Capturing children's innovations in different contexts; comparing structured problems and play.

Lead Researcher's son playing with the pirate task.

(Permission for photograph given)

Research Team

Dr Nicola Cutting (Lead Researcher)

I completed my PhD at the University of Birmingham in 2012 (graduating in 2013). Under the supervision of Professor Sarah Beck and Professor Ian Apperly my PhD 'Children's Tool Making: From Innovation to Manufacture.' investigated children's difficulty with innovating simple novel tools such as hooks to solve problems, e.g., fishing a bucket out of a tall tube. Building on my PhD work I was a named Postdoctoral Research Fellow on an Economic and Social Research Council (ESRC) grant awarded to Professor Beck (Principal Investigator), Professor Ian Apperly and Dr Jackie Chappell. On this 4- year project titled '(Re)Inventing the wheel: the development of tool innovation' I took an active role in progressing our knowledge of children's capacity for problem solving and innovation. Following this I was appointed as a Lecturer in Psychology at York St John University in 2016, promoted to Senior Lecturer in 2019. In May 2023 I was appointed Deputy Associate Head of Psychology. During my time at York St John, I have furthered my research in the area of children's problem solving as well as developing new lines of research into the relationship between children's reading and social cognition in collaboration with my colleague Dr Lorna Hamilton, and researching the relationship between bilingualism and social cognition with Dr Ruth Lee. I currently supervise four PhD students. I have published 11 research articles in international Psychology journals, and 1 book chapter, and currently have further journal articles and a book chapter under review. To date my work has produced over 850 citations, with the original paper on children's tool innovation generating over 230 citations.

Darcy Neilson (Research Assistant)

Darcy completed her undergraduate studies in Psychology at York St John University. During this time, she took a keen interest in Developmental Psychology. Darcy pursued this interest further undertaking a Master's degree in The Psychology of Child and Adolescent Development, remaining at York St John University.

Under the supervision of Dr Cutting, this project was the first time Darcy has collaborated on a professional research project to be submitted for publication. Alongside Dr Emma Tecwyn, Dr Nicola Cutting will supervise Darcy's PhD project due to commence in September 2023. Darcy's involvement in this project consolidated her decision to pursue a PhD, and the skills she gained secured her the funded PhD position at York St John University.

Background to the project – Children's tool innovation

Whilst many species make and use their own tools, it is only humans who have developed an abundance of complex tools that we use in almost every aspect of our lives. This disparity has raised the question, what makes humans unique? How have we evolved to have such complex tool culture when our nearest living relative, the chimpanzee, is limited to using sticks and stones? Researchers suggest there to be two key factors that drive the development of our tool-rich world: faithful imitation, i.e., watching and copying how others make tools, and innovations or modifications (Legare & Nielsen, 2015). First an individual needs to come up with a new idea, a new way of making a tool. This new innovation then needs to spread throughout the group so that everyone is now making their tools in this new better and efficient way. Then when an individual makes a new innovation, this new even more efficient method needs to be copied and adopted by the group. This process happens over and over again, until humans that were using basic stick and stone tools eventually create complex tools such as pneumatic drills and smartphones. This process is called cumulative culture – meaning that our tool culture builds up cumulatively over time.

Researchers investigating the process of cumulative culture state that it requires both innovation and imitation (or social learning). Most research on this topic has focused on the social learning aspect. There is an abundance of literature demonstrating that humans are extremely faithful copiers (see review by Hoehl et al., 2019). With many researchers arguing that it is human propensity for exactly copying things that we see that sets us apart from chimpanzees. Despite innovation being recognised as the second important driver of cumulative culture there has been a smaller focus on how innovations occur.

Let's go back to the question at the beginning of this section – what makes humans unique? Why has our tool culture evolved so far beyond that of other species? To answer this question, we can take a comparative approach. We can compare abilities of modern humans to other non-human primates to see which abilities we share and which ones are unique to humans. To do this we take a look at the abilities of human children, rather than adults due to their relative inexperience with the world. We do not of course imply that a human child has equivalent experiences to chimpanzees but children's relative naiveness to the world compared to adults gives us the best available opportunity to make comparisons. It is also assumed that the underlying cognitive and social mechanisms involved in innovation remain relatively unchanged over time, our understanding of the development of these mechanisms in modern society can therefore inform our knowledge of these processes in our ancestors (Dean et al. 2012)

Work by myself and colleagues was the first to investigate children's capacity for innovation. We used a problem-solving paradigm that tasked children with fishing a bucket out of a tube to retrieve a reward contained inside (Beck et al., 2011). Children were given materials such as pipe cleaners and string to solve the task, with the solution being to bend a pipe cleaner into a hook. Children found this task extremely difficult with children aged 5 rarely innovating a hook tool and only half of children succeeding by age 8. This finding has been replicated by several research teams across the world including researchers in the UK, USA, Turkey, Germany and Australia (Nielsen et al., 2014; Voigt et al., 2019). Cross-cultural work conducted with Bushman communities in South Africa and indigenous Australian societies has shown children's difficulty with innovation to be a stable finding in western and non-western populations (Neldner et al., 2017).

Another tool-innovation task that has been used by researchers is the floating object task (also referred to as the floating peanut task as this task was first used with non-human primates) (Hanus et al., 2011). This task presents children (or non-human primates) with a tube containing an object that can float. The participants are also presented with a jug of water within the task area. The participants are tasked with retrieving the object from the tube. This can be achieved by pouring in the water to make the object float. The original study conducted with children found very similar rates of innovatively using the water as a tool as were found in the hook-innovation studies, with around 60% of children succeeding on the task by age 8.

Whilst there is value in the innovation studies I have outlined here, and their controlled structure allows us to unpick the mechanisms underlying children's abilities, I have concern that the format of these experimental studies does not allow us to capture the true innovative abilities of young children. Indeed, children's lack of innovation and creativity in these tasks appears at odds with the imaginative and creative play observed in children. In artificial task environments, children are asked to work individually on very structured problems, often with short time limits imposed. Real-world innovations are unlikely to unfold in this way. They are likely to take time, be the product of collaboration and occur naturally rather than in a test situation.

Using a Froebelian Approach to further this research

The key Froebelian principles of learning through play, respecting children as powerful learners who are motivated to explore and allowing freedom to do so (Tovey, 2017), sit neatly with the proposed ideas about optimal environments to allow for innovation. A small-scale study I conducted showed that when given the hook-innovation task children explore the materials more and try more things when they are alone than when an experimenter is present, demonstrating that removing constraints of the task environment may encourage creativity. There are further constraints of the structured task environment that could also be removed. Below, I first outline the basic structure of the current study to provide a clear context for this report. I then explore the Froebelian characterisation of play and explain how I have used this to underpin the methodology of the study conducted.

Basic study outline

Full details of the study design can be found in the method section. Briefly this study tested children's propensity for innovation on two tasks – the hook task and the floating object task as described in the previous section. Both tasks were made more appealing for children by being presented as toys with a clear theme. The hook task had a pirate theme and consisted of a pirate 'treasure' island where the treasure was located at the bottom of a long tube under the island. The floating toy task was alien themed, with the objects being placed at the bottom of tubes in an alien planet landscape.

These task materials were presented to pairs of children either in their usual structured formats, i.e., a goal is set and children were asked to complete it, or in a context where children were simply told they could play with the apparatus and materials. The aim was to see whether children were more successful in the unstructured 'play' condition rather than the structured 'goal' condition.

Tina Bruce's twelve features of play

To start I will acknowledge that this project does not full encapsulate play in the Froebelian perspective. Instead, this project took inspiration from Froebelian philosophy to move the way research on innovation in children is conducted from structured to less structured with the aim of exploring how very structured tasks may put constraints on discovering children's abilities.

Bruce (2020) states that play is something that is not easy to define. It does not have clear boundaries that we can measure and as such there are different approaches to understanding what play is and how it is important. Bruce's work outlining the features of play from a Froebelian perspective has provided this current research with a framework in which to situate our thinking about how to characterise play.

Below, I highlight some of these features and outline how they have informed the methodology used in this project:

"Play exerts no external pressure on children to conform to externally imposed rules, goals, tasks or a definite direction. In this it differs from games. But the externally set rules in games enable children to experiment with breaking, making and keeping rules in the safety of their free flowing play."

"Play is an active process without an end product. When the play fades, so does its tangibility. It can never again be replayed in exactly the same way. It is of the moment and vanishes when the play episode ends. This aids flexibility of thought and the adaptability central to the intellectual life of the child."

"Play is intrinsically motivated. It does not rely on external rewards. It is self-propelling. Children cannot be made to play. The circumstances and relationships need to be right for the child's play to begin to flow."

The structured version of the two tasks places clear goals for the children. They are explicitly tasked with retrieving the treasure and the alien objects. In the 'play' version, children are not given a goal or a definite direction in which to interact with the toys. Children are free to interact with each other and the materials in any way that they wish. Focusing on the third feature presented here, it is acknowledged that we cannot make the children play, but we encourage them to do so and set no external goals of how they should interact with the materials and apparatus.

"Play is about possible, alternative, imagined worlds which involve 'supposing' and 'as if' situations. These lift participants from the literal and real to a more abstract and higher level of functioning. This involves being imaginative, creative, original and innovative. The symbolic life of the child uses life experiences in increasingly abstract ways."

The apparatus and materials were adapted from the original plain tubes into pirate and alien themed contexts to encourage children into alternate, imagined worlds. Again, the researchers acknowledge that in setting the themes we are providing some structure to children's play that does not allow the play to be truly child-led.

"Play might be in partnerships between children or between adult and child. Or it might be in a group with or without an adult participating. Adults need to be sensitive to children's play ideas, feelings and relationships and not invade, overwhelm or extinguish the children's possibilities for free flowing play. Freedom with guidance is a delicate balance."

Adult guidance was minimal on the 'play' condition. Children were simply introduced to the apparatus and told they could play in any way they wished. The researcher then stepped back and only responded if addressed by the children. Children took part in pairs to help facilitate play.

> *"During their free flowing play children use the technical prowess, mastery and competence they have developed to date. They are confident and in control. Play shows adults what children already know and have already learnt more than it introduces new learning"*
>
> *"Play is an integrating mechanism which brings together everything the child has been learning, knows and understands. It is rooted in real experience that it processes and explores. It is self healing in most situations and brings an intellectual life that is self aware, connected to others, community and the world beyond. Early childhood play becomes a powerful resource for life both in the present and the future."*
>
> *"Free flow play actively uses direct, first -hand experiences, which draw on the child's powerful inner drive to struggle, manipulate materials, explore, discover and practise over and over again."*

These features underpin the reasoning for designing this study to include a more play-like context. Rather than setting children a goal to achieve, the researchers aimed to create an environment where children could showcase their abilities.

> *"Play is sustained, and when in full flow, helps children to function in advance of what they can actually do in their real lives. They can drive a car, perform a heart operation, be a shop keeper."*

They can be an engineer, a problem-solver, an inventor.

This research is very much the first step towards reducing the structure in the tasks that already exist to measure children's tool innovation ability. A truly Froebelian approach to investigating innovation would perhaps be one of discreet observation in which children would be completely free to follow their own explorations. The authors acknowledge that in comparing the current tool innovation tasks to ones that are slightly less structured we are not fully encompassing the Froebelian philosophy. However, the aim of this study is to move this literature into the direction of understanding the importance of play for children's creativity and innovation. The 'play' condition in this instance removes the goal to be achieved, distances the researcher as a passive observer who can provide some minimal guidance if the child engages with them, and the materials and apparatus were designed to encourage children to create new imagined worlds.

The Froebelian approach suggests that children's creativity can be enhanced by supportive and nurturing environments and people. This project aimed to provide empirical evidence to support this idea by demonstrating that creativity and innovation increase when children are given opportunity to explore their ideas in relaxed supportive environments such as play with peers.

Learning, exploring, and experimenting through play are at the centre of Froebelian practice (Bruce, 2012; Tovey, 2007; 2013). Play allows children the freedom to explore and take ownership of their ideas. The Froebelian approach of gentle guidance alongside freedom to explore through play offers children a rich learning environment (Tovey, 2017). Building on the work of Bruce (2011) who stated that “play promotes flexible, adaptive, imaginative and innovative behaviour”, this research project directly assessed whether children display more innovative and creative behaviour in the context of ‘play’ compared to structured testing environments with clearly defined goals that are commonly used by child development researchers. As well as demonstrating the importance of play in its own right, one of the aims of this research project was to demonstrate that child development researchers should be adopting and replicating play-based environments when assessing the developmental trajectories of children’s abilities. Whilst experimental paradigms need to include some control measures to ensure the robustness of the research, this study aimed to demonstrate that robust experimental child development research can be conducted whilst also providing children with more optimal play-based environments in which to display their abilities. In this first step maintaining some control over the two contexts is important, but future research should also consider taking a much less structured observational approach that measures innovations in spontaneous child-led contexts.

Much existing child development research places children in structured, adult environments where they are tested for inflexible, specific abilities that must be displayed within designated time periods in order to be counted as success. Based on Froebelian principles this new line of research put children more at the centre, creating environments that were respectful of children with the aim to harness children’s innate abilities as powerful learners who are motivated to explore. This relates to the Froebelian view that children should be encouraged to be **autonomous learners**.

This project gave children the opportunity to discover, reflect and refine creative solutions for themselves with minimal adult input. Play-based scenarios measure children’s creativeness and potential for innovation whilst reducing the inclusion of unnecessary rules and external pressures. Adult experimenters took a step back, removing previous constraints on children’s behaviour and providing children with more freedom to explore. Children were provided with more time and space to engage with activities, with the aim of demonstrating that taking this approach optimises the behaviours that children display.
In contrast to the vast literature on how children learn knowledge from others, this research focused on how children gain and display knowledge by themselves or as Hargreaves et al. (2014) put it “growth of knowledge from inside rather than outside the child”.

The Froebelian approach also highlights **unity and connectedness** (Tovey, 2017), noting that children learn holistically, meaning that we should not attempt to compartmentalise children’s learning. This project aimed to demonstrate that structured, focused environments in which we try to force children to generate a particular idea are limiting children's ability to showcase their creative potential. By comparing these structured environments to more play-based situations that allow children the freedom to explore situations and generate creative ideas more organically, this project aimed to provide direct support for a Froebelian approach to children’s learning.

Method

Participants

A total of 126 primary-school children (52.38% female) aged 4- 7-years took part in the study, with a mean age of 5-years and 6-months (5;6). Children were categorised by year group, with 40 children in reception, 43 in year 1 and 43 in year 2. The children were recruited from two primary schools in West Yorkshire. Headteachers gave consent for the study to take place in their school, with letters then being sent to caregivers who filled out an online form to give their consent. Each school received £100, and each child was rewarded with a £5 Love-to-Shop voucher, as a thank you for their participation. Ethical approval for this project was obtained from the York St John University, School of Education, Language and Psychology Ethics Committee.

Materials

Task 1 – Hook Making Task (Based on Cutting et al., 2011)

Children were presented with a plastic box 100 x 50cm adorned to resemble a pirate island (depicted in Figure 1a). A three-dimensional model of an island landscape was decorated using acrylic paint, miniature artificial plants and sand to create a textured surface and facilitate engagement with the play apparatus. This was positioned on top of the box lid, which was painted blue to blend the edges of model template. Interior walls of the box were also painted blue to make the box opaque. In total, the hook task apparatus consisted of the island box, a pirate ship toy and two pirate figurines alongside two blue pipe cleaners which could be used to create functional tools. A circular hole 4cm in diameter was cut into the box lid and through the island scenery to allow a translucent plastic tube to be inserted vertically and held in place (Figure 1b). Prior to presenting the task, a small glass bottle filled with gems with a metal handle attached to the cork lid was dropped into this tube (see Figure 1c). The tube was sufficiently deep and narrow in diameter meaning the 'treasure' could not be reached by hand. To retrieve the object, children were required to bend the end of the pipe cleaner to form a hook and use this tool to effectively fish the item out of the tube. Children were informed they were not allowed to tip the box upside down or take the box lid off if they attempted to solve the problem using these methods.

Figure 1. Hook task apparatus and materials

Task 2 – Floating Object Task (Hanus et al., 2011)

A transparent plastic box 100 x 50 cm was decorated to imitate an alien planet landscape using acrylic paint and glitter, further embellished with a papier-mâché border painted black to disguise the simplicity of the box (Figure 2). Parallel to the hook-innovation apparatus, a hole – 4 cm in diameter was cut into the box allowing a translucent plastic tube – 4cm in diameter and 20cm in length to be inserted. A small plastic egg was placed at the bottom of the tube before presenting the task to children. In addition to the box, participants were provided with two alien characters with magnetic features alongside a toy spaceship and jug of water. This task can be solved by pouring water into the tube to raise the object to the top for retrieval.

Before completing the floating object task, participants were presented with a familiarisation task in which they were asked to help water an artificial plant using the jug of water (in line with procedure by Hanus et al., (2011)). This procedure served to provide children with permission to use the water in imaginative ways and to mitigate functional-fixedness orientations which may otherwise dissuade children from involving the jug as part of the play apparatus

Figure 2. Floating toy task apparatus and materials.

Procedure

Pairs completed one of the tasks in a structured format whereby they were explicitly directed towards a problem to solve, such as retrieving the treasure in the hook-innovation task. Conversely, in the unstructured condition, children were simply invited to play with the materials in any way they wanted.

The tasks and whether they were presented in a structured or play context was counterbalanced across participant groups, such that each pair partook in one of the following task configurations:

-Task 1 Play, Task 2 Structured

-Task 1 Structured, Task 2 Play

-Task 2 Play, Task 1 Structured

-Task 2 Structured, Task 1 Play

Children participated in the study in pairs to encourage interaction and play behaviours. The study took place in a quiet room at each school. Children were welcomed by the research assistant and informed they have been invited to 'play some cool games!'. They were each provided with a cushion to sit on to help establish a comfortable and relaxed environment.

The consent form clearly communicated that children would be filmed whilst undertaking the task, ensuring caregiver consent was acquired before data collection commenced. Verbal assent was obtained from both children in the pair before presenting the tasks, verifying their willingness to be recorded and participate in the project.

Once recording was started, each pair was presented with one version of either the floating object or hook-innovation task. One of the tasks was presented in a structured format whereby emphasis was on the problem to be solved in the game. The second task presented children with the opportunity to interact freely with the materials.

Task Instructions:

1) Hook Task –

Structured condition: “The pirates have been exploring the island and found treasure at the bottom of a deep hole. But they cannot reach it! Can you help them? You can work together using any of these things here, in any way that you like, to get the treasure for the pirates.”

Play condition: “I’ve been playing a game where pirates are searching for hidden treasure and have found a new island to explore. Now it’s your turn to play with the pirates! You can play with all the things here, in any way that you like.”

2a) Familiarisation Task -

In line with procedures used in previous floating object studies, children first took part in a familiarisation task to ensure they knew they had permission to pour the water that was available to them.

Children were presented with a plastic flower and the jug of water. The researcher adhered to the following script: “Before we begin, I have a little job for you. Can you help me water my plant? You can both have a go and give it a little bit of water.”

2b) Floating Object Task -

Structured – “The aliens are on an exciting mission exploring new planets looking for these special objects to take back to their home planet. They’ve landed on this planet and found a special object at the bottom of a deep hole, but they cannot reach it! Can you work together to help them get it out? You can use any of the things here.”

Play – “I’ve been playing a game where aliens are on an exciting mission exploring new planets looking for cool stuff to take back to their home planet. Now it’s your turn to play! You can play with any of the things here in any way that you like.”

For the hook task, children must bend the pipe-cleaner into a hook shape and pull up a bottle with gems in using its handle. In the floating object task, the problem to be solved was retrieving an egg through pouring water into the plastic tube. Children were given 10-

minutes to complete each task, with the 5-minute familiarisation task preceding the floating object task in both the structured and play condition. All children received a sticker after each task, as well as a £5 voucher to thank them for their participation.

Ethical Considerations

Consent

Gatekeeper consent was sought from the Headteachers at the schools involved. Parental/caregiver consent was gained by caregivers filling out an online form. Children were asked to give verbal assent that they were happy to take part.

Right to withdraw/Protection from harm

Children were able to stop taking part at any time. The researcher actively ensured that children were happy to participate.

Children or their caregivers were able to withdraw their data by contacting the research team up to 2 weeks after participating (after this it is difficult to remove the data as it has been coded and analysed).

Safeguarding

The researcher familiarised herself with each school's safeguarding procedures before commencing the research.

Anonymity

To ensure anonymity each child was given a participant number and their data was kept separate from any identifying information. Video files were transferred to a secure, password protected drive, and only viewed by the two researchers.

Coding children's behaviours

Each pair were coded as to whether or not they innovated a solution, i.e., retrieved the object (treasure or egg) within the 10-minute timeframe. If the object was retrieved the time to successful retrieval was also coded.

Children's behaviours throughout the task were measured using the Analysing Children's Creative Thinking framework (ACCT) (Robson & Rowe, 2012). This framework consists of three broad categories – Exploration, Involvement & Enjoyment, and Persistence. The researchers adapted this framework for use with the apparatus and materials used in the current study. Please see Table 1. for clear guidance on the descriptions used for each behaviour. The behaviours for each child were coded and summed to give an overall score for each pair in regards to the number of instances of exploration, involvement & enjoyment, persistence and then an overall creativity score that combined all three sub-categories. Given that children who retrieved the objects interacted with the materials for less time than the children that did not, these scores were then calculated per minute that the children interacted with the materials.

Table 1. Analysing Children's Creative Thinking Framework with adaptions for current tasks (Robson& Rowe, 2012)

Category	Operational definition:	Reflections before coding:
E: EXPLORATION		
E1: Exploring	Child is keen to explore and/or shows interest in the potential of a material or activity.	Keenness to explore may be demonstrated by self-orienting attention to the treasure and making comments such as 'ahh I really want to know what's down there!' and repetitive glances towards the treasure (particularly in cases where their partner was less engaged with the 'treasure'). This was recurrent in some of the episodes, though generally most likely to occur at the start upon first noticing treasure. Interest and zeal re-occurred as the child was re-engaging their motivation to pursue object retrieval upon encountering some difficulty and lack of success with the task. Some children examined the box scenery in detail, for example searching through the trees on the island for 'clues', to assess the potential help or guidance they could access through such exploration.
E2: Engaging in new activity	Child is interested in becoming involved in an activity and taking an idea forward. The activity could be of his or her own choice or suggested by another child or adult.	Verbal assertions such as 'we need to get it [the item] out!' indicate a commitment to the activity, which typically preceded behaviours of material collection such as gathering the aliens or pipe cleaners. Interest in involvement was perhaps evidenced by the child shuffling closer to the box, displaying an eagerness to have their turn. For example, some children began fiddling with their hands, even potentially wrapping the pipe cleaner around their fingers, as means of distraction whilst their partner was busy poking their material down the hole. Often their impatience was too difficult to inhibit, and the child resulted in asking their partner to 'move up so I can have my turn now' or 'Oh I think I've got a good idea! Let me try this."
E3: Knowing what you want to do	Child shows enjoyment or curiosity when choosing to engage with an activity.	Curiosity may be exemplified when children ask 'I wonder what it is!' Notable examples from memory particularly relate to the alien's object, which one participant hypothesised may be a baked bean! A child may observe their partner carefully with a smile (denoting enjoyment) and again make comments exclaiming 'I really want to find out what it is!'

I: INVOLVEMENT & ENJOYMENT		
I1: Trying out ideas	Child shows evidence of novel ways of looking and planning: uses prior knowledge or acquires new knowledge to imagine and/or hypothesise, or to show flexibility and originality in his/her thinking.	Examples of original thinking include detaching legs from the toy spaceship to try and reach into the tube. This also demonstrates flexibility in the object use (rather than a toy figurine being merely a convention play object). Trying to stretch their own hand or their toys arms down to retrieve the object demonstrates using prior knowledge: when you drop something, it is an intrinsic reaction to reach down to recover it. Imagining/hypothesising ideas often occurred in verbal form 'I think we need to push it up like this'.
I2: Analysing ideas	Child shows either verbal or behavioural evidence of weighing up his/her idea and deciding whether or not to pursue it.	Some children made insightful comments regarding the material properties and relations between objects such as 'this stick is too bendy; it's not strong enough to pull it [treasure] up!' and making observations such as 'we can't use the water this time anyway because the bottle is too heavy'. This was often followed by the child temporarily sitting back to contemplate what else they could try. Some children verbally expressed their idea evaluation (e.g., explicit examples of weighing up their ideas e.g., 'this isn't working…') whereas others worked silently, trying a method then pausing to reflect on what else they could try.
I3: Speculating	Child makes a speculative statement or asks a question of him/herself, or of other children or adults, relating to the activity.	Many children asked very inquisitive questions regarding how the boxes were constructed, asking who made the box, how it was made, how long it took. Other speculative questions may include children asking their partner 'have you seen this! What could it be?' in attempts to seek answers and better understand elements of the task.
I4: Involving others	Child engages with one or more children or adults to develop an idea or activity: may articulate an idea, seek to persuade others or show receptivity to the ideas of others.	Verbal communication included 'do you think we should try…' and offering new ideas to work collaboratively with their partner. Often with the water there was more collaborative speculation as to whether it would be feasible 'what about the water? We could try that!' Deciding what to do often followed scripts such as 'what about if we… do you think that could work?' (Which also offered up opportunities for I2: analysing ideas). In instances where one agent was relatively disinterested with the task, their partner may have made explicit attempts for their assistance with the task 'come and look! Have you seen this?!'. Receptivity often came from verbal praise for their partner's idea such as 'Yes! That's good; you've almost got it! Do you want me to have a look down the side and see how close you are?' Depending on who was the most dominant in the pair, the 'disinterested' child has convinced their task-oriented partner to neglect their pursuit of the object and join in with their game instead. In many cases, they gradually oriented their focus back to the game, and worked collaboratively following this.

P: PERSISTENT		
P1: Persisting	Child shows resilience and maintains involvement in an activity in the face of difficulty, challenge or uncertainty. He/she tolerates ambiguity.	Children displayed some frustration and disappointment when their attempts to retrieve the object in question were unsuccessful, for example via a sigh or dejected exclamations that the task is 'impossible!' or 'too hard!'. Resilience was demonstrated by all the children who made such comments yet did not concede their efforts. They may for example have taken a deep breathe, readjusted their hair out of their line of vision and dived back in with their pipe cleaner!
P2: Risk taking	Child displays willingness to take risks and to learn from mistakes.	Risk taking was almost a necessity of success with the floating peanut task since it required the child to use water which could potentially damage the box material. However, since this was a target behaviour, coding this as risk taking will not be sufficient and a more fine-grained analysis will be required to investigate more discrete examples of the children demonstrating a willingness to take risks. Any behaviour which was risking failure (e.g., trying an unfamiliar method which is not guaranteed to work = potential not to work). Learning from mistakes was frequently evidenced by comments such as 'well that didn't work so instead we could try…'. Abandoning unsuccessful methods in favour of trying something new.
P3: Completing challenges	Child shows a sense of self-efficacy, self-belief and pleasure in achievement: shows conscious awareness of his/her own thinking.	Comments such as 'We can do hard things!' and 'It just needs a bit of teamwork' demonstrate a commitment to completing the challenge and awareness of own capabilities. It will be interesting to examine whether this occurs in team-focussed as opposed to self-oriented terms across the conditions/ages. Comments such as 'I'm so close! I've almost got it!' evidence self-belief.

Findings

Brief Summary

- No difference between 'play' and structured conditions in the number of pairs retrieving the object.
- Older children more likely to retrieve object in the hook task, but no difference with age on the floating toy task.
- Success rates similar to those seen in previous studies.
- Children's creative behaviours did not differ between the play and structured conditions.
- Children who innovated a method to retrieve the objects displayed more creative behaviours.

Detailed findings

Question 1: Was there a difference in whether children retrieved the object between the play and structured conditions?

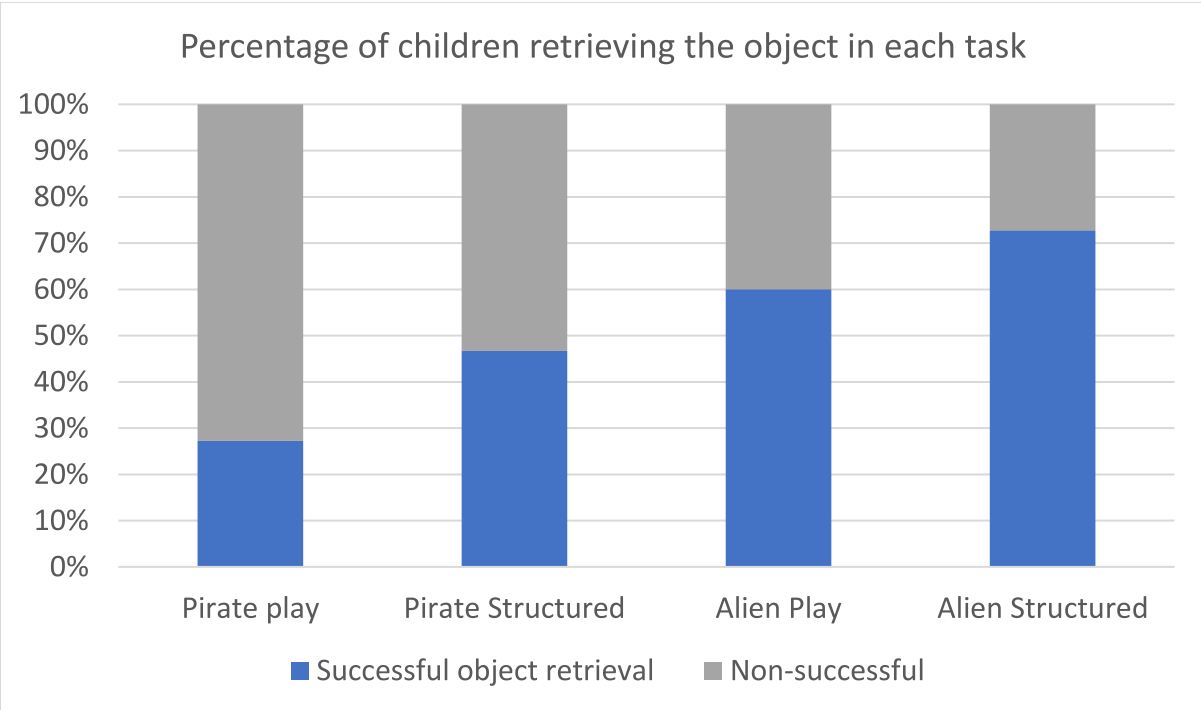

Figure 3. Bar chart showing successful retrieval.

Overall, there was no difference in the number of pairs that retrieved the objects between the play and structured conditions on either of the tasks (Pirate/hook task - $\chi2$ (1, N = 63) = 2.550, *p* = .110; Alien/water task – $\chi2$ (1, N = 63) = 1.145, *p* = .285) (See figure 3.). Overall, children were more successful on the floating object task than on the hook task, McNemar test, p < .001. There was no effect of task order, meaning that children's success levels did not change based on whether they received each task first or second.

Hook Task

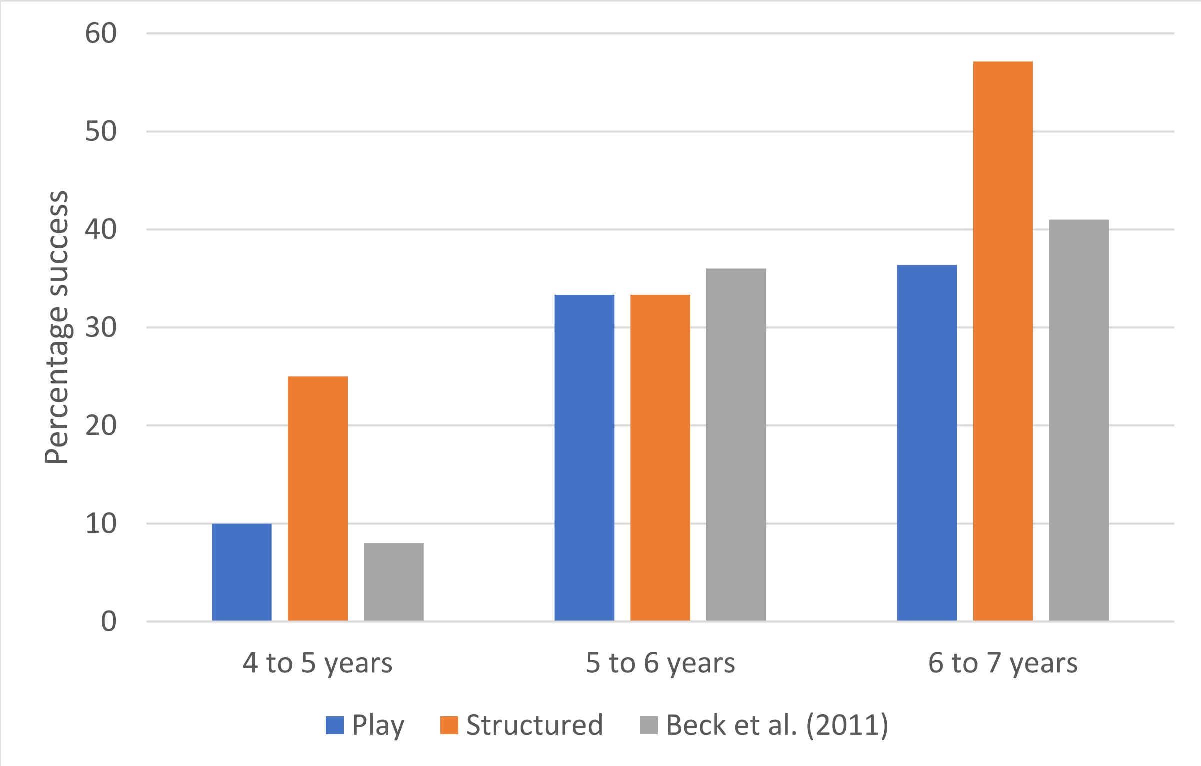

Figure 4. Percentage success on the hook task by age and condition, with comparison to original tool innovation task by Beck et al. (2011).

As shown in Figure 4. levels of retrieval were similar to the original Beck et al. (2011) hook study and as per previous studies children were more likely to retrieve the object with age, $\chi 2$ (2, N = 63) = 7.019, p = .03. Children were not differently affected by the two conditions depending on their age, Fisher's Exact Test, p = .08.

Floating Object task

All age groups contained at least 50% of children who retrieved the object, there was no significant difference in retrieval by age. Children were also not differently affected by the two conditions depending on their age (See figure 5.).

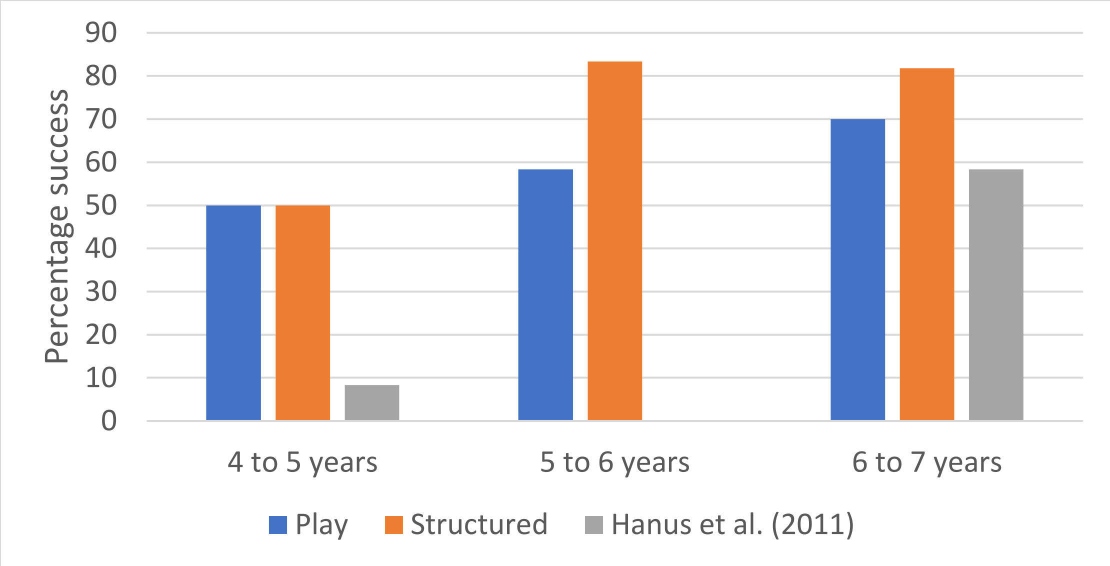

Figure 5. Percentage success on floating object task by age and condition, with comparison to original floating object task with children by Hanus et al. (2011).

Question 2: Was there a difference in time to retrieval between the play and structured conditions?

When looking at children who retrieved the object within the 10-minute timeframe, there was no difference in the time taken between the play and structured conditions for either task (Pirate/hook – $p = .704$; Alien/water – $p = .509$) (see figure 6.). There was also no difference in time to retrieval depending on age.

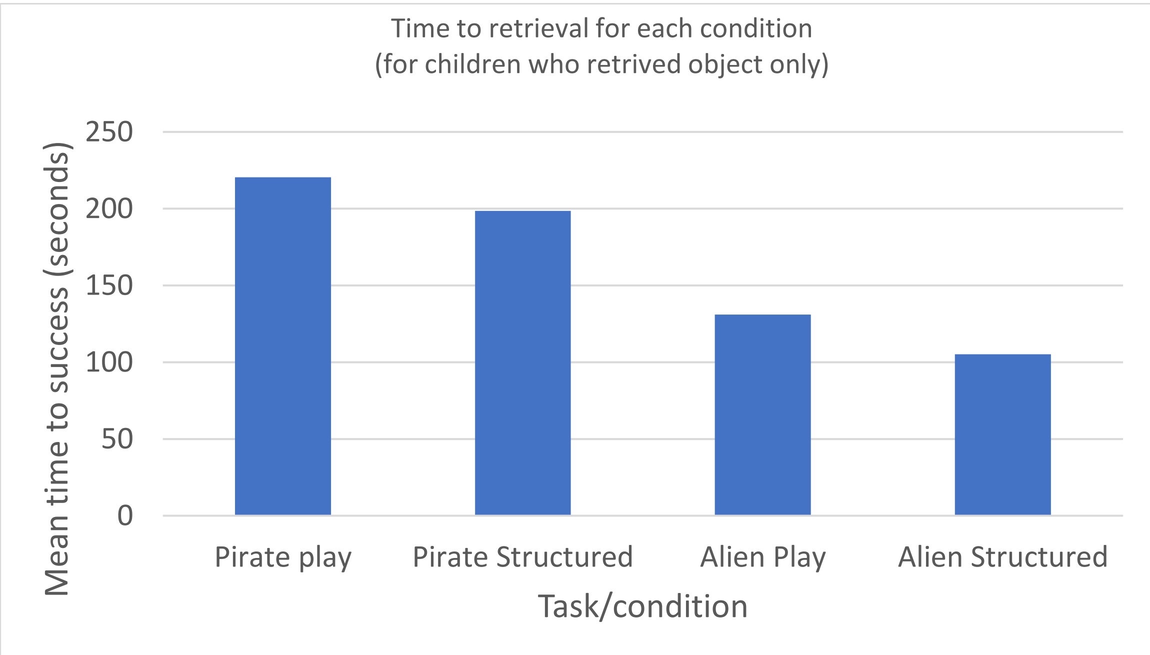

Figure 6. Mean time to retrieval on both tasks.

Question 3: Did children's creative behaviours differ between the play and structured conditions?

Children's creative behaviours were coded per minute that they engaged with each task. Scores were created for exploration, involvement & enjoyment and persistence.

On the pirate/hook task there was no difference in the three creative behaviour measures between children in the play and structured conditions. When comparing children who retrieved the object within the 10-minute timeframe versus those who did not, children who retrieved the object exhibited significantly more creative behaviours for all three measures, (all *p*s $< .001$), demonstrating a relationship between creative behaviours and solving the problem.

The same pattern of results was found for the alien/water task. No difference in creative behaviours between the play and structured conditions, but more creative behaviours for all three measures displayed by children who went on to retrieve the object.

Summary

Overall, this study did not find that creating a less structured context for children facilitated them in innovating successful solutions to retrieving the objects in each task. What this project did find was that all children when presented with new materials and objects to interact with exhibited a high level of creative behaviours irrespective of whether they were given a goal to achieve or were simply instructed to play with them. Building on this, this project found that those children who engaged in more of these creative behaviours were more likely to come up with innovative solutions. This therefore leads to the next question of whether we can facilitate these creative behaviours in children and what might be the mechanism to do this.

Whilst this study aimed to reduce structure in the way that innovation tasks are conducted with children, this project was limited due to its desire to retain the structured innovation tasks as a comparison. This meant that the project required a measurable outcome – whether or not children innovated a pre-determined solution. This limited the project in fully encompassing the Froebelian philosophy of allowing children freedom to explore and lead the way in their own learning.

Whilst aiming to be present in an unobtrusive way, the presence of the researcher would have had implications for how children interpreted the study situation. It is likely children would have tried to interpret what they were 'meant' to do with the apparatus and materials, and this would have affected how they interacted with them. Additionally, both tasks had pre-determined solutions and so did not fully allow for children to be truly innovative. This is a criticism that has been widely acknowledged in the tool-innovation literature, but has thus far been required to conduct robust experimental studies that can assess potential underlying mechanisms of innovative ability.

Future studies should focus on further reducing structure and perhaps taking a more observational approach to how children's innovations occur naturally during child-led play.

The overall take home message from this project is that children who are creative, who display exploration, involvement, enjoyment and persistence, are children that are more likely to innovate. Therefore, to create innovators of the future we need to nurture these characteristics.

Dissemination

This study was presented at the European Society for Philosophy and Psychology on Prague, Czech Republic in August 2023. The study generated a fascinating discussion with both psychologists and philosophers. I will take forward the ideas generated as I now begin to write this up as a manuscript for publication in a peer-reviewed developmental psychology journal. After publication the researchers plan to write an article for 'The Conversation'. Written by academics and researchers, The Conversation provides opportunity to disseminate research and ideas to a monthly audience of over 18 million users.

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