DOI: 10.1111/cdev.13946

EMPIRICAL ARTICLE

CHILD DEVELOPMENT

Development of teaching in ni-Vanuatu children

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Funding information
Studienstiftung des Deutschen Volkes

Abstract
Teaching is an important mechanism of social learning. In industrialized societies, 3-year-olds tend to teach through demonstrations and short commands, while 5-year-olds use more verbal communication and abstract explanations. However, it remains unclear whether this generalizes to other cultures. This study presents results from a peer teaching game with 55 Melanesian children (4.7–11.4 years, 24 female) conducted in Vanuatu in 2019. Up to age 8, most participants taught through a participatory approach, emphasizing learning-by-doing, demonstrations, and short commands (57.1% of children aged 4–6 and 57.9% of children aged 7–8). Contrary to Western findings, abstract verbal communication only became common in children aged 9–11 (63.6%), suggesting that the ontogeny of teaching is shaped by the socio-cultural environment.

Teaching is increasingly recognized as an important mechanism of social learning and as a key factor in the evolution of human culture (Csibra & Gergely, 2011; Laland, 2017; Thornton & Raihani, 2008; van Schaik et al., 2019). From an ethological perspective (Tinbergen, 1963), for a comprehensive understanding of teaching, mechanistic and evolutionary knowledge must be complemented by an understanding of developmental processes, or the ontogeny of teaching. In this paper, we examine the ontogeny of teaching among Melanesian children and compare our findings to results from Western and Asian samples; this contributes to our understanding of how teaching develops in different cultures.

Researchers working in different fields and on different topics have often defined teaching in different ways. Within the fields of evolutionary biology and behavioral ecology, researchers tend to use broad definitions of teaching focusing on adaptive function and observable social interactions, which apply whenever a knowledgeable individual modifies their behavior in such a way that it helps a learner acquire a skill (e.g., see Caro & Hauser, 1992; Hoppitt et al., 2008; Kleindorfer et al., 2014; Raihani & Ridley, 2008; Rapaport, 2011; Richardson & Franks, 2006; Thornton & McAuliffe, 2006; Troisi et al., 2018). In contrast, Strauss and colleagues, whose research has focused on ontogeny, have anchored their definition in cognitive mechanisms: they define teaching as an intentional act undertaken by a teacher to bring about knowledge change in a learner (Strauss et al., 2002; Strauss & Ziv, 2012). This entails that the act of teaching is performed on purpose and is facilitated by Theory of Mind (i.e., it requires understanding of the learner's mental state) (Strauss et al., 2002; Strauss & Ziv, 2012). Both these definitions can be applied to a broad range of behaviors, including abstract verbal explanations, nonverbal demonstrations, and more subtle forms of guidance such as opportunity scaffolding (in which a teacher may provide a learner with an object to explore, for example) (Kline, 2015, 2017). In contrast, Lancy (2015a), an anthropologist, has associated teaching with formal education settings and systems that emphasize frontal instruction. In this paper, due to our focus on ontogeny, we use the definition proposed by Strauss and colleagues (Strauss et al., 2002; Strauss & Ziv, 2012).

So, how does teaching develop in humans? Strauss and colleagues have argued that human teaching is a natural cognition that develops naturally during childhood

Abbreviations: A, abstract; D, demonstration; IQ 1, interview question 1; IQ 2, interview question 2; P, participatory.

This article was accepted under the Editorship of Glenn I. Roisman.

(Strauss et al., 2002; Strauss & Ziv, 2012). More specifically, human teaching is said to meet three requirements that qualify it for the status of a natural cognitive ability: first, it is universal in the sense that it is ubiquitous across cultures; second, teaching with an advanced Theory of Mind (the ability to represent what others think, want, and feel) is unique to humans; and third, it is developmentally reliable in the sense that we develop the complex ability to teach without being taught how to, seemingly without effort, and it emerges through a normative developmental trajectory (Strauss et al., 2015; Strauss & Ziv, 2012). This trajectory moves from demonstration to explanation, but this does not entail that explanations are absent at younger ages or that demonstrations disappear at later ones; instead, there is a shift in the dominant strategy over time (Strauss & Ziv, 2012).

In support of this view, experiments conducted in industrialized societies have found that 5-year-olds not only outperform 3-year-olds in Theory of Mind tasks (Wellman et al., 2001), but also communicate differently when teaching a game to a naïve peer. While 3-year-olds are more likely to use demonstrations or make moves for the learner, 5-year-olds use more verbal communication (Bensalah, 2011; Strauss et al., 2002; Ziv et al., 2016). The quality of verbal communication also develops, from short direct instructions in 3-year-olds to more abstract rule explanations in 5-year-olds (Ziv et al., 2016). 5-year-olds are also more likely to combine verbal statements with demonstrations (Davis-Unger & Carlson, 2008). 6-year-olds also engage in more elaborative teaching (explaining the rules of a game rather than just demonstrating) than 4-year-olds (Ye et al., 2021). Older children are also more responsive to the learner's actions, which is evident in their higher tendency to ask learners whether they understood the rules, to offer rule reminders, and to respond to errors (Davis-Unger & Carlson, 2008; Strauss et al., 2002). These age differences are not absolute (some 3-year-olds may explain here and there and 5-year-olds may perform a few demonstrations), but all these studies have found a marked shift in participants' dominant strategy (Strauss & Ziv, 2012). Finally, children's tendency to use verbal and combined teaching strategies is closely correlated with Theory of Mind: children with more advanced Theory of Mind and especially with better False Belief understanding use fewer demonstrations, more verbal instructions, and more rule explanations (Strauss et al., 2002; Ye et al., 2021; Ziv et al., 2016).

4- and 5-year-olds also show more metacognitive reflection, indicating increasing insight into how learning occurs (Davis-Unger & Carlson, 2008; Strauss et al., 2002). For example, when asked how they taught a game to their partner, 3-year-olds tend to redescribe *what* they taught (e.g., the rules of the game), whereas 4- and 5-year-olds are more likely to describe *how* they communicated with their partner, and to reflect on the transmission process between themselves, the experimenter, and the learner (Davis-Unger & Carlson, 2008). Additionally, 3-year-olds tend to describe or demonstrate their *actions* ("I pushed the truck."), whereas 5-year-olds are more likely to use *communication* terms such as teach, tell, or explain ("I told him to push it.") (Strauss et al., 2002). When asked how they knew whether their partner had actually learnt the game, 3-year-olds tend to refer to themselves, by using *their own teaching* as evidence that learning occurred ("I know that he learnt it because I taught him."), whereas 4- and 5-year-olds are more likely to refer to the learner, by using *the learner's actual behavior* as evidence that learning occurred ("I know that he understood it because he played very well.") (Davis-Unger & Carlson, 2008; Strauss et al., 2002). Again, these shifts have been linked to children's developing Theory of Mind (Strauss et al., 2002).

These results support the idea that human teaching emerges through a normative developmental trajectory, meeting one of the requirements for teaching as a natural cognitive ability (Strauss & Ziv, 2012). However, the above studies were all conducted in industrialized societies with high levels of formal education such as Israel (Strauss et al., 2002; Ziv et al., 2016), France (Bensalah, 2011), the United States (Davis-Unger & Carlson, 2008), and Singapore (Ye et al., 2021). Strauss and colleagues have acknowledged this limitation, stating that more research in diverse samples is needed to expand our understanding of the diversity and cultural variability of teaching (Strauss et al., 2015).

Observational studies have revealed that teaching practices in hunter-gatherers and kin-based subsistence societies differ markedly from the kind of instruction offered in formal education environments (Boyette & Hewlett, 2017; Dira & Hewlett, 2016; Hewlett & Roulette, 2016; Lew-Levy et al., 2020; MacDonald, 2007). Formal schooling relies heavily on abstract communication, the formulation of general principles, the presentation of information outside its immediate context, and frontal teaching (Scribner & Cole, 1973). In contrast, caregivers in these societies teach subsistence skills by involving children in ongoing activities, expecting them to observe and pitch in and assigning tasks to them; this emphasizes learning-by-doing, early participation, and practical demonstrations (Gaskins & Paradise, 2010; Paradise & Rogoff, 2009; Rogoff, 2003; Scribner & Cole, 1973). The learner's participation is initially peripheral but increases as the learner's competence develops (which also applies to many apprenticeship systems in Western countries) (Lave & Wenger, 1991).

In foragers and mixed-subsistence societies such as the Chabu, Hadza, and BaYaka, adults provide young children with tools, assign them simple chores, demonstrate skills such as butchering animals, and let learners practice their hunting with carcasses and easy prey (Dira & Hewlett, 2016; Lew-Levy et al., 2019; MacDonald, 2007). Speech is primarily used to support ongoing productive activities instead of front-loaded lessons (Paradise

& Rogoff, 2009). Among forager-horticulturalists and farming populations such as the Gusii and Tsimane, adult speech directed at young children is rare and primarily consists of short commands (Cristia et al., 2019; LeVine et al., 1994). Explaining conceptual knowledge about plants and animals is more common when interacting with adolescents (Dira & Hewlett, 2016; MacDonald, 2007). These practices are embedded in a model of childrearing that expects children to take on productive roles such as looking after siblings and helping with household chores from an early age (Lancy, 2015b; LeVine et al., 1994; Morelli et al., 2018).

This differs from the parenting norms embraced in many Western middle-class families, where caregivers model school-like interactions and literate discourse in the home by practicing intensive one-on-one communication with children (LeVine et al., 1994; Morelli et al., 2018; Rogoff, 2003). When formal schooling is introduced to communities that were previously not familiar with it, caregivers' teaching practices can change. For example, non-verbal demonstrations and egalitarian interaction styles are traditionally preferred among Peruvian Quechua and Guatemalan Maya, but parents with more formal education use more verbal instruction and hierarchical forms of communication (Chavajay & Rogoff, 2002; Visscher, 2010). In other cases, culturally distinctive forms of socialization persist after the introduction of schooling, as is the case in many Native American communities (Phillips, 1993).

Given this cross-cultural variation in adult teaching practices, children from different socio-cultural environments are exposed to different ways of teaching. This suggests that the ontogeny of teaching among children could vary cross-culturally as well. To examine this, we investigated whether the developmental trajectory documented in industrialized societies with high levels of formal education translates to rural farming societies with different conventions of cultural transmission. To this end, we implemented a peer-teaching game that has been used in previous work (Davis-Unger & Carlson, 2008; Strauss et al., 2002; Ziv et al., 2016) with children from a rural area in Vanuatu, an island nation in the South Pacific where previous studies have found that Theory of Mind develops more slowly (Dixson, 2016; Dixson et al., 2017). Children from rural areas have been found to pass classic False Belief tasks (such as the Sally-Anne test) at very low rates, with only about half of 9-year-olds (57%) passing (Dixson, 2016). If cultural differences do *not* influence the ontogeny of teaching, then the developmental trajectory identified in previous work should also translate to our sample. In that case, ni-Vanuatu children's dominant teaching strategy should shift from (1) demonstrations combined with short commands to relying more on verbal communication and abstract rule explanations by the age of 5. By the age of 5, they should also shift from (2) restating the rules of the game or describing their play behavior to being more likely to describe how they communicated with their partner and reflect on the transmission process. Further, they should shift from (3) using their own teaching as evidence that learning occurred to being more likely to use the learner's behavior as evidence that learning occurred. These changes should correlate with children's developing Theory of Mind. To the best of our knowledge, our study is the first to extend Strauss' research on the ontogeny of teaching to a kin-based subsistence society.

METHODS

Ethnographic background

We conducted field work in the Hog Harbor area of Espiritu Santo in Vanuatu, a rural area where people subsist on slash-and-burn horticulture and fishing, although wage labour and cash cropping (such as copra) are also practiced. Vanuatu's GDP per capita is among the lowest in the world (ranked 199 out of 229 countries) and most rural families are on low incomes (CIA World Factbook, 2022). People reside in villages made up of extended families and headed by chiefs. Locals refer to their indigenous language as Wanohe, but Bislama (pidgin English) is widely used as well. In daily life, children are exposed to informal learning through early participation in household chores, running errands for their parents or performing simple tasks their parents have assigned to them such as cleaning pots or cutting food. Adults occasionally intervene and decide that the occasion merits additional guidance. Children also spend much of their free time in play groups with other children, often assisting with looking after their younger siblings and engaging in shared activities. While many adults emphasize that it is important to "teach their ways" to the next generation, young people are also expected to be proactive and "sit with their elders" to pick up the information.

Many children also attend kindergarten, primary school, or Sunday school, where they are exposed to classroom instruction. Hog Harbor is a historic mission site that was established in 1897, where the ancestors of the current residents eventually came to settle (see Miller, 1990). The missionaries soon began to instruct locals in subjects such as reading, writing, and religion, although this was initially very informal (Miller, 1990). By the mid-20th century, this arrangement had morphed into a permanent primary school with a standardized curriculum. However, caregivers' level of education continues to vary widely. In a survey of the Hog Harbor area, we found that 49.4% of female caregivers with dependent children had up to 6 years of schooling (corresponding to a primary-level education), 33.7% had 7–10 years, and 16.9% had 11 or more years of education (Brandl, 2021). While more and more young people now finish secondary school, some locals (and researchers) have critiqued classroom teaching in Vanuatu, arguing that it artificially removes children from the village setting and disrupts the contextual, embedded-in-life nature of local forms of knowledge transmission (McCarter & Gavin, 2011).

Procedure

In this paradigm, the participants play a game adapted from Color Train by Jumbo (Davis-Unger & Carlson, 2008; Strauss et al., 2002; Ziv et al., 2016). Each round of the experiment involves one experimenter and two children, one of whom acts as 'teacher' who first learns the game from the experimenter in a standardized familiarization phase and then teaches the game to a naive 'learner'. Before teaching their peer, the child undergoes rule checks during which they are quizzed about the rules of the game they have just learnt. If they give an incorrect answer, the relevant information is repeated and the same question asked again, which is repeated up to four times per question. During the game, the players move a toy truck on a game board, then stop next to one of a series of flowers placed at the side of the board. They roll a dice: if the color on the dice matches the color of the flower the truck is stopped next to, the player can take the flower and place it on their side of the board. If the colors do not match, the player cannot take the flower. The first player to collect three flowers wins the game. In our version of the game, the dice also features three sides with a star shape, which indicates that the player should roll the dice again. This is a simplified version of the original paradigm, where the three non-flower sides featured three different activities and the players could only collect a flower if they had not won that color already (Davis-Unger & Carlson, 2008; Strauss et al., 2002; Ziv et al., 2016). The rules were modified after consulting with a local research assistant, who felt that the original was too complicated. Game objects such as trucks and flowers are familiar to the children at the field site. After the end of the game, the 'teacher' is asked two short interview questions (1. How did you teach the game? and 2. How do you know that your partner learnt to play the game?), which were designed to tap their metacognitive reflection about teaching and their tendency to take the learner's perspective into account (for detailed protocol see Supplement).

We also administered a four-task Theory of Mind test battery that assessed children's understanding of False Beliefs and Knowledge Access (Location False Belief, Explicit False Belief, Contents False Belief, and Knowledge Access), with tasks taken from a Theory of Mind scale developed by Wellman and Liu (2004) that has been used in previous research in Vanuatu (Dixson, 2016; Dixson et al., 2017). The participants also had to justify their responses to the Theory of Mind questions, based on a design devised by Blijd-Hoogewys et al. (2008). This was done to have an additional measure of children's ability to understand and communicate about mental states, giving them an opportunity to engage in mental state talk (for detailed test battery and coding scheme see Supplement).

All testing was conducted in a quiet room at Hog Harbor Primary School on Espiritu Santo. The role of experimenter was performed by a research assistant, a teacher's aide at the primary school who was fluent in Bislama, English and Wanohe and familiar with the children. During testing, the first author recorded children's responses to the rule checks and interview questions *verbatim* on paper forms and filmed children's game play from a corner of the testing area with a handheld mobile phone camera (Samsung Galaxy xCover). All testing was conducted in Bislama. We based our protocol on the instructions provided in Davis-Unger and Carlson (2008), which the first author translated into Bislama. The translation was then checked by a primary school teacher who was fluent in both English and Bislama. Ambiguities were resolved through discussion. Depending on how long children played, one session took ca. 10–15 min to complete. All data were collected in 2019.

Sample

We initially tested 126 ni-Vanuatu children (all Melanesian) on the 4-part Theory of Mind test battery. Some children ($n=3$) were excluded because they chose to interrupt their testing session. The final sample included 123 participants (56 female) and ranged from 3.8 to 11.3 years ($M=7.63$, $SD=1.89$). The birthdates of 2 children were unknown; their ages were estimated based on the mean age of their class, rounded to one decimal. Following Strauss et al. (2002), we then selected half of participants to take on the teacher role in the game task (the child who learns the game and then teaches a peer). In order to qualify for the teacher role, primary schoolers had to respond to all the target and control questions in the Theory of Mind assessment and pass all the control questions without repetitions. The selection rules were relaxed for preschoolers, who had to pass all the control questions in the Theory of Mind assessment with no more than one repetition across all four tasks. We then used the sample (without replacement) and cbind functions in R *v.3.5.1* (R Core Team, 2018) to randomly select teachers from the group of eligible participants and group them into pairs with a learner. All teachers taught another student from their primary school or kindergarten class.

Among the children who completed the Theory of Mind test, 62 were assigned the teacher role in the game task, of which 61 were tested. Some participants were excluded because they refused to teach ($n=3$) or because they engaged their partner in unstructured play instead of teaching the game ($n=3$). The final sample for the game task consisted of 55 participants (24 female), ranging from 4.7 to 11.4 years ($M=8.09$, $SD=1.67$) (calculated based on the date of testing for the game task). The birthdate of one teacher was unknown; their age was estimated based on the mean age of their class, rounded to one decimal. The Theory of Mind and game sessions were presented 1–2 weeks apart.

Children were recruited at their primary school and kindergarten after obtaining permission from the principal, chief's council, and chairman of the school board, who functions as the community representative at the school. Children also provided verbal assent prior to each testing session. Caregivers received an information sheet ahead of testing. Some children requested to have a parent waiting for them outside the testing area, which we complied with. In all cases, verbal permission was obtained from teachers or parents. The study was approved by the Vanuatu Cultural Centre, Port Vila, as well as the Department of Anthropology (Approval Code: ANTHPGR_2018_005) and the central Research Ethics Committee at University College London (Project ID: 12951/001).

Scoring

We recorded the number of repetitions needed during the rule checks. We coded the children's game videos with a coding scheme based on Davis-Unger and Carlson (2008), which captures various verbal, gestural, and combined teaching strategies. These include verbal statements (of any kind), non-verbal physical demonstrations, combined teaching (verbal statements accompanied by physical demonstrations or gestures), abstract elaborations (conditional statements that establish decision rules such as "If you roll the right color, you can take the flower"), checking in (asking a question to confirm whether the partner understood the rules), rule reminders (prompting the partner to recall the game rules), verbal commands (imperative statements such as "Push the truck!"), and move commentary (statements describing or commenting on game moves such as "That's right") (see Supplement for detailed descriptions). Each game is divided into two phases: a *teaching phase* (which corresponds to all explanations and demonstrations performed before inviting their partner to play, or failing that, before their partner starts their first move) and a *play phase* (which corresponds to all interactions performed after inviting their partner to play, or after their partner starts their first move). For each strategy, we recorded whether it was present during the relevant game phase (=1) or not (=0) and summed up all instances of each category to yield the number of times a given strategy was used during each phase. Furthermore, we coded for children's overall approach to teaching. Some children used an abstract approach to teaching that resembled the kind of instruction used in formal education environments and thus Lancy's (2015a) definition of teaching: they verbally walked their partner through the rules of the game before starting to play, abbreviated as 'A' in the tables. Others used a participatory approach to teaching that emphasized learning-by-doing: they made a move and then invited their partner to play or they told their partner to make a move, expecting them to pick up on the rules during game play without expounding on them first, abbreviated as 'P' for participatory. Yet others played a whole round by themselves, expecting their partner to learn from observation and non-verbal demonstrations, abbreviated as 'D' for demonstration. These latter two categories differ from classroom instruction but meet the broader definitions of teaching used by other researchers (see Background). We also recorded the length of the teaching phase, measured in seconds, and scored children's responses to the interview questions with a coding scheme based on previous work (Davis-Unger & Carlson, 2008; Strauss et al., 2002) (see Table 1).

Inter-rater reliability

30% of children had their responses to the Theory of Mind test battery, teaching phases in the game task videos, and game task interviews rated by a second coder, who was blind to the hypothesis tested and the general theoretical background of the study. We assessed inter-rater reliability by calculating 0-tolerance agreement and unweighted Cohen's κ for all categorical measures (Theory of Mind answers, approach to teaching, teaching strategy absent/present, and interview questions) and the intraclass correlation coefficient (two-way model comparing consistency of single values) for continuous measures (frequency of teaching strategies) using the *irr* package (Gamer et al., 2019; *v.0.84.1*). Agreement was very good for the Theory of Mind tasks (target questions: agreement = 98.6%, $\kappa = 0.97$, $z = 11.8$, $p < .001$; controls: agreement = 100%, $\kappa = 1$, $z = 12.2$, $p < .001$; justifications: agreement = 83.1%, $\kappa = .80$, $z = 24.4$, $p < .001$), excellent for the interview questions (agreement = 100%; $\kappa = 1$, $z = 10.4$, $p < .001$), and good for the categorical teaching measures (agreement = 89.0%; $\kappa = .78$, $z = 7.95$, $p < .001$). Inter-rater consistency for the continuous measures was also good (ICC = .98 [95% CI: 0.96, 0.98], $F(84, 84) = 81.4$, $p < .001$).

Analysis

We used Spearman correlation to examine whether children's understanding of the game rules (assessed through the number of repetitions needed during the rule checks) improved with age. We calculated descriptive statistics for children's behavior in the teaching phase, binning participants into 4–6- ($n = 12$), 7–8- ($n = 17$), and 9-11-year-olds ($n = 22$), with cut-offs at 6.9 and 8.9 years of age (there was only one 4-year-old). We then ran pairwise Wilcoxon comparisons to compare the teaching

TABLE 1 Coding scheme for interview questions.

Question	Category	Description	Score
(1) Method of Teaching -How did you teach the game to your partner?	Rule description	The child repeats the rules of the game without referring to their own teaching	1
	Play reference	The child describes how they played the game with their partner without referring to communication terms such as teach, tell, show or explain	2
	Teaching reference	The child describes how they taught the game to their partner using communication terms such as teach, tell, show or explain	3
	Metacognitive reference	The child reflects on their own teaching or extrapolates from the pattern of learning and teaching they have just participated in. Applicable if the child relates the full sequence research assistant-participant-partner or alternatively if they talk about their own or their partner's ability to teach more children	4
(2) Evidence of Learning—How do you know that your partner learnt to play the game?	Teacher reference	The child describes how they taught the game to their partner. Accordingly, they use *their own teaching* as proof that their partner learnt to play the game. It is not important whether they use communication terms such as teach, tell, show or explain, or whether they refer to game moves they showed to their partner	1
	Learner reference	The child draws on the actions *of their partner* to determine whether they learnt to play the game. Accordingly, they use their partner's behavior as a marker of learning. The child must refer to something their partner said or did during the session instead of just stating 'he learnt the game', 'now he knows' or 'now he understands'	2

Note: When multiple categories are present in an answer, the more highly rated category is coded for. All responses not fitting the categories in the coding scheme are rated 0. This includes difficult to code answers or vague statements such as "at first he didn't know how to play but now he knows how to play". The category 'Play Reference' in question 1 has no equivalent in Davis-Unger and Carlson (2008). We created it to account for descriptions of teaching that made no direct reference to communication terms. Davis-Unger and Carlson (2008) also required the use of communication terms in the category 'Teacher Reference' in question 2. This was relaxed here to group all responses that mentioned the teacher's but not the learner's behavior into one category.

strategies of children who had used different teaching approaches (abstract vs participatory vs demonstration-focused, with *p*-value adjustment for multiple testing). Effect sizes were calculated with the package *rstatix* (Kassambara, 2021; *v.0.7.0*) in R *v. 4.1.1*. We then used multinomial logistic regressions with the package *nnet* (Venables & Ripley, 2002) and Spearman correlations to investigate whether children's tendency to use the abstract approach and verbal teaching strategies increased with age (based on continuous age data). We also ran multinomial logistic regressions to examine whether sex was predictive of children's teaching approaches, and whether the use of these approaches was related to their initial understanding of the game rules. This was done to control for the possibility that children who struggled more with the game rules may be less likely to walk their partner through the game. We then performed the same analyses for children's teaching strategies during the play phase. For the latter, we excluded 2 children because the learner refused to play the game and due to experimenter error (who intervened during game play).

After excluding unscorable responses (=0), we used Spearman correlation and logistic regressions to investigate whether children's interview scores increased with age. We also examined whether children's responses to the two questions were related by running a logistic regression with interview question 1 as the predictor and question 2 as the outcome variable. We then used Kruskal-Wallis tests and logistic regressions to examine whether children's approach to teaching was predictive of their interview scores. Finally, we ran multinomial logistic regressions to examine whether children's Theory of Mind (their cumulative score in the Theory of Mind questions) and mental state talk (their point score in the justifications, see Supplement for coding scheme) predicted their approach to teaching. After excluding children with unscorable responses (=0), we also ran Spearman correlations and further logistic regressions to examine whether children's interview scores were related to their performance in Theory of Mind and mental state talk.

We predicted that participants' understanding of the game rules, their use of the abstract teaching approach and verbal teaching strategies, and their interview scores would increase with age and match age patterns observed in previous samples. We also predicted that children who had scored higher in interview question 1 would score higher in question 2, that children who had used the abstract teaching approach would have higher interview scores, and that children with higher scores in Theory of Mind and mental state talk would be more likely to use the abstract teaching approach and score higher in the interview questions. These analyses were confirmatory; the comparison of individual teaching strategies between children who had used different teaching approaches was exploratory in nature. We confirmed the consistency of our *p*-values using StatCheck; no inconsistent *p*-values were found.

RESULTS

Teaching strategies

On average, participants needed few repetitions in the rule checks, and the number of repetitions declined with age ($r(53)=-.41$, $p=.002$, see Table 2). While children aged 4–6 needed 2.5 repetitions on average ($M=2.50$, $SD=2.53$), children aged 9–11 usually did not need any ($M=0.36$, $SD=0.66$, see Table 2). During the teaching phase, most children used verbal statements (80.0%), physical demonstrations (85.5%), and combined methods (74.5%) (see Table 3). However, only half used abstract elaborations or statements about conditional rules (47.3%) and only one child checked in with their partner (1.8%). Overall, half of participants emphasized the participatory approach to teaching (49.1%), and slightly fewer used the abstract approach (i.e. a prior walk-through) (43.6%). Only few children used the demonstration-focused approach by playing a whole round by themselves ($n=4$ or 7.3%). As implied in the definition, children who used the abstract approach used significantly more verbal statements, combined teaching, and abstract elaborations than children who used the participatory approach (r ranging from .58 to .90, $p<.001$, see Table 4). They also taught slightly longer, which was associated with a medium effect size ($r=.30$, $p=.03$). Conversely, children who used the participatory approach gave slightly more demonstrations than children who used the abstract approach, although the size of this effect was smaller and this was not significant ($r=.28$, $p=.05$). Children who used the demonstration-focused approach spent the longest time before engaging their partner (nearly 4 min on average) and were outliers on teaching strategies, with a very high number of demonstrations ($M=37.00$, $SD=17.38$, see Table 4) while none of them made verbal statements.

Children's tendency to use the abstract approach (as opposed to the participatory one) increased significantly with age (OR = 1.60, 95% CI = [1.09, 2.34], $p=.02$, see

TABLE 2 Relation between age and frequency of rule repetitions and teaching strategies in the teaching and play phases (with and without outliers). Descriptive statistics and Spearman correlations.

	M(SD)—Age cohorts					
Outcome	**4–6 years**	**7–8 years**	**9–11 years**	***r***	***p***	***n***
Repetitions	2.50 (2.53)	0.58 (0.84)	0.36 (0.66)	−.41	.002	55
Teaching phase						
Duration (s)	75.5 (64.19)	69.0 (93.27)	36.0 (19.45)	−.25	.06	55
Verbal statement	6.00 (4.90)	2.74 (3.11)	4.23 (3.19)	−.04	.79	55
Demonstration	5.93 (9.39)	8.05 (15.02)	2.82 (2.34)	−.06	.69	55
Combined	5.21 (3.77)	2.47 (2.89)	3.77 (3.29)	−.07	.62	55
Checking in*	0.14 (0.53)	0.00	0.00	—	—	55
Abstract elaboration	0.86 (1.17)	0.79 (1.55)	1.86 (1.70)	.34	.01	55
Teaching phase (without outliers)						
Duration (s)	36.00 (23.51)	30.31 (17.08)	34.43 (18.45)	.05	.74	42
Verbal statement	5.25 (3.24)	3.62 (3.36)	4.05 (3.15)	.01	.94	42
Demonstration	2.13 (1.64)	2.00 (1.29)	2.86 (2.39)	.07	.66	42
Combined	5.13 (2.90)	3.31 (3.15)	3.57 (3.23)	−.04	.80	42
Checking in*	0.00	0.00	0.00	-	-	42
Abstract elaboration	1.00 (1.20)	1.15 (1.77)	1.76 (1.67)	.32	.04	42
Play phase						
Verbal command	25.57 (17.49)	17.94 (9.26)	15.19 (8.39)	−.31	.02	53
(without outliers)	19.92 (10.77)	17.94 (9.26)	15.19 (8.39)	(−.25)	(.07)	(51)
Move commentary	8.29 (7.31)	8.11 (5.98)	4.33 (4.26)	−.24	.09	53
Rule reminder	0.00	0.00	0.19 (0.87)	—	—	53
Abstract elaboration	0.43 (0.76)	0.17 (0.38)	0.33 (0.66)	−.08	.57	53

*Only one child checked in with their partner, and they had a delay in their teaching phase.

Table 5). Up to age 8, children rarely used the abstract approach: less than a third did so (ages 4–6: 28.6%; ages 7–8: 31.6%, see Table 5). In that age group, most children used the participatory approach (ages 4–6: 57.1%; ages 7–8: 57.9%); the remainder used the demonstration-focused approach (14.3% and 10.5%, respectively, see Table 5). The abstract approach only became common from age 9 onwards: about two thirds of children aged 9–11 used it (63.6%, see Table 5 and Figure 1). Children's approach to teaching was also related to their initial understanding of the game rules. Children who needed more repetitions in the rule checks were significantly less likely to use the abstract approach compared to the participatory one (OR = 0.46 [0.24, 0.90], $p = .02$); while half of children who only needed 0–1 repetitions used the abstract approach, among those who needed at least 2 repetitions only few did (14.3%, see Table 5). However, in post-hoc ANOVA model comparisons, a combined model incorporating both age and rule repetitions, plus an interaction term, did not significantly improve on an age-only baseline model (LR = 4.56, $p = .34$, see Table 5). While repetitions already declined substantially between ages 4–6 ($M = 2.50$, SD = 2.53) and ages 7–8 ($M = 0.58$, SD = 0.84, see Table 2), the use of the abstract approach remained stable in these age groups (ages 4–6: 28.6%; ages 7–8: 31.6%, see Table 5) and only increased in children aged 9–11 (63.6%). This suggests that the increase of the abstract approach in older children is not reducible to changes in children's understanding of the rules. Boys were slightly less likely than girls to use the abstract approach compared to the participatory one, but the confidence interval overlapped 1 (OR = 0.70 [0.23, 2.13], $p = .52$); post-hoc ANOVA model comparisons revealed that a combined model incorporating both age and sex, plus an interaction term, did not improve model fit compared to an age-only baseline (LR = 3.18, $p = .53$, see Table 5).

The duration of the teaching phase declined with age, although this was not linear: a substantial drop was only observed between children aged 7–8 ($M = 69.0$, SD = 93.27) and children aged 9–11 ($M = 36.0$, SD = 19.45), not before, and the decline was not significant ($r(53) = -.25$, $p = .06$, see Table 2). Age analyses for individual teaching strategies revealed very small effect sizes for children's use of verbal statements, demonstrations, and combined teaching, likely due to up-and-down trends for these variables ($r(53)$ ranging from −0.04 to −0.07, see Table 2). However, the use of abstract elaborations increased from about one in children aged 4–6 ($M = 0.86$, SD = 1.17) to about two in children aged 9–11 ($M = 1.86$, SD = 1.70), showing a moderate increase ($r(53) = .34$, $p = .01$, see Table 2).

Some of the youngest children were outliers with very long teaching times and many more verbal statements than other children their age (see Supplement). This was the case for children with uncooperative partners, which required repeated teaching episodes before they eventually joined the game, and for children who got distracted momentarily before they resumed teaching, which was more common in younger children. Our

TABLE 3 Descriptive statistics for the teaching task. Frequency of different teaching approaches, teaching strategies, and interview responses (whole sample).

Game phase			
Teaching approach			
Participatory	49.1%		
Abstract	43.6%		
Demonstration	7.3%		
Teaching phase		**Play phase**	
Verbal statement	80.0%	Verbal command	98.1%
Demonstration	85.5%	Move commentary	83.0%
Combined	74.5%	Abstract elaboration	22.6%
Abstract elaboration	47.3%	Rule reminder	1.9%
Checking in	1.8%		
Interviews			
Question 1		**Question 2**	
Rule description	34.5%	Teacher reference	43.6%
Play reference	18.2%	Learner reference	25.5%
Teaching reference	20.0%	Not scorable	30.9%
Metacognitive reflection	10.9%		
Not scorable	16.4%		

TABLE 4 Comparison of children's teaching approaches.

	***M*(SD)**			***p*(*r*)**			
Outcome	**P**	**A**	**D**	**P vs. A**	**P vs. D**	**A vs. D**	***n***
Duration (s)	38.56 (36.24)	50.21 (34.28)	228.50 (124.11)	0.03 (0.30)	0.005 (0.53)	0.005 (0.57)	55
Verbal statement	2.70 (3.54)	6.50 (2.96)	0.00	<0.001 (0.62)	0.02 (0.44)	0.003 (0.60)	55
Demonstration	3.59 (3.10)	2.21 (2.30)	37.00 (17.38)	0.05 (0.28)	0.002 (0.58)	0.002 (0.60)	55
Combined	2.26 (2.73)	5.92 (2.96)	0.00	<0.001 (0.58)	0.03 (0.40)	0.004 (0.58)	55
Abstract elaboration	0.07 (0.27)	2.75 (1.26)	0.00	<0.001 (0.90)	0.63 (0.10)	0.002 (0.61)	55

Note: Descriptive statistics and pairwise Wilcoxon comparisons for duration of the teaching phase and frequency of different teaching strategies in the teaching phase by children using different teaching approaches (P = Participatory, A = Abstract, D = Demonstration).

TABLE 5 Children's approach to teaching (P=Participatory, A=Abstract, D=Demonstration) as predicted by age, sex (male), and rule repetitions.

Predictor	P	A	D	Level	OR [95% CI]	z	p
Age							
4–6 years	57.1%	28.6%	14.3%	A	1.60 [1.09, 2.34]	2.39	.02
7–8 years	57.9%	31.6%	10.5%	D	0.85 [0.43, 1.66]	−0.48	.63
9–11 years	36.4%	63.6%	0.0%				
Repeats							
0–1	30.0%	50.0%	20.0%	A	0.46 [0.24, 0.90]	−2.27	.02
2+	78.6%	14.3%	7.1%	D	0.94 [0.52, 1.69]	−0.22	.83
Sex							
Female	41.7%	45.8%	12.5%	A	0.70 [0.23, 2.13]	−0.64	.52
Male	54.8%	41.9%	3.2%	D	0.20 [0.02, 2.15]	−1.33	.18

Model	df	LR	p	Residual deviance
Age				91.42
Age × repeats	4	4.56	.34	86.86
Age × sex	4	3.18	.53	88.24

Note: Descriptive statistics, multinomial logistic regressions (univariate), and ANOVA model comparisons (multivariate). The reference level for the multinomial logistic regressions was P (= Participatory).

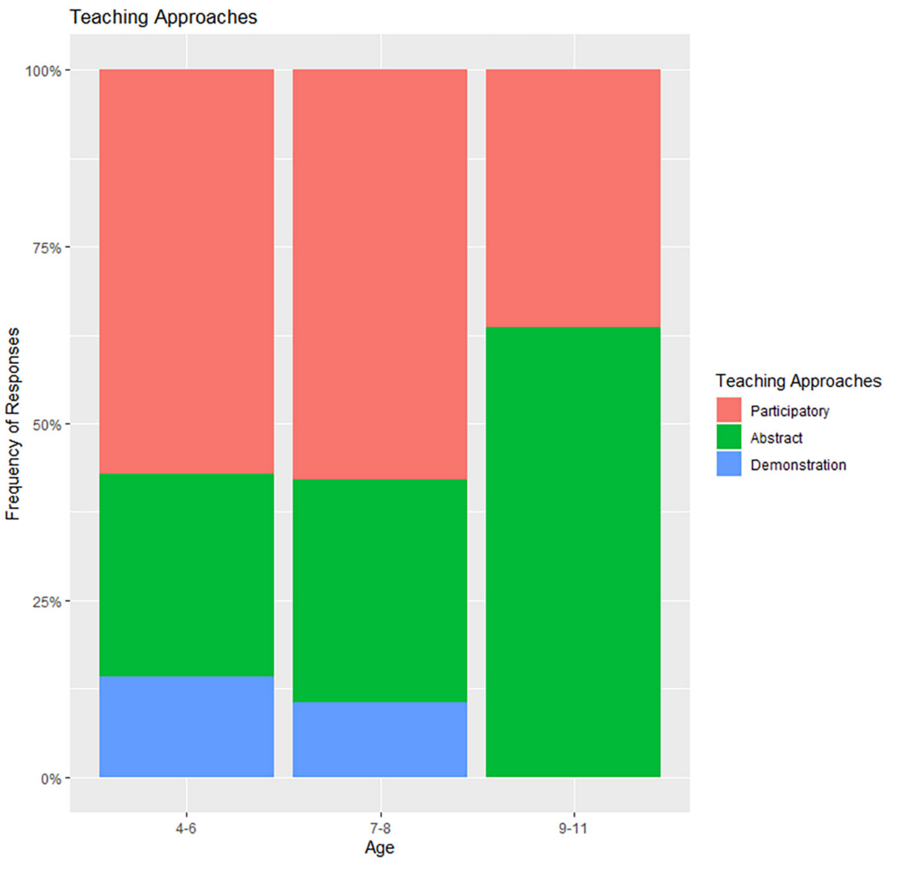

FIGURE 1 Use of different teaching approaches by age.

coding scheme also played a role, where we cut off ambiguous cases for the end of the teaching phase when the partner joined the game. When excluding children who had experienced such delays ($n=9$) and children who had used the demonstration-focused approach (as the latter were also outliers on many measures, $n=4$), age analyses revealed that effect sizes for teaching duration, verbal statements, demonstrations, and combined teaching hovered around zero, indicating that there were no substantial linear age trends for these strategies ($r(40)$ ranging from −0.04 to 0.07, see Table 2). However, the use of abstract elaborations increased with age with a medium-sized effect ($r(40)=.32$, $p=.04$), from around one such statement in children aged 4–6 ($M=1.00$, SD = 1.20) to around two in children aged 9–11 ($M=1.76$, SD = 1.67, see Table 2). Accordingly, older children did not necessarily talk more, but they used more explanatory statements.

No distinct teaching approaches were evident during the play phase. Most children used verbal commands (98.1%) and move commentary (83.0%), but only few made use of abstract elaborations (22.6%, see Table 3). Only one child used rule reminders (1.9%), quizzing their partner after playing with them. Unlike the pattern found in the teaching phase, children's use of abstract elaborations did not increase with age ($r(51)=-.08$, $p=.57$, see Table 2). Children's use of move commentary declined with age, but this was not linear: the effect was small and the relation was not significant, with a decline evident by age 9 ($M=4.33$, SD = 4.26) but not age 7 ($M=8.11$, SD = 5.98) ($r(51)=-.24$, $p=.09$, see Table 2). Across all ages, children used a high number of verbal commands, often directing their partner every step of the way (e.g., "now you! push the truck, now take the dice! shake it!"). While the number of verbal commands declined moderately with age ($r(51)=-.31$, $p=.02$), children aged 9–11 still used this strategy very often ($M=15.19$, SD = 8.39, see Table 2). Removing two outliers (see Supplement) decreases the size of this age effect, and the relation is no longer significant (see Table 2).

Metacognitive reflection about teaching

In response to the first interview question (How did you teach the game?), many children restated the rules of the game (34.5%); play descriptions (18.2%) and teaching references with communication terms (20.0%) were less common (see Table 3). Few children mentioned metacognitive reflections (10.9%), and slightly more gave unscorable responses (16.4%). Among the children with scorable responses, scores only increased very slightly with age; this was not significant and the effect size was small ($r(44)=.10$, $p=.49$, see Table 6; the 4-year-old gave no scorable responses). In all age groups, just under half of children restated the rules of the game (ages 5–6: 45.5%; ages 7–8: 40.0%; ages 9–11: 40.0%, see Table 6 and Figure 2) while metacognitive reflection was uncommon (ages 5–6: 0.0%; ages 7–8: 20.0%; ages 9–11: 15.0%). Up to age 8, only few children used teaching references (ages 5–6: 18.2%; ages 7–8: 6.7%); instead, many used play references without communication terms (ages 5–6: 36.4%; ages 7–8: 33.3%). Teaching references with communication terms only became more common in children aged 9–11 (40.0%). In response to the second question (How do you know that your partner learnt the game?), most children referred to their own teaching (43.6%) as evidence that learning occurred, with few commenting on the learner's behavior (25.5%, see Table 3). Nearly a third gave unscorable responses (30.9%). Among the participants with scorable responses, the odds of using the learner's behavior as evidence that learning occurred increased slightly with age, but the confidence interval overlapped 1, indicating a null effect (OR = 1.16 [0.75, 1.85], $p=.50$, see Table 6): only a third of children aged 5–8 (ages 5–6: 33.3%; ages 7–8: 31.2%) referred to the learner's behavior, and less than a half of children aged 9–11 did so (43.8%, see Table 6 and Figure 2).

Against expectations, children who had used the abstract approach to teaching were slightly *less likely* to use learner references in question 2 (31.6%) than children who had used the participatory approach (50.0%); but confidence intervals were consistent with a negligible effect (OR = 0.46 [0.11, 1.80], $p=.27$, see Table 7). Participants who had used the abstract approach scored

TABLE 6 Relation between Age and Performance in Interview Questions (Scorable Responses, Des. = Description, Ref. = Reference, Metacog. = Metacognitive Reflection, IQ 1 = Question 1, IQ 2 = Question 2). Descriptive statistics, Spearman correlations, and logistic regressions (univariate, Teacher Reference = 0, Learner Reference = 1).

	Interview question 1 ($n=46$)					Interview question 2 ($n=38$)	
Age	Rule Des.	Play Ref.	Teaching Ref.	Metacog.	M(SD) Score	Teacher Ref.	Learner Ref.
5–6 years	45.5%	36.4%	18.2%	0.0%	1.73 (0.79)	66.7%	33.3%
7–8 years	40.0%	33.3%	6.7%	20.0%	2.07 (1.16)	68.8%	31.2%
9–11 years	40.0%	5.0%	40.0%	15.0%	2.30 (1.17)	56.2%	43.8%

Tests	Outcome = IQ 1		Outcome = IQ 2	
Predictor	r	p	OR [95% CI]	p
Age	.10	.49	1.16 [0.75, 1.85]	.50

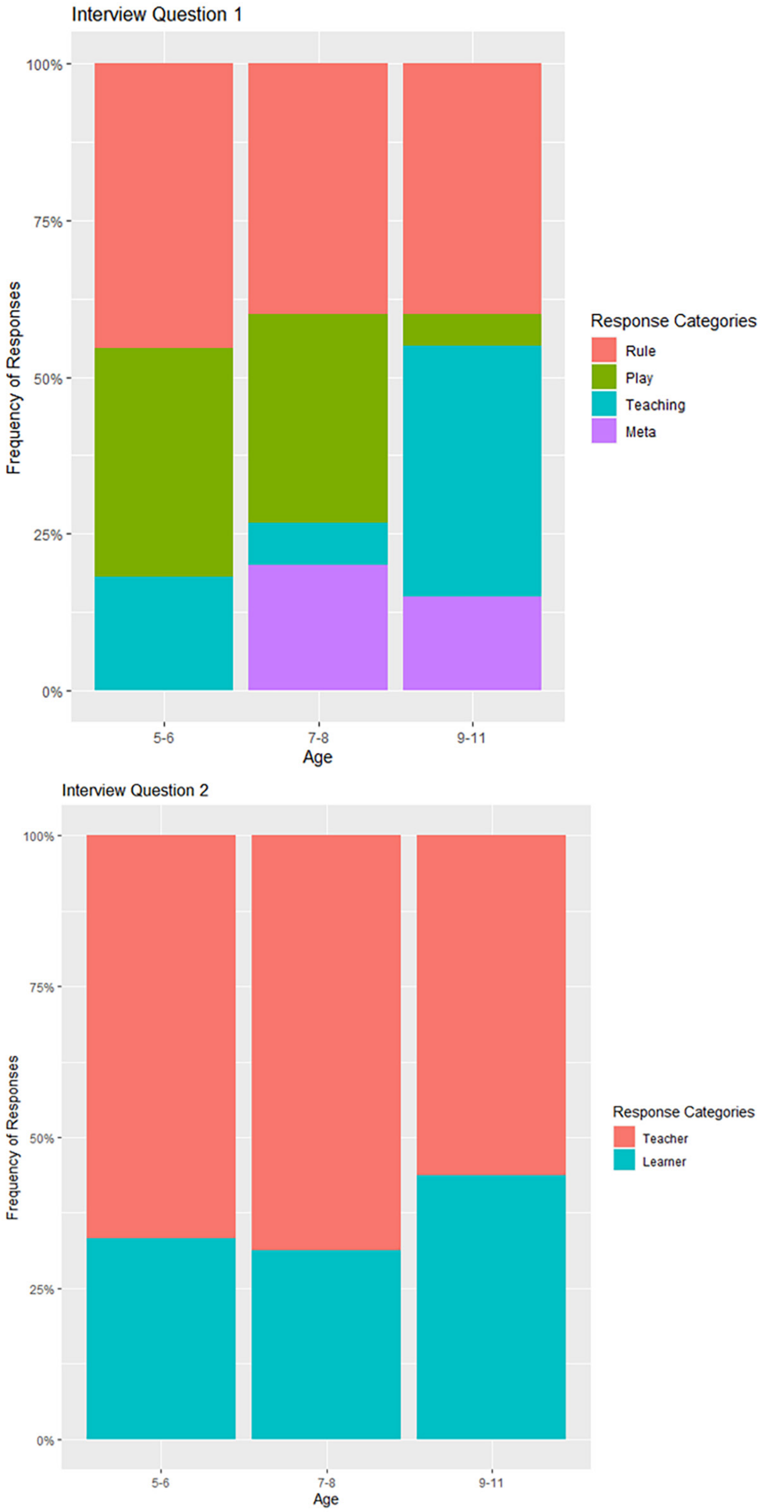

FIGURE 2 Responses to interview questions by age (Question 1: Rule = Rule description, Play = play reference, Teaching = teaching reference, Meta = metacognitive reflection, question 2: Teacher = teacher reference, Learner = learner reference).

slightly higher on question 1 (M = 2.43, SD = 1.21) than children who had used the participatory approach (M = 1.73, SD = 0.83), but the effect size was small and the difference was not significant (η^2 = .04, $\chi^2(2)$ = 3.89, p = .14, see Table 7). Children's responses to the two interview questions were not related (OR = 0.66 [0.31, 1.29], p = .24, see Table 7). Children's performance in the Theory of Mind test battery was either not related to their teaching approach and their responses to the interview questions, or correlations pointed in the opposite

TABLE 7 Relation between Children's Approach to Teaching (P = Participatory, A = Abstract, D = Demonstration) and Performance in Interview Questions (IQ 1 = Question 1, IQ 2 = Question 2, Learner = Learner Reference), and between the two Questions. Descriptive statistics, Kruskal-Wallis tests, and logistic regressions (univariate, Teacher Reference = 0, Learner Reference = 1). The reference level for the logistic regressions with teaching approach as the predictor was P (= Participatory).

	IQ 1	IQ 2	Tests						
Teaching	*M*(SD) Score	% Learner	Predictor	Outcome	OR [95% CI]	χ^2	η^2	*p*	*n*
P	1.73 (0.83)	50.0%	Teaching	IQ 1	—	3.89	.04	.14	46
A	2.43 (1.21)	31.6%	Teaching	IQ 2	A: 0.46 [0.11, 1.80]	—	—	.27	38
D	2.33 (1.53)	0.0%			D*: -	—	—	—	38
IQ 1 score									
1	—	38.5%	IQ 1	IQ 2	0.66 [0.31, 1.29]	—	—	.24	34
2	—	62.5%							
3	—	33.3%							
4	—	0.0%							

*The 95% confidence interval for this level could not be estimated.

direction of the one predicted (meaning that higher scores in Theory of Mind or mental state talk were correlated with less, not more, use of the abstract approach and lower scores in the interview questions, for details see Supplement).

DISCUSSION

Teaching strategies

In industrialized societies with high levels of formal education, the ontogeny of teaching follows a normative developmental trajectory where children's dominant strategy shifts from demonstrations to more explanations (Strauss & Ziv, 2012). Consistent with this, ni-Vanuatu children's dominant approach also changed over time, from more hands-on engagement to more verbal exposition. But the timing of this trajectory differs from previous samples. In industrialized countries, children's dominant strategy shifts to verbal explanations by the age of 5 (see Strauss et al., 2002; Strauss & Ziv, 2012). In contrast, up to age 8, most ni-Vanuatu children used a participatory approach that relied on learning-by-doing (ages 4–6: 57.1%; ages 7–8: 57.9%; ages 9–11: 36.4%). Abstract teaching with an emphasis on verbal explanations only became the dominant strategy in children aged 9 and older (ages 4–6: 28.6%; ages 7–8: 31.6%; ages 9–11: 63.6%). This suggests that the ontogeny of teaching is shaped by the socio-cultural environment with cross-cultural differences in the role of direct instruction, indicating that the pattern identified in previous studies may not necessarily translate to other samples. At the same time, the findings point to some underlying commonality: in both settings, most children eventually incorporate abstract verbal communication into their teaching, although the pacing and dosage differ depending on the social environment.

The results are consistent with observational work among hunter-gatherers and mixed-subsistence societies where exposure to formal education is either recent or limited. In these societies, caregivers often teach by involving children in everyday activities (Gaskins & Paradise, 2010; Lew-Levy et al., 2019; Paradise & Rogoff, 2009). Our results also reflect findings from a recent cross-cultural experiment where caregivers taught their child how to complete a puzzle (Clegg et al., 2021). While US caregivers used more direct active teaching and caregiver-led interaction, ni-Vanuatu caregivers relied more on collaborative learning (e.g., by dividing the task between them and the child) (Clegg et al., 2021). Finally, the findings fit with our personal observations in the field. We often observed children being taught through learning-by-doing in the home, which usually involved giving commands and verbal feedback, assigning simple chores (opportunity scaffolding), letting them participate in activities, and expecting them to observe adults.

Why, then, would children's tendency to use the more abstract approach increase with age, and why by age 9? This pattern is consistent with the idea that in societies with a slower development of Theory of Mind, children should start to favor more abstract verbal communication and shift to more metacognitive reflection at later ages. However, higher Theory of Mind scores did not correlate with greater use of abstract verbal communication in our sample (putting the findings at odds with the mentalistic account of teaching in Strauss et al., 2002; Strauss & Ziv, 2012). At the same time, our study should be taken as a first step towards more research on the ontogeny of teaching across cultures, and not as conclusive evidence against the link between abstract verbal approaches to teaching and Theory of Mind. Caution is advisable as some have expressed doubt about the cross-cultural validity of common Theory of Mind tests (for an anthropological critique see Astuti, 2015).

Another possibility is that older children were more responsive to the social context of the experiment, which took place at their primary school. In the classroom, children have many opportunities to observe direct active teaching with a strong reliance on advance verbal instruction. As a result, older children, who have more experience with schooling, might have enacted a set of behaviors associated with the kind of instruction typical of formal education. Experiments with adults and adolescents indicate that exposure to formal education can indeed shift people's teaching strategies. For example, ni-Vanuatu adults whose communities embrace schooling have been found to use more diverse teaching behaviors than those from communities without schooling (Boyette et al., 2022). Liberian students and those proficient in local scripts also provide more verbal exposition than nonliterate counterparts (Scribner & Cole, 1981). This may come down to the fact that formal education and written communication provide people with a set of techniques for framing and structuring information (Scribner & Cole, 1981).

At the same time, all children in the study had been exposed to schooling, including the younger ones, suggesting that formal education may not be the only factor explaining the observed pattern. Another possibility is that older children were more likely to emulate the type of instruction they had just observed in the experimenter. Older children may have assumed that the purpose of the task was to demonstrate that they had internalized the methods used by the experimenter, i.e., they assumed that the purpose of the task was to learn how to teach. In contrast, it might be that younger children simply taught the way they preferred, or they assumed that the purpose of the task was to just play the game, even though they had been told to teach.

Alternatively, the observed trajectory may simply be typical of societies that emphasize task assignment, pitching in, and learning-by-doing over direct instruction in everyday life. This idea is backed up by an observational study recording Maya children while they were teaching their younger siblings how to perform everyday tasks (Maynard, 2002). Children aged 3–5 used commands but not much combined teaching or verbal feedback, and no explanations (Maynard, 2002). These strategies only increased in children aged 6–7, and their use continued to increase in children aged 8–11 (Maynard, 2002).

The findings are also intriguing regarding children's use of language. The natural cognition model of teaching (see Strauss et al., 2002, 2015; Strauss & Ziv, 2012) treats the increasing involvement of language as a sign of developmental progression and has sometimes equated more verbal communication with higher teaching ability. Others have already criticized the assumption that abstract verbal communication is the best way to transmit knowledge (Kline et al., 2018). This type of instruction may be more effective in technically demanding tasks (Caldwell et al., 2017; Lombao et al., 2017; Morgan et al., 2015) and for social norms (Salali et al., 2019), but not across the board (Cataldo et al., 2018; Ohnuma et al., 1997; Putt et al., 2014). Some of the younger children talked a lot, but also repeated themselves or stated the obvious by narrating what they were doing. In contrast, children's use of abstract elaborations increased with age. This result is consistent with Ziv et al. (2016), who found that the use of short instructions declines, while the use of explanatory statements increases with age. Taken together, both studies suggest that it is the quality rather than the quantity of verbal communication that matters.

Finally, our study raises the question to what extent cultural transmission plays a role in the development of teaching. Lancy (2015a) has long argued that teaching (in the sense of formal education and frontal instruction) is not just a method of cultural transmission but is itself culturally transmitted. More broadly, Heyes (2012, 2018) has proposed that the mechanisms that enable cultural transmission are themselves socially learnt. This includes Theory of Mind (Heyes & Frith, 2014) and pedagogy (Heyes, 2016a), which refers to infants' receptivity to communicative acts from their caregivers such as ostensive eye contact and infant-directed speech; the latter can be subsumed under a broad definition of teaching (Csibra & Gergely, 2011; Heyes, 2016a). Our findings extend the work of Strauss and colleagues (Strauss et al., 2002; Strauss & Ziv, 2012) by suggesting that the ontogeny of specific teaching strategies may be shaped by social learning. One conceptual question that remains is whether cultural variability in teaching and its ontogeny emerges from shared (i.e., universal) cognitive foundations (as proposed in Strauss et al., 2015) and if so, what those are: complex Theory of Mind (as in the natural cognition model), a specifically selected cognitive system (Csibra & Gergely, 2011), or a combination of various domain-general mechanisms. Another issue that remains to be clarified is whether young children start teaching spontaneously, or whether they are socialized into it during interactions with their caregivers. One promising avenue for future investigation may be cross-cultural studies on proto-teaching in infants, which could illuminate at what age children growing up in different socio-cultural environments start to diverge from each other.

Metacognitive reflection about teaching

We also found cross-cultural differences in questions assessing children's metacognitive reflection about teaching. This was evident in the first interview question (How did you teach the game to your partner?). By the age of 5, children in industrialized countries with high levels of formal education shift from being more likely to restate the rules of the game to being more likely to describe how they communicated with their partner and comment on the transmission process (see Strauss et al., 2002; Strauss & Ziv, 2012). In contrast, among ni-Vanuatu children, restating the rules of the game was common in all age groups (ages 5–6: 45.5%; ages 7–8: 40.0%; ages 9–11: 40.0%). Up to age 8, some children also used play references, although these were less frequent than rule descriptions (ages 5–6: 36.4%; ages 7–8: 33.3%; ages 9–11: 5.0%). Metacognitive references were rare in all age groups (ages 5–6: 0.0%; ages 7–8: 20.0%; ages 9–11: 15.0%) and communication terms only increased from age 9 onwards (ages 5–6: 18.2%; ages 7–8: 6.7%; ages 9–11: 40.0%). Differences were also evident in the second interview question (How do you know that your partner learnt the game?). By the age of 5, children in industrialized countries with high levels of formal education shift from being more likely to treat their own teaching as evidence that learning occurred to being more likely to draw on the learner's actual behavior (see Strauss et al., 2002; Strauss & Ziv, 2012). In contrast, most ni-Vanuatu children referred to their own teaching as evidence that learning occurred, and this applied to all ages (ages 5–6: 66.7%; ages 7–8: 68.8%; ages 9–11: 56.2%). This is consistent with the idea that cultural learning shapes people's metacognitive reasoning about teaching (Heyes, 2016b).

The fact that children used play references with some frequency up to age 8 but communication terms became more common after age 9 might reflect younger children's emphasis on participatory teaching. But cultural discourses about knowledge, teaching, and authority may also account for children's responses to the interview questions. An ethnographic account of local conceptions of knowledge on Tanna, Vanuatu, suggests that from a ni-Vanuatu perspective, people can own, exchange, and consume knowledge in much the same way as material possessions (Lindstrom, 1990). Knowledge is viewed as an external reality that is revealed and passed down, rather than being created in individual minds (Lindstrom, 1990). Knowledge is created through "practices that promote the transmission of a knowledge statement from authority to spokesman" (Lindstrom, 1990, p. 83). These authorities (ancestors, elders, or God) inspire people through dreams and rituals (Lindstrom, 1990). This ethno-theory of culture learning emphasizes the 'osmotic' absorption from authorities: "Learners watch and listen to teachers instead of actively questioning. […] Students learn, instead, by unquestioningly and repetitively imitating others" (Lindstrom, 1990, p. 45). In this model, the learner's "processes of knowing are [represented as] sensual and passive, rather than reflective or interactive" (Lindstrom, 1990, p. 45). However, according to the ethnographer, this is a "discursive condition" (Lindstrom, 1990, p. 72)—a way of conceptualizing, speaking about, and legitimating knowledge—rather than a genuine cognitive difference (Lindstrom, 1990): in practice, ni-Vanuatu learners obviously question and reflect on what they see and hear.

In the first interview question (How did you teach the game?), children may have emphasized the game rules (rather than their communication strategies) to demonstrate that they had absorbed the knowledge content they were tasked with transmitting. Children may have viewed this knowledge content as an external reality that people can possess, exchange, and circulate, and that exists independently of individual communicative acts. In the second interview question (How do you know that they learnt the game?), children may have emphasized their own teaching (rather than the learner's behavior) to emphasize their role as a source in the transmission process, reflecting the notion that knowledge circulates through osmosis. Accordingly, the fact that ni-Vanuatu children's responses diverged from those of previous samples is probably not caused by some difference in degree of metacognitive reflection. Rather, people use metacognitive reasoning to form different ethno-theories of teaching in different cultural contexts.

Limitations and future directions

The experimental approach this study is based on (i.e., Strauss et al., 2002) has ecological limitations. At the field site, children have access to some Western toys and games, but board games are not common. As a result, we would expect them to have more difficulty understanding the rules than participants in previous studies, many of whom have encountered board games either in their homes or in a childcare setting. But while the initial understanding of the task was lower in younger children, this cannot explain the whole pattern. Notably, children aged 7–8 still preferred the participatory approach over the more abstract, front-loaded one even though they outperformed younger children in the rule checks. A related limitation concerns the fact that we simplified the game rules, which may have reduced the need for abstract elaborations. This may limit the comparability of our results with previous tests conducted in other populations. Finally, the protocol we followed embeds school-like forms of instruction in the experiment (by explaining the game rules and then quizzing the children about them, see Methods); this is exacerbated by the fact that the experiment took place at school and was performed by a staff member, followed by a directive to teach a classmate. This creates a mismatch of sorts between the experimental protocol and how children are taught in their home environment. In the absence of these school-like instructions, when tested in a different setting, or when taught in ways that match local forms of knowledge transmission, the results may have been different. For example, without this inadvertent priming, the older children who emphasized abstract verbal communication may have opted for a more participatory approach instead.

Future studies should address these issues by using different activities in the peer teaching task. Of particular interest are local skills and activities that children have observed in their home environment. Developmental researchers could also investigate whether different experimental set-ups (such as removing the elements of the familiarization phase that resemble school-like instruction or testing participants at a different venue) influence children's teaching, and thus examine directly whether children copy the kinds of teaching they observe. More broadly, future research should examine whether the trajectory identified in ni-Vanuatu and Maya children (Maynard, 2002) translates to other societies where informal and collaborative learning is common. Of particular interest are societies where children have no access to schooling at all, and whether in those locations participatory and demonstration-focused approaches to teaching persist at older ages. Experimental work should also explore metacognitive reflection about teaching in ni-Vanuatu adults (such as how they reason about whether learning occurred) and whether it matches our findings.

Finally, our findings speak to the conceptual issues we have touched on at the beginning of the paper (see Background). Based on our own experiences, we encourage researchers to reflect on the way they conceptualize teaching when working with underrepresented populations. Different definitions can lead to different conclusions when interpreting results: if we were to apply a schooling-focused definition, we would conclude that teaching itself emerges comparatively late in our sample. Conversely, under the broader definition we have used here, we conclude that a specific *type* of teaching emerges later, with other types predominating in the sample. While we do not suggest that researchers must endorse any particular definition, we do encourage researchers to examine how their preferred framings compare to those used in other disciplines and how this affects the way they present their results. Finally, we encourage researchers to bring their own notions of teaching in dialogue with the way local people at their field site conceptualize teaching; ideally, this should be done by incorporating qualitative ethnographic methods (such as in-depth interviews and participant observation) into their projects.

ACKNOWLEDGMENTS

We thank the communities that participated in the project and all staff at Hog Harbor Primary School and Kindergarten, including the principal, the chairman of the school board, and the teachers. Special thanks go to John Toc for his contribution as experimenter as well as Nellie Niala for her feedback on the translation. We further thank Daniel Symons for assisting with data coding and Henlyn Mala from the Vanuatu Cultural Centre for helping with the research permit. Finally, we thank two anonymous reviewers for their helpful comments on our manuscript.

FUNDING INFORMATION

This work was supported by a doctoral grant from the German Academic Scholarship Foundation (Studienstiftung des Deutschen Volkes, Ahrstraße 41, 53,175 Bonn, Germany) to Eva Brandl.

CONFLICT OF INTEREST STATEMENT

None to declare.

DATA AVAILABILITY STATEMENT

The materials necessary for an attempt replicate our study are publicly available on OSF: https://osf.io/w8eam/. The data and code necessary to reproduce our analyses are available from the first author upon request. The analyses presented here were not preregistered.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Brandl, E., Emmott, E. H., & Mace, R. (2023). Development of teaching in ni-Vanuatu children. *Child Development*, *00*, 1–17. https://doi.org/10.1111/cdev.13946