Authors: Burdett, Emily R. R. & Ronfard, Samuel.

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Title:
A cognitive developmental approach is essential to understanding Cumulative Technological Culture

Full names: Emily Rachel Reed Burdett[1] & Samuel Ronfard[2]

Institutions: [1]University of Nottingham, [2]University of Toronto

Addresses: [1]University of Nottingham, School of Psychology, University Park Campus, East Dr, Nottingham, NG7 2RD, UK,
[2]Psychology UTM CCT4059, 3359 Mississauga Road, Mississauga, Ontario, L5L 1C6, Canada

Telephone: 0115 748 6970 (Burdett) and 1 905 828 5415 (Ronfard)

Email: Emily.burdett@nottingham.ac.uk and samuel.ronfard@utoronto.ca

Homepage: https://www.nottingham.ac.uk/psychology/people/emily.burdett and
https://www.utm.utoronto.ca/psychology/faculty-staff/ronfard-samuel

Abstract: Osiurak and Reynaud argue that children are not a good methodological choice to examine cumulative technological culture. However, the manuscript ignores other current work that suggests that young children do display some aspects of creative problem-solving. We argue that using multiple methodologies and examining how technical reasoning develops in children will provide crucial support for a cognitive approach to CTC.

Main text:

Osiurak and Reynaud (n.d.) claim that children do not possess the technological expertise required to innovate new solutions to problems and conclude it is debatable whether children are a good 'methodological choice' to examine CTC (section 3.4). Indeed, children do struggle with tasks requiring creative problem-solving and we agree that sufficient technical-reasoning is required for innovation. However, the manuscript ignores a growing body of research that suggests some early innovative capacities and does not give adequate discussion to the early development of technical reasoning skills. Indeed, based on recent developmental evidence, we argue that young children display some aspects of creative problem solving under limited conditions. Understanding these constraints on innovation in early childhood is key to understanding what is developing.

Osiurak and Reyanud (n.d.) argue based on four developmental studies (Beck et al. 2011; Cutting et al. 2014; Reindl et al. 2017; Reindle & Tennie, 2018) that young children are poor innovators. It is true that young children's innovation is limited when they have to innovate over a short period of time (Beck et al. 2011; Cutting et al. 2014) and with limited materials (e.g., a pipecleaner and string, or water and cup) (Beck et al. 2011; Cutting et al. 2014; Cutting et al. 2019; Ebel, Hanus, & Call, 2019). However, young children can innovate new and effective solutions when working in small groups (Mcguigan et al 2017), when they have prior experience with the task (Whalley et al. 2017), when the task is open-ended and allows them to use multiple manufacturing methods (i.e., reshaping, adding, subtracting, detaching) (McGuigan et al. 2017; Voigt et al., 2019), and when they have plenty of time (McGuigan et al. 2017; Voigt et al., 2019). In sum, young children appear to be able to explore their way to a solution but seem restricted in their ability to come up with the "right" solution in tasks that are more constrained both in terms of time, materials, and manufacturing methods (e.g., Beck et al., 2011).

Intriguingly, a similar pattern has been observed when examining the development of children's hypothesis testing. When faced with a surprising event or with surprising data, young children deploy sophisticated exploration and search strategies, make appropriate inferences, and test these hypotheses (e.g., Gopnik, 2012; Gopnik et al. 2015; Gopnik et al. 2017). However, children struggle until middle childhood (and even adulthood in some contexts) to design controlled experiments that isolate causal factors (Chen & Klahr, 1999). Explicitly testing a hypothesis and solving a specific technical problem are analogous in important ways and children seem to solve both tasks around the same time. Around 8-years-old, their problem solving in both contexts is more flexible and targeted and less reliant on imitation and exploration (Carr et al., 2016; Chen & Klahr, 1999; Lucas et al. 2017). Given the cognitive overlap between designing an experiment and developing an innovative solution to a technical problem, the fact that scientific problem solving and innovation follow similar developmental trajectories suggests that domain-general developments (in addition to domain specific knowledge) may play an important role in constraining innovation in childhood.

Some domain-general factors presumed to increase technological reasoning can be tentatively ruled out. On more constrained tasks (like the hook task) executive functioning (Chappell et al. 2013) including inhibitory demands, working memory, attentional flexibility (Beck et al. 2016) and divergent thinking (Beck et al. 2016) are not associated with innovation success rates. By implication, young children are not failing to innovate because of limits in their abilities to process information. Instead, their ability to innovate may be constrained by their ability to make connections between their prior knowledge and current tasks constraints (analogical reasoning, e.g., Gentner et al. 2016), by their ability to consider how different steps could be taken to solve a problem (advanced planning, Tecwyn et al. 2014), and by improvements in children's metacognition—their ability to represent their own technical skills. This latter skill may be particularly important in allowing children to engage in more targeted forms of innovation and thus may allow children to not only explore their way to innovation but also to direct their way to innovation (see Carr, Kendal, & Flynn, 2016 for a similar proposal).

In conclusion, we agree with Osiurak and Reynaud that a suite of non-social cognitive factors contribute to technological reasoning and innovative thinking. We think that more work into understanding the development of these cognitive factors in children is promising. Specifically, we propose that further work examines the development of cognitive factors in both open-ended and constrained tasks. The cognitive skills required for either task may reveal multiple developmental pathways to innovation, such as via exploration or through a more directive, analogical approach.

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