for example, can impact the development of the child's mental ability (e.g., reading comprehension) without being thereby affected. In contrast, other types of developmental scaffolds (e.g., caregiver's contingent responses) are often dynamically accommodated to children's characteristics and needs as they grow.

Scaffolding can be also distinguished in terms of "user-resource" and "mind-shaping" models. User-resource models are those where fully formed agents (the "users") deliberately modulate their affectivity/cognition by recruiting affective/cognitive scaffolds, such as when a person uses a notebook to record memories. In contrast, mind-shaping models denote interactions where minds are shaped "outside-in" in ways that can, but need not, be beneficial for the individual (Walter and Stephan 2023). Developmental scaffolds blur this distinction, however. Though developmental scaffolds are employed by children whose skills and agency are developing, children learn by actively recruiting environmental artefacts and engaging with their social environment. This shows that user-resource and mind-shaping models are often intertwined in real-life developmental scenarios and, hence, should be conceived as representing two ends in a continuum where concrete scaffolding interactions can be located with respect to the weight of each type of process.

2.1.3 Dimensions of Scaffolding

Dimensions of scaffolding interactions are features on which the quality and efficiency of the scaffolds gradually rely. Sterelny (2010), for example, proposes trust, individualisation, entrenchment, and the number of users as key criteria for categorising cognitive scaffolds. Using these criteria, we may consider a person with memory impairments who relies on notebooks to store memories (Clark and Chalmers 1998). For this individual, the notebook serves as a highly trusted, highly personalised, deeply ingrained, single-user scaffold. However, in other scenarios, the same or different artefacts might qualify differently along these dimensions, thus influencing their relative efficiency (Newen and Fabry 2023). Developmental scaffolds can also be categorised along these dimensions. A child's book, for example, might be trustworthy but not tailored to the child's skill level, making it less effective. However, we consider that dimensional analyses of developmental scaffolds constitute a first step in the assessment of their efficiency. As the studies in Sect. 3 will illustrate, empirically assessing whether a scaffold is

likely to foster a particular developmental outcome (e.g., reading comprehension) additionally requires measuring the low-level interactions between the specific characteristics of individuals (e.g., age, gender, attention levels, etc.) and scaffolds' features (e.g., format, content, etc.) in specific contexts.

To sum up, developmental scaffolding interactions (i) involve processes occurring at the onto-microgenetic interface, (ii) are often located on a continuum whose endpoints are user-resource and mind-shaping forms of interactions and (iii) trigger outcomes that may be characterised using dimensions or low-level interactions.

2.2 Insights from Developmental Psychology

The role of scaffolds in development was initially investigated in psychology in the work of Lev Vygotsky, David Wood, Jerome Bruner, and Gail Ross (Vygotsky 1978; Wood et al. 1976). They explored the role of educational environments within scaffolding processes that support problem-solving, emotion regulation, and language acquisition in children. To characterise these processes, Vygotsky (1978) introduced the concept of the "zone of proximal development" (ZPD). The ZPD consists of a lower limit, which corresponds to the child's independent skill level, and an upper limit, which represents the potential skill level the child can reach for a particular task with the help of a more knowledgeable other (Vygotsky 1978, p. 86).

Although Vygotsky did not use the term "scaffolding", the concept was later developed by others who applied the ZPD to educational settings. Wood et al. (1976), for example, defined scaffolding as a process that allows a child or novice to solve a problem, complete a task, or achieve a goal that is beyond their unassisted efforts at their particular developmental stage. Building upon Vygotsky's work, other researchers also investigated the processes underlying scaffolding interactions in children's development within the framework of the "developmental niche". The developmental niche is the set of ecological, epistemic, social and symbolic legacies transmitted to the next generations to guide their developmental processes (Super and Harkness 1986; see also Flynn et al. 2013; Stotz 2010). As Krueger (2013) emphasises, scaffolding structures offered during ontogenesis by societal agents, including family members, educational institutions, and organisations, support children's development as well as the transgenerational transfer of societal norms and values.

In the empirical study of developmental scaffolds, three basic features stand out. First, the more knowledgeable other, in recent research and contemporary digital ecology, can be something other than an older or more experienced person (Flynn et al. 2013). Besides traditional instructional support, technology-based scaffolding is becoming increasingly common. Indeed, digital environments afford novel opportunities to scaffold children's learning. For example, children's eBooks can offer multiple "scaffolding features", such as read-aloud functionality and visual support for word meaning.

Second, the effectiveness of developmental scaffolds significantly depends on how well they are tailored to the user. At a coarse level, scaffolds' individualisation is observed in how caregivers adapt their behaviour when interacting with children (Fernald and Mazzie 1991; Hills 2013). For example, *child-directed language* has been observed to vary in degree of complexity as a function of children's assumed skills (Snow 1972), and its prosodic characteristics have been shown to support word learning in children (Ma et al. 2011; Schwab and Lew-Williams 2016). At a more fine-grained level, recent empirical research demonstrated that adult caregivers dynamically adjust their communication in very subtle ways by taking into account the child's knowledge of specific words (Diprossimo and Cain 2023a; Leung et al. 2021; Shi et al. 2023).

Third, scaffolding interactions are meant to be temporary. That is, instructional scaffolding is intended to be gradually removed as children acquire skills or reach specific goals, similar to how construction scaffolds are taken down once a building is finished. For instance, in emotional regulation, a child is expected to be eventually able to self-regulate once the adult is not present (Varga 2016). Therefore, developmental scaffolding interactions in educational psychology refer to environments or artefacts aimed at becoming superfluous by helping individuals develop their agency in specific experiential domains. In contrast, other types of scaffolds (e.g., a notebook, a walking cane, a musical instrument) are generally used continually on an as-needed basis without the objective of becoming unnecessary.[1]

To sum up, the empirical study of developmental scaffolding reveals that these are environments and artefacts (i) that can be natural (e.g., caregivers) or artificial (e.g., digital support), (ii) that require a high degree of individualisation to children's needs, and (iii) that ultimately aim at their own uselessness.

2.3 Challenging the Dogma of Harmony

Significant similarities exist between philosophical and psychological views on scaffolding processes, but a difference stands out. Psychologists view developmental scaffolds as

[1] Superfluousness may not be exclusive to developmental scaffolds. For instance, consider a calculator that, after extensive use, becomes redundant. Nevertheless, we believe this trait is particularly prominent in developmental scaffolding. We thank a reviewer for highlighting this point.

temporary aids that eventually become superfluous once the agent's goal is achieved. This perspective reveals a specific assumption about the role of developmental scaffolds: while some may be more or less efficient than others, they are expected to promote adaptive outcomes. Any artefact that fails to assist in helping individuals reach a goal (e.g., solve a problem) or improve a skill (e.g., learn new vocabulary) is not regarded as a scaffold in the first place. This expectation is not surprising. Numerous studies show, for example, that the lack of parental scaffolding—such as a parent's absence during children's reading or viewing activities—can lead to lower story comprehension (Dore et al. 2018) and is negatively associated with language development (Madigan et al. 2020).

Yet, this perspective of developmental scaffolds is evaluatively loaded. Developmental scaffolds would not just be those tools or environments intended to support skill acquisition, but those which are somewhat effective in doing so. Thus, such perspective echoes (and reinforces) the dogma of harmony. In recent years, various proposals have emerged to diagnose scaffolding interactions—and niche construction processes in general—that might negatively impact an agent's wellbeing. These proposals may help us understand the detrimental effects of developmental scaffolding in the present context. Slaby (2016), for example, argues that some interactions instantiate a "mind invasion" model, whereby technologies, institutions, or similar environmental structures frame the individual's mind against their interests. Timms and Spurret (2023), on the other hand, distinguish between "harmful" and "hostile" scaffolds. Harmful scaffolds fail to be beneficial due to inefficiency or unreliability, as exemplified by a calendar that encourages inaccurate inferences about scheduling. Hostile scaffolds, although efficient, exploit the user by concurrently advancing the interests of another party, as illustrated in the addictive design of casinos. Liao and Huebner (2021), in turn, argue that material objects can perpetuate oppression when their effects are embedded in an oppressive system.

Some developmental scaffolds certainly fit into these categories. For instance, some educational technologies might unintentionally undermine a person's agency, seek to further external agendas or be embedded in an oppressive context. Yet, it is worth noting that the negative impacts of developmental scaffolds on individuals' wellbeing are often more subtle than typically acknowledged. In the following section, we will discuss how the effectiveness of scaffolds can change depending on interaction effects, that is, based on the relationship between children's unique traits and the characteristics of the scaffolds over different time periods. We contend that, due to these interaction effects, scaffolds designed to enhance children's skill development might inadvertently increase marginalisation by reinforcing pre-existing inequalities.

3 Uncovering Interaction Effects in Language Acquisition Research

In order to comprehend the impacts of developmental scaffolding interactions, we examine three recent studies on language acquisition in early childhood and technological scaffolds. Before we proceed, however, it's important to define "children's individual characteristics" more clearly. Individuals can be of different developmental stages and genders or belong to diverse ethnicities or socio-economic statuses. Sometimes, however, variation does not fit into readily identifiable categories. For instance, individuals may have differences in their genetic makeup, executive functions (that is, cognitive skills that support attention and memory), or quirks in their preferences. The former type of variation is called "group differences", while the latter, a less easily categorised variation, is called "individual differences" (Trappes 2022; Kaiser et al. 2024). In what follows, we will use this distinction.[2]

3.1 Contextual Determinants: Madigan et al. (2020)

There is mixed evidence as to whether screen-based programming, including educational programming, helps or interferes with critical aspects of children's development, including language development. Madigan et al. (2020) conducted a systematic review and meta-analysis including 18,905 participants to quantify the impact of screen time on children's language development. The authors quantitatively analysed both the amount and quality aspects of screen use to assess their associations with children's language skills. In particular, the researchers used effect sizes measured as correlations to determine the strength of the associations between quantity and quality of screen use and child language skills. The key findings of the study are the following:

- *Quantity of Screen Use*. Greater screen use, encompassing both duration of screen time and background television exposure, was generally associated with lower language skills in children. Duration of screen time refers to the amount of time children spend engaging

[2] Note, however, that group-based comparisons can be applied to the study of individual differences. For instance, individuals may be separated into groups based on their ability levels (e.g., low, average, or high literacy skills) to enable meaningful comparisons and facilitate interpretation. These statistically generated groups, however, are different from the pre-defined groups mentioned earlier, which do not only depend on the researcher's goals and methods.

with screens, such as watching TV or using electronic devices. Background television includes having the television on while children are involved in other activities.
- *Quality of Screen Use*. Improved quality of screen use, including exposure to educational programs (i.e., screen content designed to be educational and beneficial for children's learning) and co-viewing (i.e., parents or caregivers watching and interacting with children while they engage with screen media), was found to have a positive association with children's language skills.
- *Age at Onset of Screen Use*. The age at which children begin viewing screens was associated with language skills. In particular, the advantages of screen exposure on language development are more likely to be observed when screen use is initiated later in childhood. Thus, although developmental scaffolds are designed to be abandoned after helping the child achieve a developmental goal (see Sect. 2.2), this does not imply that they should always be used as early as possible.

Despite their correlational nature, these ecologically valid findings underscore the importance of considering both the quantity and quality of screen usage, as well as the age at which children are exposed to screens, to understand the complex relationship between technological scaffolds and language development. Importantly, the study highlights that quality also involves contextual factors, such as parental engagement with children during screen time, as opposed to solitary screen exposure. As the authors suggest, caregivers "may also scaffold screen content or supplement screen viewing with live interactions, which in turn can help children effectively apply learning concepts" (Madigan et al. 2020, p. 6). Hence, the effectiveness of scaffolds likely depends not only on its features but also on how and in which context it is utilised (e.g., supervised or unsupervised), as also evidenced by experimental studies (e.g., Dore et al. 2018).

3.2 Group-level Differences: Diprossimo et al. (2023)

Diprossimo et al. (2023) explored the links between children's use of digital vocabulary scaffolds and their reading comprehension, as evidenced by performance in a sense-matching task. The authors focused on the potentially moderating role of various characteristics of children, such as literacy skills, age, gender, and bilingual status. The study involved a large sample ($N \sim 120{,}000$) of children aged 5 to 8 years who participated in a gamified comprehension task in the context of a digital reading supplement utilised in United States' classrooms. During the task, children were asked to determine whether picture-text pairs were related in meaning or not. Critically, certain words were highlighted, and children could select them to receive audio and visual support for their pronunciation and meaning (vocabulary scaffolds). Below is a summary of the study's findings:

- *Literacy skills*. Expanding on previous findings (e.g., Cuevas et al. 2002), this study found that individuals with lower literacy skills, regardless of their other characteristics, were more likely to use and benefit from scaffolding features.
- *Age*. Younger learners were also more likely to use and benefit from the vocabulary scaffolding features, suggesting that specific scaffolds may be particularly beneficial at the beginning of literacy instructions but less so once literacy skills develop.
- *Gender*. Girls were more likely than boys to use scaffolding features. One potential explanation for girls' increased use of scaffolds is that they are typically reported to show enhanced metacognitive skills compared to boys, such as being more aware of their linguistic level, i.e., what they already (don't) know (Wu 2014). However, boys benefitted slightly more than girls from the use of scaffolds.
- *Bilingual Status*. Bilingual students were more likely to use scaffolds and benefit from them. Because bilingual students often struggle with early literacy compared to their monolingual peers, such findings are promising in reducing achievement gaps.

This study provides insights into the role of the scaffolding features of digital technologies—the different components that scaffolds may offer to users, such as audio and visual support—and group differences within scaffolding interactions. In particular, the study shows that the outcomes of the scaffolding process are modulated by children's group characteristics, such as literacy skills, age, gender, and bilingual status. In other terms, it demonstrates that the characteristics that the child brings to the interaction significantly predict the uptake of vocabulary scaffolding features and modulate their effectiveness in supporting early literacy skills.

The upshot of this study is twofold. On the one hand, understanding children's group differences is crucial to tailoring digital reading tools effectively. Educational programs can provide targeted support by recognising that lower-achieving groups (e.g., groups who are found to typically have poorer literacy performance, such as boys and bilingual students) are more likely to benefit from vocabulary scaffolds. This approach would be promising in helping to reduce performance gaps between students. On the other hand, digital scaffolds can offer several benefits for struggling learners by incorporating multimodal support. For example, enhancing digital scaffolds with written

definitions, auditory pronunciation, and visual aids, particularly for unfamiliar, abstract, or morphologically complex words, can provide learners with multiple cues to word learning, ultimately leading to improved comprehension of texts.

3.3 Individual Variability: Diprossimo and Cain (2023b)

The emergence of new media of story presentation raises questions as to whether electronic book formats are as effective as traditional print books in supporting children's language development, especially vocabulary acquisition. In this respect, recent meta-analytic syntheses highlight a mixed and inconclusive set of findings (Furenes et al. 2021; Savva et al. 2022). To address this issue, Diprossimo and Cain (2023b) investigated the effects of book format (print vs. digital) on young children's word learning during shared reading with a caregiver and examined the mediating role of individual differences. A consideration of these differences—in particular, children's prior vocabulary knowledge and executive function—is deemed to be critical for providing an accurate estimate of any unique or mediated effect of the scaffolds' format on word learning. Below is a summary of the study's findings:

- *Book Format*. There was no evidence of a main effect of book format (print vs. digital) on word learning from shared reading in young children.
- *Executive Function*. Although there was no overall main effect, the study revealed that the format of the book interacted with executive function to influence word learning as assessed through a semantic recognition task. Children with higher executive function demonstrated better semantic recognition than those with lower executive function, but only when engaging in digital-based shared reading (as opposed to print-based shared reading). This suggests that children's cognitive skills that support attention and memory play a crucial role in learning from digital books.
- *Prior vocabulary knowledge*. Across print and digital formats, children with greater prior vocabulary knowledge demonstrated significantly higher accuracy across word learning measures. This suggests that prior vocabulary knowledge is a crucial determinant of word learning across book formats.

The study's findings suggest that the effect of book format (print vs. digital) on word learning in young children is modulated by children's individual differences in executive function. This underscores the importance of considering not only the main effects of different types of scaffolding supports in learning (e.g., print vs. digital books) but also how learners' characteristics modulate those effects. By examining these interaction effects, the study provides a more nuanced understanding of how individual differences modulate the impact of scaffolding on learning and development.

As the authors point out, these findings echo the so-called "Matthew Effects" in early literacy, referring to processes where the "rich" get richer and the "poor" get poorer (Stanovich 1986). Children with a larger prior vocabulary acquired new words more easily during shared reading, no matter the book format. This might eventually result in greater differences between children with low and high vocabulary over time. A possible reason why Matthew Effects would arise is that children with larger vocabulary are better equipped to understand the story and, therefore, have more cognitive resources available to learn new words. Furthermore, greater knowledge of semantic categories eases the acquisition of new words (Borovsky et al. 2016).

Moreover, children with a higher executive function learned new words more easily during digital-based, but not print-based, shared reading. Critically, these interaction effects suggest that digital books might inadvertently widen the gap between children's ability levels. A possible reason why Matthew Effects might also arise in this context is that digital devices can be operated in multiple ways, compared to traditional scaffolds (e.g., flipping pages on an eBook can be done by tapping, swiping, or using voice commands). This, in turn, increases children's cognitive load, eventually disadvantaging those with less developed executive functions. If replicated, this evidence will need to be considered in the selection of reading media for children with still immature executive functioning.

4 A Model of Scaffold-mediated Development

As noted in Sect. 2.1, real-life examples of developmental scaffolding interaction often struggle to fit neatly into categorical distinctions. In these interactions, agents typically use external resources in order to build and shape their skills, thus involving both user-resource and mind-shaping processes. Instead, the empirical studies reviewed above measure fine-grained aspects of the interaction. By merging their insights, we propose a new model of scaffolding processes (see Fig. 1). This model focuses on low-level interaction effects and might be applied to scaffolds that serve other functions (e.g., affective scaffolds) to showcase blindspots in how they are studied. In this section, we take a look at each of its variables: the context, the focal individual, and the scaffold.

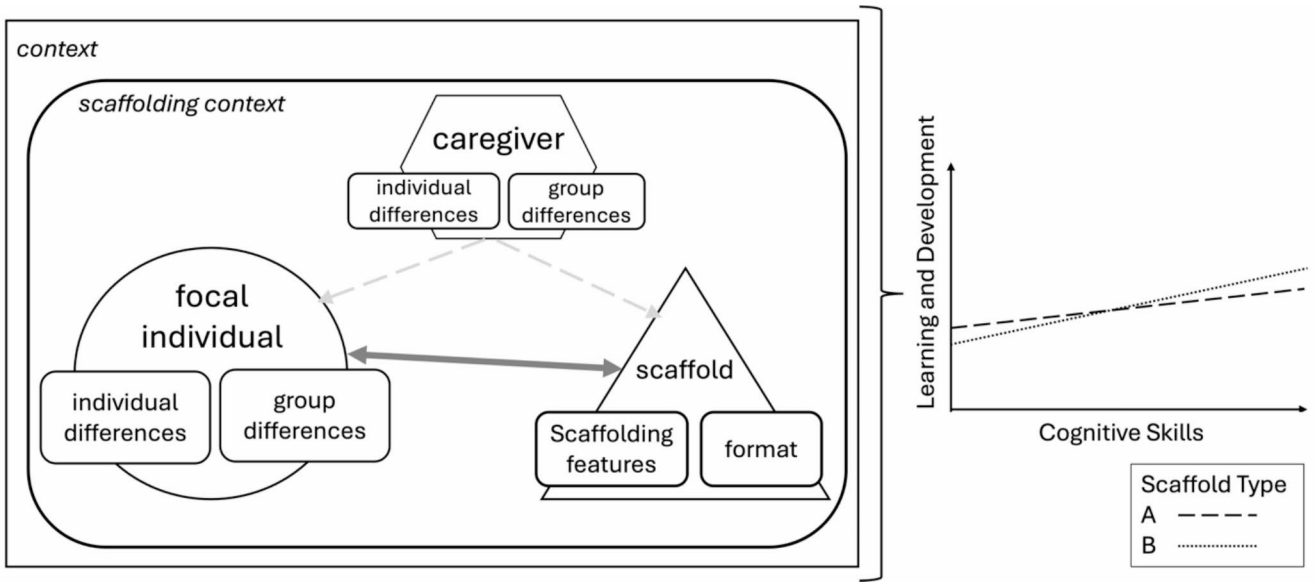

Fig. 1 This diagram illustrates our model of scaffolding interactions, as applied to developmental processes. The focal individual, such as a child or a novice, brings individual and group differences that modulate the process. These elements interact independently with the features and format of the scaffolds, producing different outcomes, as represented by the thick bidirectional arrow. Caregivers/supervisors' group and individual differences are also considered, as they can influence the interaction, as represented by the thin unidirectional arrows. The scaffolding context is situated within a larger context, where external factors such as designers' interests and social norms (e.g., gender biases) may also impact the scaffolding process. On the right, we can observe the hypothetical developmental result of such interaction (Y-axis) within a particular time point for individuals with different skills (X-axis) for two types of scaffolds (**A**, **B**)

Scaffolds don't occur in the void but are influenced by external factors. External factors can be subdivided into two categories. On the one hand, there are contextual factors which, while not directly involved in the interaction, can still influence the interactions' outcomes. This includes the broader socio-cultural environment where the process takes place and the psychology of the agents within it (e.g., the designers of educational software). On the other hand, other contextual factors are directly involved in the scaffolding process. For example, the interaction between a child and a digital scaffold can occur in the presence of a caregiver, whose assistance (or lack thereof) can highly modulate the interactions' outcomes (Madigan et al. 2020). To have a better grasp of the role of caregivers, their group and individual differences should be considered too (e.g., their educational background, language proficiency, level of sensitivity, etc.).

Next, individuals whose abilities are scaffolded possess different traits which play an important role in shaping the interactions' outcomes. Group differences, such as gender and bilingual status, can predict the way agents interact with the scaffold and its overall effectiveness. For instance, in Diprossimo et al.'s (2023) study, groups often linked to lower literacy skills, like bilingual children, utilised and benefited from scaffolds more, as evidenced by their performance in a reading comprehension task. Similarly, individual differences also predict the effectiveness of scaffolds. Children with higher executive functions, for example, learn new words more readily during shared reading with digital books compared to those with weaker executive functions, a trend not observed with print books (Diprossimo and Cain 2023b).

Third, scaffolds are also multiplex phenomena whose specific features can be closely examined. Madigan et al. (2020), in particular, observed that the type of content provided by developmental digital scaffolds modulates their outcomes. Diprossimo et al. (2023), in turn, highlight that educational scaffolds can have either unimodal features (e.g., offering solely visual support) or multimodal ones (e.g., incorporating both visual and auditory aids). Multimodal scaffolds supply learners with various cues to aid word learning, which can better address their unique needs, enhance engagement, and promote learning. Additionally, Diprossimo and Cain (2023b) note that the format of the scaffold, digital vs. print, influences learning, particularly when factoring in children's individual differences.

Lastly, to assess scaffolds' potential ontogenetic outcomes, we need to observe microgenetic interactions over time. For example, consider a hypothetical case where children with varying cognitive skills interact with developmental scaffolds of different formats (A: print and B: digital) in a context in which a caregiver supervises the interaction. As we observe in Fig. 1, in a specific timeframe, print and digital scaffolds might aid children with varying cognitive skills in achieving developmental outcomes to a similar extent.

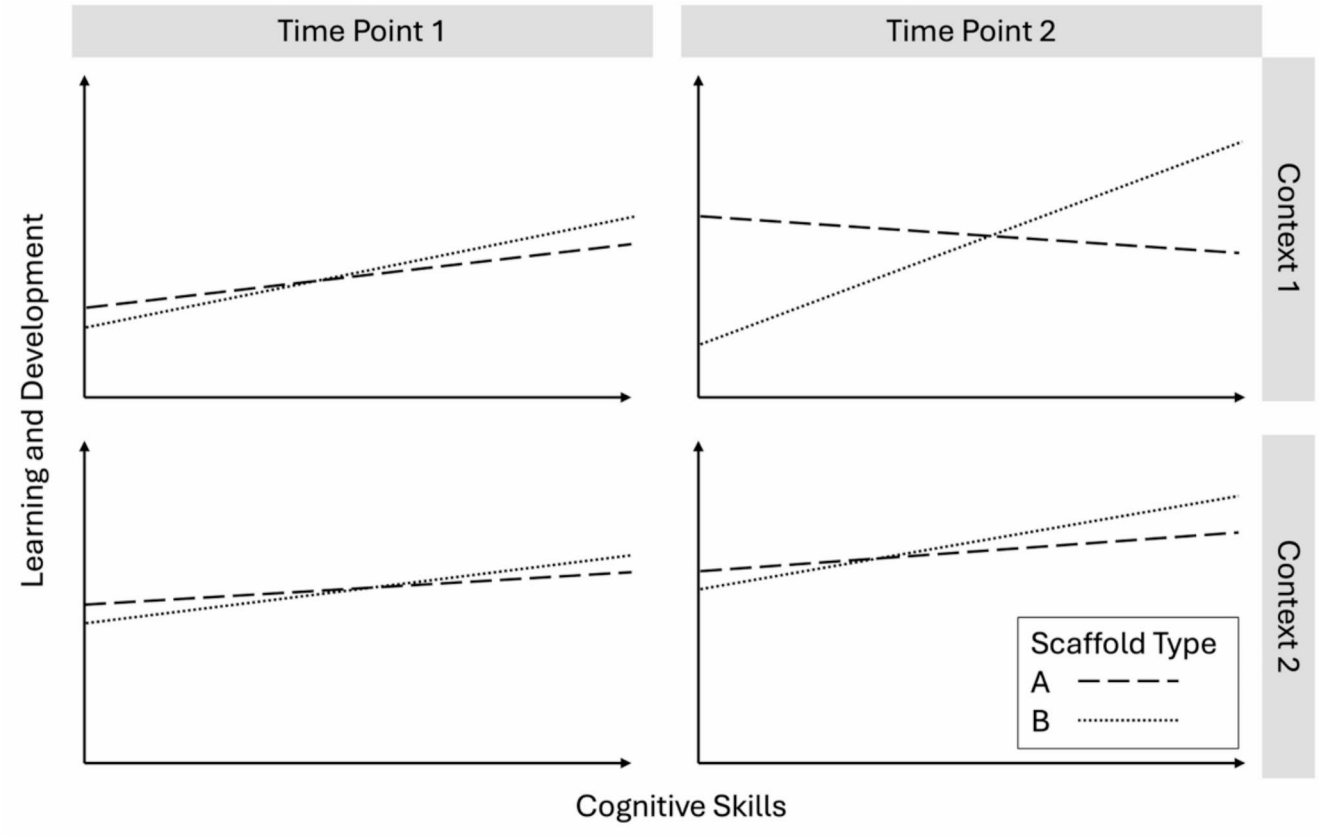

Fig. 2 This figure, inspired by Diprossimo and Cain's (2023b) study, depicts hypothetical scenarios where children's individual differences in cognitive skills, the format of the scaffold (print vs. digital) and the context (supervised vs. unsupervised) interact at two different points in time. We observe that both print and digital scaffolds can support to a similar extent the learning and development of children with varying cognitive skills at Time Point 1, in both unsupervised (Context 1) and supervised (Context 2) contexts. However, at Time Point 2, where the complexity of the learning material may increase, digital scaffolds are beneficial for children with higher cognitive skills and detrimental for those with lower cognitive skills, likely because they require more cognitive effort to be used correctly. This difference is most apparent when caregivers are not present (Context 1), highlighting how multiple factors interact to influence developmental outcomes

Nevertheless, digital scaffolds might be slightly less helpful for children with lower cognitive skills and slightly more helpful for those with higher cognitive skills (as measured in terms of executive function). This would occur, as speculated above, due to the higher cognitive load digital scaffolds require to be correctly manipulated.

This model also allows us to observe how performance outcomes can differ when we control for different variables and timeframes. For example, inspired by Diprossimo and Cain's (2023b) study, we might consider the hypothetical set of scenarios illustrated in Fig. 2, which involve the interaction between scaffolds of two formats (A: print and B: digital) and individual differences in cognitive skills. At Time Point 1, we can observe that both digital and print scaffolds might have similar effects in unsupervised (Context 1) and supervised (Context 2) scaffolding contexts for individuals with varying cognitive skills. However, at Time Point 2, it emerges that in unsupervised contexts (Context 1) but not in the supervised context (Context 2), digital scaffolds might be detrimental for individuals with lower cognitive skills and beneficial for those with higher cognitive skills.

Our model distinguishes itself from others as follows. First, future discoveries regarding how scaffolding processes work, the factors therein involved, or their underlying cognitive mechanisms can extend, refine or correct this model by iteratively adding incremental constraints. Second, the model can be used to single out paradigmatic kinds of scaffolding interactions (e.g., user-resource interactions) described in philosophy and better distinguish them from other kinds of interactions. Third, the model focuses on causal relationships relevant to the scaffolding of an individual's ability, to the exclusion of irrelevant background conditions (Coninx and Stephan 2021; Newen and Fabry 2023). It is important to note that although the data gathered in the observational studies reviewed in Sect. 3 is correlational, they support causal claims. The reason is that, when hypothesised associations are found after controlling for other established predictors, and when these are found

to converge with experimental evidence, the nature of the observed associations is likely to be causal.

5 Wellbeing Conflicts of Developmental Scaffolds and how to Address them

Some view wellbeing as a matter of the availability of resources and their efficient use, while critics point out that this view downplays the significance of what individuals can actually achieve with those resources (Sen 1974). Under this framework, external and internal factors that improve the individual's capacity to employ a resource to achieve a valued goal enhances their wellbeing, while factors that reduce such capacity are detrimental. The role of external factors has been discussed by de Carvalho and Krueger (2023), who observe that caregivers with implicit ableist biases often provide impoverished scaffolded opportunities to differently-abled children, thus harming their achievement of developmental goals. While both external and internal factors are intermingled in real-life scaffolding interactions, our discussion will concentrate on the role of internal factors in the use of educational technologies.

Internal factors can negatively influence the wellbeing outcomes of developmental scaffolds in various ways, among which two scenarios stand out. In scenario A, scaffolds are effective but to varying degrees depending on children's inter-individual differences. As noted in Sect. 3.3, findings on the differential efficiency of specific scaffolds reveal Matthew Effects. Some devices benefit children with higher executive functions more readily than those with lower executive functions, those who already possess a rich vocabulary more than those with a poorer vocabulary, and so on. In these cases, the scaffold fulfils its intended function by aiding in the acquisition of a specific cognitive skill in children. However, it also leads to widening achievement gaps among them. In other terms, the scaffold facilitates progress toward a desirable goal while simultaneously undermining the broader goal of being well-educated, which can be measured comparatively against peers at the same developmental level.

In scenario B, in contrast, a developmental scaffold proves beneficial for individuals on a short-term scale but loses effectiveness over the long term. In this scenario, the efficiency of scaffolds within microgenetic interactions does not necessarily match the achievement of a valued developmental goal from an ontogenetic viewpoint, leading to a negative impact on an individual's wellbeing. Situations like these might arise due to intra-individual differences. In particular, they may occur when children's development and growth shift their relationship with the scaffold, rendering it unsuited for enhancing the acquisition of a skill. Following Coninx (2023), we can characterise cases like these as "interscale conflicts", that is, instances where the degree to which wellbeing optimisation from a microgenetic perspective does not align with its optimisation at the ontogenetic level.

How can we mitigate these detrimental effects on wellbeing, particularly in young children with still immature abilities? One strategy is to prioritise design in the hope of improving the efficacy of scaffolds without widening achievement disparities. However, it remains uncertain whether scaffolds' design process can take into account all external and internal factors in such a way as to always ensure wellbeing maximisation. Alternatively, an argument could be made for prioritising the maximisation of scaffold usability for the most disadvantaged (e.g., those with limited vocabulary), as it could lead to a significant overall improvement in welfare despite its associated costs (Bianchin and Heylighen 2017a). Lastly, another strategy is to prioritise fairness within the design process of the scaffolds rather than exclusively in their end results, incorporating a deliberative component that allows stakeholders to voice their interests throughout the design process, from conception to implementation (Bianchin and Heylighen 2017b).

While there are advantages to each of these approaches, we consider that the most promising way forward to improve the effects of technological scaffolds is to promote more individualisation in their design. Despite scepticism regarding the implementation of better design, enhanced technology—in particular, technologies inspired by human behaviour—holds promise in mitigating effects that favour some individuals to the exclusion of others. As discussed in Sect. 2.2, natural environmental supports such as infant-caregiver interactions are typically individualised and fined-tuned to the child. In these interactions, caregivers adjust to children's needs by, for example, using child-directed speech and adapting the complexity of their language to their children's level (Snow 1972; Leung et al. 2021). Thus, with the rise of AI-powered technologies, digital scaffolds might be fine-tuned to meet children's individual needs, mimicking the adaptive efforts of caregivers towards their children (Diprossimo et al. 2024; Diprossimo and Cain 2023a).

To address cases like those represented by scenario B, we need to distinguish between *static personalisation*, which provides individualised scaffolding opportunities based on a single assessment, and *dynamic personalisation*, which involves continual monitoring and timely updates. Dynamic personalisation can help avert inter-scale wellbeing conflicts before they escalate. Moreover, AI-powered dynamic personalisation might also help prevent detrimental wellbeing outcomes linked to external factors, such as caregivers' ableist biases. By guiding decision-making through machine learning methods that rely on children's actual performance

rather than on caregivers' assessments, the negative impact of their implicit biases can be lessened. To reach this goal, it is essential to continue conducting empirical studies that assesses how children's traits interact with technological support during learning and development, such as those discussed in this paper. By doing so, we could establish clearer guidelines for implementing technological support in more inclusive educational environments.

6 Conclusion

When examining harmful scaffolding interactions, it's important to highlight instances where external factors—whether intentionally or not—hinder our goals, undermine our autonomy, or benefit others. However, concentrating on external influences should not lead us to overlook the significance of internal factors, which can also have detrimental effects in many contexts. As we argued in this paper, overlooking internal factors can become a source of exclusion and negatively affect the pursuit of valuable social goals, including in those cases where external factors may appear favourable. To highlight their effects, we introduced a general model of scaffolding that highlights how agents' group and individual characteristics modulate scaffolds' outcomes. Although we used this model to analyse scaffolds used during development, it can also help shed light on the mechanisms underlying other types of scaffolding interactions, such as those that structure individuals' social identities or emotional experiences.

In this paper, we also aimed to foster integration between psychological and philosophical perspectives on the development of the human mind in the light of a view of cognition as an embedded phenomenon. By introducing an empirically driven model of scaffolding interactions, we hope to facilitate the formulation of specific hypotheses regarding the role of agents' group and individual differences across contexts and time scales in future research endeavours. In today's rapidly evolving digital environments, it is vital to understand under which conditions educational technologies effectively scaffold children's learning and development and, more importantly, whether they bring the expected wellbeing outcomes. In more applied contexts, research in this area is fundamental for effectively guiding stakeholders within the educational sphere, maximising learning opportunities for every child in today's digital world.

Acknowledgements We would like to express our gratitude to Lea Mascherrek, Rose Trappes, and two anonymous reviewers for their valuable suggestions on earlier versions of this paper, which significantly enhanced its clarity and cohesion.

Funding Open Access funding enabled and organized by Projekt DEAL. V.C-P research was funded by the German Research Foundation (DFG) as part of the CRC TRR 212 (NC^3) – Project number 316099922 – Sub-project D01 (396781674). L.D. has received funding from the Women in Research (WiRe) Postdoctoral Fellowship, University of Münster.

Declarations

Conflicts of Interest The authors declare that there are no conflicts of interest to disclose in relation to this research.

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