DOI: 10.1111/cdep.12451

ARTICLE

Child Development Perspectives

After a decade of tool innovation, what comes next?

Bruce S. Rawlings

Department of Psychology, Durham University, Durham, UK

Correspondence
Bruce S. Rawlings, Department of Psychology, Durham University, Upper Mountjoy, South Road, Durham DH1 3LE, UK.
Email: bruce.rawlings@durham.ac.uk

Abstract

A decade ago, now-seminal work showed that children are strikingly unskilled at simple tool innovation. Since then, a surge of research has replicated these findings across diverse cultures, which has stimulated evocative yet unanswered questions. Humans are celebrated among the animal kingdom for our proclivity to create and use tools and have the most complex and diverse technology on earth. Our capacity for tool use has altered our ecological environments irrevocably. How can we achieve so much, yet tool innovation be such a difficult and late-developing skill for children? In this article, I briefly summarize what we know about the development of tool innovation, then discuss five outstanding questions in the field. With a focus on different empirical and theoretical perspectives, I argue that addressing these questions is crucial for understanding fully the ontogeny of one of humans' most notable skills.

KEYWORDS
children, creativity, tool innovation

INTRODUCTION

The study of tool innovation—broadly defined as designing new tools or using old tools in novel ways to solve new problems—has accelerated rapidly over the past decade, almost exclusively in developmental research. Since the seminal findings of Beck and colleagues (Beck et al., 2011) that young working- and middle-class children in the United Kingdom were strikingly unskilled at tool innovation, a wave of research has explored the ontogeny of this skill. Studies reporting that children from geographically diverse cultures find seemingly simple tool-based problem-solving tasks difficult have stimulated evocative questions. Humans are capable of extraordinarily complex technology, including gene mapping, self-driving spacecraft, and augmented reality. How can we achieve so much and be renowned in the animal kingdom for our ability to create and use tools, yet simple tool innovation be such a difficult and late-developing skill? In contrast, how can young children easily master other sophisticated behaviors, such as using smartphones, being multilingual, and understanding complex social norms? After a decade of research, what comes next for the study of children's tool innovation? In this article, I briefly synthesize what we know about the development of tool innovation, then describe five outstanding questions in the field. Combining theory and data, I argue that addressing these questions is crucial to understanding fully the ontogeny of one of humans' most defining skills.

WHAT DO WE KNOW ABOUT THE DEVELOPMENT OF TOOL INNOVATION?

It is now well-documented that young children find tool-innovation challenges remarkably difficult to solve. About a decade ago, a task famously solved by Betty the crow (Weir et al., 2002) was adapted for children, who were presented with a transparent tube containing a

Abbreviation: WEIRD western, educated, industrialized, rich, democratic.

bucket alongside a pipe cleaner (now typically termed the hook task). Inside the bucket was a reward, and children were required to create a hook shape from the pipe cleaner to fish the bucket from the tube and retrieve the reward (Beck et al., 2011). The results were unexpected: In studies of working- and middle-class U.K. children, fewer than a tenth of those under age 5 made a hook, only about half of 7- to 8-year-olds succeeded in fishing the bucket from the tube, and almost a third of 11-year-olds failed. Yet most children who watched a successful demonstration solved the task, indicating that a lack of dexterity or tool-making abilities could not explain the low success rates.

These findings spurred numerous empirical studies, reviews, and special issues over the subsequent decade. Although detailed reviews have been published elsewhere, briefly, hook task results have been widely replicated, including across diverse cultures (Neldner et al., 2017, 2019; Rawlings & Legare, 2021). Performance improves with age, but a nontrivial proportion of 11-year-olds still fails to fashion a pipe cleaner into a hook shape. Children's tool-innovation struggles go beyond the hook task. In other tasks administered in studies of Western populations, children have needed to form a loop from a piece of wooden wool to pull an out-of-reach platform (Tennie et al., 2009), pour water into a tube to bring a toy into reach (Ebel et al., 2019), and unbend pipe cleaners to push a ball from a horizontal tube (Cutting et al., 2011). Results remain consistent: Young children have low success across tasks.

Although this work has provided rich information on the ontogeny of tool innovation and factors that promote or inhibit its expression, many questions remain, and we have much to learn. Next, I describe five outstanding questions that are crucial to progress in the field. For each, I integrate data and theory to explain why they are important to study, what we know about them, and what researchers should continue studying.

WHY DO CHILDREN FIND TOOL INNOVATION SO DIFFICULT?

A significant body of work has aimed at understanding why children struggle so much on tasks on which crows readily succeed (Rutz et al., 2016). Some studies have examined the conceptual nature of tool innovation. For example, researchers have proposed that tasks like the hook task represent an ill-structured problem. Ill-structured problems are those in which information is absent from the start state, end (goal) state, or regarding how to get between the two (Cutting et al., 2014). Children may find coordinating knowledge to solve ill-structured problems difficult and find well-structured problems comparatively simpler to solve. When 3- to 7-year-old working- and middle-class U.K. children were presented with the hook task but asked to choose between a straight and a hook-shaped pipe cleaner, 80% selected the appropriate tool (Beck et al., 2011). Thus, most tool innovation challenges may present an ill-structured problem that children find problematic (Cutting et al., 2011, 2014). However, the concept and developmental trajectory of ill-structured problem solving is not well understood, and more research is needed to investigate how it develops and why children find it difficult, so we understand its contribution to tool innovation more thoroughly.

Relatedly, some have also suggested that tool innovation is a particularly cognitively demanding task, requiring coordination of multiple high-level cognitive processes, including problem solving, causal reasoning, planning, creativity, and executive functions (Rawlings & Legare, 2021). Tool innovation likely taxes these types of processes. Making tools involves planning and causal reasoning, while implementing appropriate strategies ostensibly requires executive functions for inhibiting or switching from inappropriate strategies (Rawlings & Legare, 2021). The maturation of many of these processes coincides with age-related improvements in tool innovation, suggesting they are important to performance. However, the relation between these cognitive processes and tool innovation also appears to be nuanced; one study found no link between executive function performance and tool innovation in working- and middle-class U.K. children (Beck et al., 2016), though the small sample means these findings need to be validated. Additionally, by early childhood, typically developing children outperform crows and apes on many measures of these cognitive processes (Rosati, 2017), yet apes seem to at least match or outperform children on tool innovation tasks (Laumer et al., 2018; Rutz et al., 2016). Again, further comparative work is needed with larger samples and more diverse tasks, particularly since hook making may be part of crows' natural behavioral repertoire.

Other contributing factors may include children's prior experiences and their preference for solving problems by observing others rather than through individual innovation. Regarding the former, children suffer from functional fixedness—the inability to use tools for purposes other than their original use (German & Defeyter, 2000)—and may therefore struggle to envisage using a pipe cleaner as a hook. When working- and middle-class, predominantly White U.K. children were shown a hooked pipe cleaner prior to testing (Whalley et al., 2017), or were allowed to explore materials as well as observe a ready-made hook (Cutting et al., 2014), their performance improved significantly.

Infants also show fixedness in tool use (without needing to modify them): Middle-class, predominantly White U.S. 12- to 18-month-olds found it difficult to use the handle end of a spoon to illuminate a lightbox, but when the tool was novel (but still spoon shaped), they showed more flexibility (Barrett et al., 2007), suggesting that flexibly using novel tools may be easier than using familiar ones. Regarding the latter, if offered the choice of solving novel problems themselves (through innovation) or watching demonstrations first, most working- and middle-class, predominantly White U.K. children chose the demonstrations (Flynn et al., 2016; Rawlings, Flynn, et al., 2021). Those who chose to solve tasks themselves showed greater tool innovation than those who chose to observe demonstrations (Rawlings, Flynn, et al., 2021). This proclivity for observing others over innovating solutions may impede opportunities for acquiring innovative skills (Rawlings, Flynn, et al., 2021).

Thus, although several explanations have been proposed, no widely accepted explanation addresses why children struggle with tool innovation. A combination of these and other factors probably contribute. Children likely approach tool innovation challenges with vastly different prior experiences, frames of reference, and cognitive biases than other animals, which may explain why they require the development and coordination of multiple sophisticated cognitive mechanisms. Children's strong preference for social information may underpin humans' rich cultural diversity, but it may also depress opportunities to acquire innovative skills. Researchers could empirically assess these theories individually and in unison.

For example, do children who solve ill-structured problems in other domains also do so in tool innovation contexts (see Beck et al., 2016, for tentative evidence suggesting no relation between rule-based ill-structured problem-solving and hook task performance in middle- and working-class U.K. children)? What is the relation between executive functions and ill-structured problem solving or functional fixedness? Are tasks such as the hook task so challenging because they require convergent thinking (generating single, correct solutions) rather than divergent thinking (generating multiple, diverse solutions), or non-goal-directed discovery, at which children are comparatively skilled (Bateson & Martin, 2013)? Do experimental conditions constrain innovation? Would performance be enhanced if adults, from whom children may be reluctant to deviate, were not present, or if materials children frequently modify (e.g., Play-Doh) were presented instead?

Another conceptual issue that could preclude a complete understanding of children's tool innovation is that the widely used definition of tool innovation—designing new tools or using old tools in novel ways to solve new problems—may theoretically reflect two separate skills (*designing new tools* vs. *using old tools in novel ways*). This raises two related questions: Do these behaviors have distinct or overlapping developmental trajectories? How generalizable are tasks such as the hook task for broad definitions of tool innovation? Most tasks used in research on tool innovation (e.g., reshaping pipe cleaners, forming a loop from wooden wool) involve using old tools in novel ways, especially in postindustrialized populations where young children are exposed to items such as pipe cleaners in the context of arts and crafts at child care and preschool (Lew-Levy et al., 2021). We need more studies comparing children's performance on designing new tools to using old tools in novel ways to establish whether they show similar developmental trajectories.

Relatedly, researchers could also develop more varied measures of tool innovation. While other tasks have been used, the field undoubtedly has overrelied on the hook task, in no small part because it is easy to use, captures variation in performance across the entire childhood period, and allows comparison with nonhuman animals. These factors notwithstanding, the field would benefit from developing more tasks requiring actions other than reshaping tools to assess different forms of tool innovation and their developmental trajectories (see Neldner et al., 2019, for an example of tasks requiring adding and subtracting tools from one another).

WHAT IS THE NATURE OF CROSS-CULTURAL CONSISTENCY AND VARIATIONS IN THE DEVELOPMENT OF TOOL INNOVATION?

Coincidentally, around the same time as the seminal findings of Beck and colleagues on children's struggles with tool innovation, researchers recommended that psychologists diversify the populations studied beyond western, educated, industrialized, rich, democratic (WEIRD) countries (Henrich et al., 2010). Since then, the pace of cross-cultural psychological research has accelerated and the study of tool innovation is no exception: The hook task has now been administered in more than a dozen countries, including at least five non-WEIRD nations. These studies consistently report low success rates in children and consequently, researchers often claim that children are universally unskilled tool innovators.

The replication of hook task performance across populations suggests the robustness of the finding. However, several key gaps in the literature remain. First, most experimental studies outside western contexts have focused on young children, typically under 6 years (but see Lew-Levy et al., 2021; Neldner et al., 2019). We know little about the developmental trajectory of tool innovation across diverse populations over the entire childhood period. Some research suggests cultural variation in innovation propensities beyond early childhood and the norms surrounding innovation. For example, older working- and middle-class, predominantly White U.K. children were more likely to choose to solve tool-use problems themselves rather than observe demonstrations first, and to deviate from adult demonstrations, than were younger children (Carr et al., 2015; Rawlings, Flynn, et al., 2021). Conversely, older children and adolescents living in Pune, West India, copied others (particularly adults) frequently when solving simple tasks (Molleman et al., 2019). In ethnographic data from both the Aka of southwestern Central African Republic and the northeastern part of the Republic of Congo, and the Chabu of the Oromo, Southern Nations Nationalities and Peoples Region, and Gambela regions in southwestern Ethiopia, similarly aged children actively sought to learn knowledge and skills by observing innovative adults (Hewlett, 2021). In other work, adults' attitudes towards children's conformity have varied culturally: Ni-Vanuatu adults from Tanna, Tafea Province, endorsed children's conformity positively, whereas middle-class U.S. adults in Texas praised innovative behaviors more (Clegg et al., 2017).

Second, most experimental studies on tool innovation in non-Western populations have involved either the hook task or slight variations of it. While replicating findings is very useful, researchers have raised valid concerns about the construct validity of using tasks designed and verified in Western populations in non-Western ones (Hruschka et al., 2018). In some studies, children from non-Western populations have had significantly lower success rates than children from Western populations (Lew-Levy et al., 2021; Neldner et al., 2019). This may reflect population differences in tool innovation abilities, but it may also suggest unfamiliarity with task materials (such as pipe cleaners) or experimental conditions. The performance of children who are presented with materials or contexts familiar to their own culture may differ (Lew-Levy et al., 2020), which would help address questions about potential differences between designing new tools and using old tools in novel ways; this is because in populations with no exposure to pipe cleaners, children presented with this tool would see it as a new tool.

In one study, BaYaka forager and Bondongo fisher-farmer 4- to 12-year-olds in the Likouala region of the Republic of Congo were given pipe cleaners 2 weeks before the hook task. While task success rates were low, the children reshaped the pipe cleaners to make decorative ornaments such as necklaces and bracelets, indicating that they may not have understood the parameters of the task (Lew-Levy et al., 2021). Research in other areas of cross-cultural psychology is beginning to address the concept of construct validity, recommending that tasks should be extensively piloted and, if required, modified, to maximize ecological and construct validity (Hruschka et al., 2018). This type of progress is needed in research on tool innovation.

Finally, cross-cultural research on children's tool innovation remains largely descriptive, with studies generally reporting or comparing success rates. More work is needed to examine the predictors of success. What sociocultural variables affect the development of tool innovation? Does the socialization of tool use predict performance? To what extent is tool-based functional fixedness found across cultures? Answering questions such as these is vital to understand how culture shapes the development of tool innovation.

ARE ADOLESCENTS AND ADULTS ALSO UNSKILLED TOOL INNOVATORS?

Largely because psychologists' interest in tool innovation was piqued by comparative research, which tends to focus on comparing animals to human children (which itself may be a problematic approach; see Rawlings, Legare, et al., 2021), few studies have examined tool innovation beyond childhood. We know little about if, and how, it continues to improve into adolescence and adulthood, which in many cultures may be periods when tools are used more frequently (Hewlett, 2021).

The reasons to suspect that tool innovation improves linearly until adulthood are obvious. As noted, children's success on tool innovation tasks improves with age and adults perform at ceiling levels on the hook task (Beck et al., 2011). Many cognitive processes develop into adolescence and beyond, including ones theorized to be important to tool innovation (Rawlings & Legare, 2021). Likewise, the prefrontal cortex, which is associated with tool use (Johnson-Frey, 2004), continues to mature until around 25 years (Arain et al., 2013).

Yet linear improvement until adulthood may not be a straightforward conclusion. First, the hook task is unlikely to be an appropriate task for adults. Indeed, adults often struggle at insight-based problem-solving tasks, including those with tools. This is perhaps most famously illustrated by Duncker's candle problem, in which participants were presented with a matchbox, a box of thumb tacks, and a candle, and were tasked with mounting the candle on a corkboard. About 75% of middle-class U.S. adults failed, unable to use the matchbox and thumbtacks as tools (Fleck & Weisberg, 2004). Tool innovation tasks that are appropriate for adolescents and adults should be developed to assess the extent to which these skills continue to improve beyond childhood and which cognitive processes underpin this development.

Second, changes in personality across the lifespan may also suggest that we become less innovative as we age. Across cultures, humans' openness to experience rises until around the late teenage years and early 20s but declines thereafter across adulthood (Costa et al., 2019). Openness to experience denotes being inventive, curious, and exploratory, and it is strongly linked with innovation and creativity in Western children and adults (Baer, 2010; Rawlings, Flynn, et al., 2021). Conversely, humans' agreeableness rises over the lifespan; this encompasses being kind, trusting, and prosocial, and is negatively associated with innovation (Rawlings, Flynn, et al., 2021). Therefore, personality changes may lessen innovative capacity as we age, and researchers should assess how such changes interact with innovative abilities.

IS INNOVATION CONSISTENT ACROSS DOMAINS?

Childhood is characterized by play, exploration, and new experiences. While children are unskilled tool innovators, they are capable of impressive creativity and innovation during activities such as play and storytelling (Bateson & Martin, 2013). Are children who are innovative in one domain innovative in others? Whether skills such as creativity, which involves *generating* new, useful ideas, and innovation, which involves *implementing* new, useful ideas, are domain specific or general remains a controversial question (Qian et al., 2019), yet answering it is crucial to understanding what underpins individual differences in tool innovation performance.

Research on the domain generality or specificity of innovation remains scarce and equivocal. Some evidence indicates that children are consistent across domains. In one study, the performance of working- and middle-class, predominantly White U.K. children was consistent across several measures of tool innovation and creativity (Rawlings, Flynn, et al., 2021). In another study, middle-class, predominantly White U.S. 2-year-olds were consistent in their propensity to deviate from observations in tool- and nontool-use tasks (Yu & Kushnir, 2020), and in yet another, middle-class, predominantly White U.S. 4- and 5-year-olds who engaged in elaborate role play were more innovative in storytelling and drawing contexts than children who engaged in less or no elaborate role play (Mottweiler & Taylor, 2014). Yet other research, of U.S. 7- and 8-year-olds, suggests that innovation and creativity are domain specific, reporting weak correlations between creative performance on measures such as divergent thinking, storytelling, writing poems, making collages, and mathematical problem solving (Baer, 1994).

Therefore, researchers should assess whether children are innovative across diverse domains. Several questions warrant exploration: Are children who succeed as tool innovators also inventive storytellers? Is social innovation—influencing others to help oneself achieve goals—related to tool innovation? To what extent are cognitive processes involved in innovation across domains? Can research determine why children are comparatively skilled at divergent thinking, storytelling, and creative free play, yet struggle on tasks requiring convergent thinking, such as the hook task? Can we develop new measures of tool innovation to assess its generalizability across tasks? Such studies will improve our understanding of whether children are innovative across time, tasks, and contexts, as well as the mechanisms underpinning different types of innovation, and will build on research to further understand the relation between creativity and innovation over development.

DOES FORMAL EDUCATION AFFECT INNOVATION?

In its 2020 *Workplace Learning Report*, LinkedIn, the global employment company, surveyed professionals in 18 countries, finding that creativity was employees' most desired soft skill (LinkedIn, 2020). Surveys such as these highlight the increasing demand for innovative and creative skills as valuable economic resources and have motivated global research and educational initiatives exploring whether these skills can be taught in formal education settings (Qian et al., 2019). The impact of formal education on creativity and innovation remains a debated topic. Some argue that the focus of most educational institutions on norm following, rote learning, and standardized teaching and assessments inhibits creative and innovative expression (Goens & Streifer, 2013). Others contend that the experiences afforded by schools, such as wider social interaction, collaboration, and exposure to novel information, promote these skills (Sahlberg, 2009).

To my knowledge, no study has directly assessed the impact of formal education on innovation. However, indirect evidence suggests that exposure to and the quality of formal education may be influential. In one study, 8- to 18-year-olds from the Tsimane population of Amazonian Bolivia who attended high-quality schools outperformed children of the same age and region who went to low-quality schools on abstract reasoning and problem-solving tasks; also, the performance of the children who went to high-quality schools improved significantly more over time (Davis et al., 2021). In developmental studies and research with adults, richer and more diverse social experiences (which attending school presumably promotes) facilitate innovation (Baer et al., 2015; Rawlings, 2018). However, proponents of informal education correctly highlight the cognitive and social benefits of learning outside of school contexts (Sefton-Green, 2012), including how such learning relates to divergent thinking (Dahlman et al., 2013).

These findings are indirect observations, and it is difficult to draw strong conclusions about the relation between formal education and innovation without direct assessments. Given the importance of innovation as a major skill of the 21st century, whether schools can foster the next generation of innovative minds is a topic of global interest. Researchers should examine if and how school curricula, attendance, and academic achievement shape innovation. Even within formal educational settings, approaches to education vary, and work is needed to examine whether specific educational philosophies or activities (e.g., engaging in innovative problem solving, peer collaboration) promote innovation, and whether others (e.g., rote learning, standardized assessments) hinder it. Many schools promote convergent problem solving, focusing on single, correct solutions (e.g., in mathematical problem solving);

how does this affect tool innovation? Does informal education shape innovation and if so, how? The globalization of formal education provides a unique and time-sensitive opportunity to document the impact of formal and informal education on the next generation of innovators.

CONCLUSION

Humans' proclivity to make and use tools is one of our most distinguished skills, allowing us to survive and prosper in diverse and harsh environments. Particularly puzzling, then, is that tool innovation is such a difficult and late-developing skill. Although the field has made significant progress over the past decade, many outstanding questions remain, and using theoretically derived empirical research to answer them will allow us to make significant strides in our understanding of the development of tool innovation. However, doing so will require rigorous planning, and addressing each question posed here presents unique challenges.

Understanding why tool innovation is so difficult for children calls for disentangling the contributions of cognitive, social, and environmental factors through carefully designed experiments. It also requires introspection about the definitions and methods we currently use to assess tool innovation. Conducting cross-cultural work requires striking a balance between control and generalizability across populations, versus implementing culturally appropriate tool innovation measures, to draw fair comparative conclusions.

This is a difficult endeavor that can only be tackled by extensive piloting alongside collaboration with local researchers and community members. Understanding the trajectory of tool innovation abilities beyond childhood necessitates designing tasks and paradigms that ostensibly capture the same skills and processes in children, adolescents, and adults—a feat the field has yet to achieve. Studying how tool innovation transfers across domains will involve establishing a variety of appropriate measures of innovation and creativity, ideally with longitudinal data to document consistency over time. Finally, examining the association between formal education and innovative skills requires collating measures of school quality and educational philosophy, which vary meaningfully across samples as well as within and across nations. If these challenges are overcome, the field will move forward in a way not before seen.

ORCID

Bruce S. Rawlings https://orcid.org/0000-0001-9682-9216

REFERENCES

Arain, M., Haque, M., Johal, L., Mathur, P., Nel, W., Rais, A., Sandhu, R., & Sharma, S. (2013). Maturation of the adolescent brain. *Neuropsychiatric Disease and Treatment*, *9*, 449–461. https://doi.org/10.2147/NDT.S39776

Baer, J. (1994). Divergent thinking is not a general trait: A multidomain training experiment. *Creativity Research Journal*, *7*(1), 35–46. https://doi.org/10.1080/10400419409534507

Baer, M. (2010). The strength-of-weak-ties perspective on creativity: A comprehensive examination and extension. *The Journal of Applied Psychology*, *95*(3), 592–601. https://doi.org/10.1037/a0018761

Baer, M., Evans, K., Oldham, G. R., & Boasso, A. (2015). The social network side of individual innovation: A meta-analysis and path-analytic integration. *Organizational Psychology Review*, *5*(3), 1–33. https://doi.org/10.1177/2041386614564105

Barrett, T. M., Davis, E. F., & Needham, A. (2007). Learning about tools in infancy. *Developmental Psychology*, *43*(2), 352–368. https://doi.org/10.1037/0012-1649.43.2.352

Bateson, P., & Martin, P. (2013). *Play, playfulness, creativity and innovation*. Cambridge University Press.

Beck, S. R., Apperly, I. A., Chappell, J., Guthrie, C., & Cutting, N. (2011). Making tools isn't child's play. *Cognition*, *119*(2), 301–306. https://doi.org/10.1016/j.cognition.2011.01.003

Beck, S. R., Williams, C., Cutting, N., Apperly, I. A., & Chappell, J. (2016). Individual differences in children's innovative problem-solving are not predicted by divergent thinking or executive functions. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *371*(1690), 20150190. https://doi.org/10.1098/rstb.2015.0190

Carr, K., Kendal, R., & Flynn, E. (2015). Imitate or innovate? Children's innovation is influenced by the efficacy of observed behaviour. *Cognition*, *142*(September), 322–332. https://doi.org/10.1016/j.cognition.2015.05.005

Clegg, J. M., Wen, N. J., & Legare, C. H. (2017). Is non-conformity WEIRD? Cultural variation in adults' beliefs about children's competency and conformity. *Journal of Experimental Psychology: General*, *146*(3), 428–441. https://doi.org/10.1037/xge0000275

Costa, P. T., McCrae, R. R., & Löckenhoff, C. E. (2019). Personality across the life span. *Annual Review of Psychology*, *70*(1), 423–448. https://doi.org/10.1146/annurev-psych-010418-103244

Cutting, N., Apperly, I. A., & Beck, S. R. (2011). Why do children lack the flexibility to innovate tools? *Journal of Experimental Child Psychology*, *109*(4), 497–511. https://doi.org/10.1016/j.jecp.2011.02.012

Cutting, N., Apperly, I. A., Chappell, J., & Beck, S. R. (2014). The puzzling difficulty of tool innovation: Why can't children piece their knowledge together? *Journal of Experimental Child Psychology*, *125*(September), 110–117. https://doi.org/10.1016/j.jecp.2013.11.010

Dahlman, S., Bäckström, P., Bohlin, G., & Frans, Ö. (2013). Cognitive abilities of street children: Low-SES Bolivian boys with and without experience of living in the street. *Child Neuropsychology*, *19*(5), 540–556. https://doi.org/10.1080/09297049.2012.731499

Davis, H. E., Stieglitz, J., Kaplan, H., & Gurven, M. (2021). School quality augments differences in children's abstract reasoning, driving educational inequalities. Evidence from a naturally occurring quasi-experiment in Amazonia, Bolivia. *PsyArXiv*. https://doi.org/10.31234/OSF.IO/D3SGQ

Ebel, S. J., Hanus, D., & Call, J. (2019). How prior experience and task presentation modulate innovation in 6-year-old-children. *Journal of Experimental Child Psychology*, *180*(April), 87–103. https://doi.org/10.1016/j.jecp.2018.12.004

Fleck, J. I., & Weisberg, R. W. (2004). The use of verbal protocols as data: An analysis of insight in the candle problem. *Memory and Cognition*, *32*(6), 990–1006. https://doi.org/10.3758/BF03196876

Flynn, E., Turner, C., & Giraldeau, L. A. (2016). Selectivity in social and asocial learning: Investigating the prevalence, effect and development of young children's learning preferences. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *371*(1690), 688–699. https://doi.org/10.1098/rstb.2015.0189

German, T. P., & Defeyter, M. A. (2000). Immunity to functional fixedness in young children. *Psychonomic Bulletin & Review*, *7*(4), 707–712. https://doi.org/10.3758/BF03213010

Goens, G., & Streifer, P. (2013). *Straitjacket: How overregulation stifles creativity and innovation in education*. R&L Education.

Henrich, J., Heine, S. J., & Norenzayan, A. (2010). The weirdest people in the world? *Behavioral and Brain Sciences*, *33*(2–3), 61–83. https://doi.org/10.1017/S0140525X0999152X

Hewlett, B. (2021). Social learning and innovation in adolescence. *Human Nature*, *32*, 239–278. https://doi.org/10.1007/s12110-021-09391-y

Hruschka, D. J., Munira, S., Jesmin, K., Hackman, J., & Tiokhin, L. (2018). Learning from failures of protocol in cross-cultural research. *Proceedings of the National Academy of Sciences of the United States of America*, *115*(45), 11428–11434. https://doi.org/10.1073/pnas.1721166115

Johnson-Frey, S. H. (2004). The neural bases of complex tool use in humans. *Trends in Cognitive Sciences*, *8*(2), 71–78. https://doi.org/10.1016/j.tics.2003.12.002

Laumer, I. B., Call, J., Bugnyar, T., & Auersperg, A. M. I. (2018). Spontaneous innovation of hook-bending and unbending in orangutans (*Pongo abelii*). *Scientific Reports*, *8*(1), 16518. https://doi.org/10.1038/s41598-018-34607-0

Lew-Levy, S., Milks, A., Lavi, N., Pope, S. M., & Friesem, D. E. (2020). Where innovations flourish: An ethnographic and archaeological overview of hunter-gatherer learning contexts. *Evolutionary Human Sciences*, *2*, E31. https://doi.org/10.1017/ehs.2020.35

Lew-Levy, S., Pope, S. M., Haun, D. B. M., Kline, M. A., & Broesch, T. (2021). Out of the empirical box: A mixed-methods study of tool innovation among Congolese BaYaka forager and Bondongo fisher-farmer children. *Journal of Experimental Child Psychology*, *211*(November), 105223. https://doi.org/10.1016/J.JECP.2021.105223

LinkedIn. (2020). *4th Annual 2020 workplace learning report*. https://learning.linkedin.com/content/dam/me/learning/resources/pdfs/LinkedIn-Learning-2020-Workplace-Learning-Report.pdf

Molleman, L., Kanngiesser, P., & van den Bos, W. (2019). Social information use in adolescents: The impact of adults, peers and household composition. *PLoS One*, *14*(11), e0225498. https://doi.org/10.1371/JOURNAL.PONE.0225498

Mottweiler, C. M., & Taylor, M. (2014). Elaborated role play and creativity in preschool age children. *Psychology of Aesthetics, Creativity, and the Arts*, *8*(3), 277–286. https://doi.org/10.1037/A0036083

Neldner, K., Mushin, I., & Nielsen, M. (2017). Young children's tool innovation across culture: Affordance visibility matters. *Cognition*, *168*(November), 335–343. https://doi.org/10.1016/j.cognition.2017.07.015

Neldner, K., Redshaw, J., Murphy, S., Tomaselli, K., Davis, J., Dixson, B., & Nielsen, M. (2019). Creation across culture: Children's tool innovation is influenced by cultural and developmental factors. *Developmental Psychology*, *55*(4), 877–889. https://doi.org/10.1037/dev0000672

Qian, M., Plucker, J. A., & Yang, X. (2019). Is creativity domain specific or domain general? Evidence from multilevel explanatory item response theory models. *Thinking Skills and Creativity*, *33*(September), 100571. https://doi.org/10.1016/j.tsc.2019.100571

Rawlings, B. (2018). *Establishing predictors of learning strategies; an investigation of the development of, and evolutionary foundations of, intrinsic and extrinsic factors influencing when we learn from others and from whom we learn* [Doctoral thesis, Durham University]. http://etheses.dur.ac.uk/12800/

Rawlings, B., Flynn, E. G., & Kendal, R. L. (2021). Personality predicts innovation and social learning in children: Implications for cultural evolution. *Developmental Science*, *25*(1), e13153. https://doi.org/10.1111/desc.13153

Rawlings, B., & Legare, C. H. (2021). Toddlers, tools, and tech: The cognitive ontogenesis of innovation. *Trends in Cognitive Sciences*, *25*(1), 81–92. https://doi.org/10.1016/j.tics.2020.10.006

Rawlings, B., Legare, C. H., Brosnan, S. F., & Vale, G. L. (2021). Leveling the playing field in studying cumulative cultural evolution: Conceptual and methodological advances in nonhuman animal research. *Journal of Experimental Psychology: Animal Learning and Cognition*, *47*(3), 252–273. https://doi.org/10.1037/xan0000303

Rosati, A. G. (2017). The evolution of primate executive function: From response control to strategic decision-making. *Evolution of Nervous Systems*, *3*, 423–437. https://doi.org/10.1016/b978-0-12-804042-3.00093-2

Rutz, C., Sugasawa, S., van der Wal, J. E. M., Klump, B. C., & St Clair, J. J. H. (2016). Tool bending in New Caledonian crows. *Royal Society Open Science*, *3*(8), 160439. https://doi.org/10.1098/rsos.160439

Sahlberg, P. (2009). The role of education in promoting creativity: Potential barriers and enabling factors. In E. Villalba (Ed.), *Measuring creativity* (pp. 337–344). Publications Office of the European Union (OPOCE).

Sefton-Green, J. (2012). *Learning at not-school: A review of study, theory, and advocacy for education in non-formal settings*. MIT Press. https://doi.org/10.7551/MITPRESS/9351.001.0001

Tennie, C., Call, J., & Tomasello, M. (2009). Ratcheting up the ratchet: On the evolution of cumulative culture. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1528), 2405–2415. https://doi.org/10.1098/rstb.2009.0052

Weir, A. A. S., Chappell, J., & Kacelnik, A. (2002). Shaping of hooks in New Caledonian crows. *Science*, *297*(5583), 981. https://doi.org/10.1126/science.1073433

Whalley, C. L., Cutting, N., & Beck, S. R. (2017). The effect of prior experience on children's tool innovation. *Journal of Experimental Child Psychology*, *161*(September), 81–94. https://doi.org/10.1016/j.jecp.2017.03.009

Yu, Y., & Kushnir, T. (2020). The ontogeny of cumulative culture: Individual toddlers vary in faithful imitation and goal emulation. *Developmental Science*, *23*(1), 1–18. https://doi.org/10.1111/desc.12862

How to cite this article: Rawlings, B. S. (2022). After a decade of tool innovation, what comes next? *Child Development Perspectives*, 00, 1–7. https://doi.org/10.1111/cdep.12451