

Title: Science in Action in Spontaneous preschool play - an essential foundation for future understanding

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Abstract

Children are born to play; it is the means by which young mammals acquire life essential skills. Human children are born imaginative scientists, who use numeracy and literacy in activities which, when the tools are designed and made are engineering, as well as tuned to recognise phenomena and people, listen to sounds and acquire language as well as the many manipulative skills needed to survive. From where do these emergent STEM practitioners acquire their understanding of their everyday world? Playing is an essential apprenticeship for developing scientific (STEM) literacy. In the empirical tradition, observing children at their spontaneous play reveals that they are experiencing STEM in action, learning through thinking and doing, experience what happens if? Observing phenomena, asking questions, solving problems, designing investigations and ingeniously adapting what is valuable to use in their active investigations. Non-speaking children, until they acquire verbal language for themselves and communicating by gestures and actions about findings. They observe as well as taking actions.

We maintain that children have various modes of play. Observations and Investigative play when they explore, plan, and do as well as evaluating the outcome and imaginative play where they replicate activities of adults that they have witnessed, such as dressing up as an adult, cooking in a make-believe kitchen, or, for example, composing and acting out a narrative in a mud kitchen. In all these activities children do compose their own narrative.

Communities tell stories to children; hence they also learn about the world through listening and watching physical representations of stories. In these representations of their everyday world children see representations of the world on and in media, which may be authentic representations or imaginary such as in cartoons, toys and pictorial fiction books. Humans have always been storytellers and telling young children stories are a key activity in their development and growing membership of their community. However, many enjoyable stories contain Science information inadvertently and not written to accurately inform. Hence some understandings of the natural world are obtained which are incorrect, in fact mythical and there develops a conflict in the mind of the emergent scientist between myth and reality. This cognitive conflict begins to be resolved at about 6 years when children start being able to recognise myth as such, but the misinformation may linger. This paper examines issues raised above.

Key words: early years science, play, emergent science

Introduction

Science education has changed since the first half of the 19th century from a philosophy of providing for the privileged when the government decided to make provision for the elementary education of all children aged 5-13 creating a level of competency within the labouring classes, who had moved to cities with industry forsaking the land following the Industrial revolution, to enable them to be literate and numerate sufficient to work in industry. Such basic education was established in 1870 with the Forster Education Act. In the reconstructions of the United Kingdom after the Second World war great changes in education were implemented. The Education Act of 1944 implemented education for primary secondary tertiary aged learners but this act followed a number of education papers published during the war advocating three segments of secondary education, modern, technical and grammar. Change occurred again with the issuing of Government Circular 10/65 *The organisation of secondary education*. Thus, Comprehensive education was introduced but some selective schools remained. However, it was in an era singly recognised that Science teaching was not meeting the needs of many children and that primary children could also learn science. Hitherto Nature Study and nature tables had been a feature of elementary school rooms. More recently, a call has been made to encourage such learning and teaching tools again, (Tomkins and Tunnicliffe, 2007). Tables on similar principles do occur in some primary schools as Discovery Tables, Bring and Share.

The Schools Council, the Nuffield Foundation and the Scottish Education Department (1967-1975) in the United Kingdom sponsored a series called Science 5-13 of activities which really helped primary teachers under confident in their science knowledge deliver competent lessons different to watered down secondary science, half recalled, from their own secondary school days to their pupils (Tunnicliffe, 2015). In the second half of the 1980s the UK Government gave Educational Support Grants (ESG) which enabled local authorities in England to set up teams' Advisory teachers to provide In-service and hence continuous professional development (CPD) for primary teachers to enhance their understanding of science concepts and skills, and also introduce Design and technology into primary schools. The creation of CPD is still needed for later initiatives and emphasis. As Clarke and Hollingsworth (2002) pointed out such needs to be continuous if it is to be effective. A Change in emphasis for science teaching style from declarative style to supporting learners through coactive instructions was beneficial to outcomes was suggested (Driver et al. 1983). Driver challenged the establishment to involve learners in active participants of science and that concrete experiences of 'doing' assisted them in concept acquiring. She also said learners required teachers' support in helping them develop new ways of thinking about their activities. Moreover, she also recognised that learners possess alternative frameworks, not misconceptions, which they developed from their experiences and thinking of explanations from what they knew. Osborne, Bell and Gilbert (1983) at the same time pointed out that children came to formal science teaching with their self-formulated children's science understanding which was developed in formal science education to school science.

Argumentation in science had become a critical aspect of science thinking in school science. It was first highlighted by Toulmin (1958; 2003) who proposed the argumentation structure. Such an approach requires the learners to develop and evaluate the argument and the higher order thinking skills of synthesis and evaluation (Osborne, Erduran and Simon, 2004).

The ability to make claims based on observable and empirical evidence and to be able to justify these claims and point out claims that do not have an evidential base are key aspects of science. Such an approach was developed by some primary educators of science in the

1980s (Tunnicliffe, 1990). Zimmerman (2007) looked at scientific thinking and reasoning skills by children in early years summarising the contribution of the research sector this and concluded that the thinking skills of present science teaching will be an important sector after. Monteiro and Jimez-Aleixandre (2017) observed 5-6-year olds in Spanish Kindergarten over 5 months of a science investigation and concluded that these young children were able to ask questions, investigate, make meaningful observations, recognise the data from observations, interpret such and draw conclusions. In comparing, the actions of 3 to 4-year olds and the older, 5 to 6-year olds, these researchers noticed an increase in a child's ability in engaging in science processes developed with age, (Monteria, et al 2018). The younger children were able to establish observations and some data but the older child was able to identify patterns from observation evaluate claims. They stress this cannot be generalised but was a developmental sequence observed and these children following the same longitudinal investigation of 5 months by having some teacher support. These researchers accepted the drawings of the children and thinker simile few word sentences if they could write, and their utterances in explanatory dialogue as evidence of entering the science process. Younger children in our experiences are able to carry out the same.

Children's attitudes towards science are extremely important as these can influence their early attainment in the subject and their outlook in adulthood to scientific issues, young learners in the early years of schooling young children are particularly enthusiastic and enjoy practical experiments and independent investigation but this enthusiasm diminishes (Pell & Jarvis, 2010).

A twentieth first century development has been the increased recognition of early years science. Piekeny et al. (2014) point out that previous to conventional wisdom preschool children have basic ability to consider the merits of evidence and possess an intrinsic understanding of finding out through experimenting. They worked with 4 and 5-year-old children. Bulenz (2013) worked with Kindergarten children who were 5 and 6 in Turkey to explore at whether science instruction and play together increased understanding.

The realisation that the pre-formal education stages important in establishing the foundations of learning has resulted in more research about this age group and the development of resources. The English Early years foundation stage (EYFS) introduced by the UK Government in sets standards for the learning, development and care of your child from birth to 5 years old. The Early Years Foundation Stage (EYFS) curriculum was introduced in 2008 in England. In 2012 revisited versions was issued. A revised version came into effect in September 2012 and at 2017 the latest revised version is available (<https://www.gov.uk/early-years-foundation-stage>).

This curriculum applies to all settings, not just schools that work with children from birth to five. It has 7 areas of which 'understanding the world' is particularly relevant to science content, where children are encourage to explore their own immediate environment and how environments might vary from one another, as well as living things and objects. Other areas such as literacy and numeracy as well as physical development, communication and language as a well as personal and emotional development, and indeed art and design, all have a role in the experience of fundamental science experiencers, non-can be or should be, isolated. Non-statutory guidance material providers people working in this area with the practice of an average child's abilities and expected involvement through these early years

learning progression is an area of interest to assessors as well as parents and teachers. Zimmerman (2009). However, relatively little research on the scientific ideas that young

children build has been hitherto reported. Allen and Kambouri-Danos (2017) suggested strategies connecting applicable developmental psychology research with that of educational research conducted with older children suggesting learning progressions as a possible academic perspective for providing these links.

Children's imagination is an area of intellectual activity important to young children in particular, (Egan 1986). Early years children in developed societies enjoy brightly coloured often-stylistic illustrations of fictional stories frequently featuring certain plants or animals depicted in anthropomorphic ways for structure and behaviour. Children, before they have mastered reading themselves learn the sequence of a book, recognise the characters and often can predict, once they have heard the story a few readings, what will happen next. Using pictorial fiction books reinforces teaching as a story and stimulates children's imagination whilst providing relevant opportunities to explore the relevant real world (Egan, 1986). In some pictorial fiction book the stories often have a biology focus, albeit inaccurate, (Tunnicliffe and Bruguriere, 2017). Picture books can develop some understanding of conceptual categories (Gelman and Waxman, 2009). Furthermore, we know that children can transfer fantastical characteristics to real animals (Ganea et al, 2004). We also know that learning through reading pictorial fiction books is affected by the manner of interaction between the adult and child during the reading (Mol and Bus, 2011). Bruguiere and Tunnicliffe (2018) conclude that reading these stories of realistic fiction generates explanation-seeking curiosity but does not provide directly scientific explanations. However, the situation provides an opportunity for such but needs an informed adult to interpret the relevant science content at an appropriate level for these emergent scientists to comprehend and discuss, drawing on the child's relevant experiences and listening to what they raise from associations. Such books allow children to indicate problems in the story but not to resolve it and should not stand-alone but are interpreted with accurate science learning.

Growing amounts of research on aspects of pre-formal school play have been produced looking at various aspects. Much has been written on the acquisition of concepts but little on science learning proceeds (Lloyd et al, (2016). Gopnik (2009) asserts that these early year children are intuitive scientists whilst Fleer (2000) conducted studies looking at practices promoting germinating science amongst these children the recycle link earth.

The starting point for science is observation, (Sylva et al. 1980). As Tunnicliffe (2013 p.8) states learning science is talking science and the starting point for science is observation, and adults working with children can share and talk about observations increasing their own self-esteem and confidence.

Researchers may effectively theorise based on observations. There are for examples various categories of play which can be derived from either theory or observation. The California-based National Institute for Play (n.d.) describes seven play patterns:

1. Attunement play,
2. Body play,
3. Object play,
4. Social play,
5. Imaginative or pretend play,
6. Storytelling play,
7. Creative plays,

Like many of us who have observed children at play, Russell and McGuigan (2017, p. 38) noticed that ‘science specific’ behaviours were evident during children’s play and in other curriculum areas as well. Such included basic numeracy activities, as matching, recognizing salient features having the same colour or shape, essential in science learning, particularly biological taxonomy, and aspects of dialogues when children ask themselves or voice aloud questions stimulated by their environment, and ponder what might happen if...? Talking after they found out something, and talked, about what did happen. Such activities are foundation or pre-experiences on which formal science learning may be built at in formal schooling (Gkouskou and Tunnicliffe, 2017). Russell and McGuigan (2016) summarised their thoughts about links they perceive between what happens with some examples of observed behaviours, in a table, as an example of clustered threads and other links with emergent science. The three main headings were General development, with threads of behaviour and links between threads, such as paying attention, naming and labeling concepts. The second relevant category was science enabling with as an example for a gathered of concrete operational experiences, and hands on and use of multi-modality. Their example was the provision of many ‘science settings’, particularly ‘messy play’ areas such as sand and water trays. The opportunity to observe changes in materials and how the learner could change and control materials and events. Their last of the three categories was Science, specific where the threads were exploring and investigating for very early encounters with the situations, in some method recording and evaluating outcomes and simple forms of justifying or argumentation. Practical outcomes of such like electronic photographs, 3D histograms with blocks.

‘If we fail our children and students in science, the reasons may include lack of appropriate experiences during early childhood’ (Roth et al., 2013.p.14)

Play is the work of children and essential for intellectual achievement and emotional wellbeing (Whitbread et al., 2012). Some researchers consider there to be two aspects of play (Wood, 2015 in Robson, 2015) ‘Educational play’ or ‘freely chosen play’ which we term spontaneous or free choice play.

Play has become an increasingly important area of research and recognition. Experience using cognitive and kinaesthetic skills is essential into learning and understanding science in the observable everyday context (Gkouskou and Tunnicliffe, 2017). From their earliest years children are hands on intuitive scientists observing thinking and trying out things and observing the results, hence collecting and evaluation data. Such observations and investigations occur in everyday contexts, often unasked and is verbalise through hidden questions presented and statement. However, we believe that before practitioners should introduce specific activities targeted to introduced a particular scientific concept and skill we should first establish which activities children in preschool or at home choose to do themselves, free choice learning and identify the actions that illustrate scientific basic idea, are Science in action (Gkouskou and Tunnicliffe, 2017). Gopnik (2009) documents the abilities of young preschool children and identifies them as intuitive scientists. Hence, we adopted a grounded theory approach and observed a variety of play groups and children in their own home environment to observe what actions they carried out. Strikingly they observed, thought through questions for themselves, even in verbal children we could observe. Hence, we looked at free choice play, guided to a certain extent in organised groups

by the material put out for the children, but in their gardens and other play areas, including imaginative and role play in and outside. The research was carried out according to the British Education Research Association (2018).

Methodology

We were interested in identifying science foundation experiences in play which we consider essential to understand before designing specific activities to assess a child's science development and competency. Grounded theory is a systematic methodology in the social sciences involving the construction of theory through methodical gathering and analysis of data. Grounded theory is a research methodology which operates inductively, in contrast to the hypothetico-deductive approach (Glaser, 2011). A study using grounded theory is likely to begin with a question, or even just with the collection of qualitative data. This is a method whereby the researcher collects data and then develops a means to analyse the data. It is often used in discourse analysis. In that dialogues are analysed for concept. A 2-year-old boy who has some vocabulary looked at mealworm on a table in a dish. 'Oh worm' he said, 'It looks like a worm'. He meant earth worm. Mealworms are in fact the larval stage of a beetle but there is some superficial resemblance, so he used information he already held, specific feature in this case a segmented body longer than it was wide, to categorise the organism. This was an observation, matching what he saw to his mental model he held. It would come into a theme of naming, which is basic human instinct and indeed allocating a name- or label- to a concept is the last stage in concept acquisition (Bruner et al. 1956 p.5)

We observed the child's interpretation of the scene for potential involvement, his choice, the thinking that must have been present with resultant investigations and outcome. In particular a two year old boy in a Stay and Play centre (Lloyd et al, 2016) in an outside play area, brought to a mornings session by his grandfather, chose two different small wheeled vehicle and ran round to the back of the small play side, climb up to the launch platform and after positioning the two vehicles carefully at the top of the slide and letting them go at the same time, rushed round and observed their descent and noted which arrived first at the other end of the slide.

Examples of children observing, playing with toys used, science actions, and experiencing basic concept such as pushing wheeled truck, force is pushing, they child encountered friction when he had difficulties physical pushing the truck over rough surface. Two examples are presented at this section to demonstrate a further understanding of our research. case studies are presented at this research to demonstrate the

Example 1

A group of five preschool children, 3 girls and 2 boys attending a private nursery in England participating in free choice art activity. The age of the preschool children was from 2 years and 5 months till 4 years old. The children were using colourful paper to create their art craft. A G1(4 years old) observing a basket with fruits at the home corner and suggest to the rest of the team to plant vegetable. 'we will use the colourful paper as solid', she says and continues 'They will grow'. The rest of the children group agree while they pick up their favourite vegetables they use a tray and the colourful paper as solid. A B1 (3 years and 7 months) add to the conversation 'do not place them depth, as they will not come up'. The child try to advice the group not to place the fruit depth at the pretend 'solid'- colourful paper as it will not grow. Finally, a G2 (3 years and 9 months) add 'But we need water, plant do not grown without water'.

At this example the group of children demonstrate an emergent science understanding of a biological concept which developed from a free play activity and children initiative.

Example 2

Two toddler age 1 years and 9 months(A) and two years old (B) attending a private nursery in England they are exploring Wooden Beads Around Intelligence game. Firstly, they present a coordination of movements while playing with the wooden beads. During the game they notice that the balls can be used different paths to reach the top. They start exploring the possibility of the ball to reach faster the top by using different routes the game provide. By demonstrating an understanding and using mostly gestures the toddlers come to a conclusion that the straight line is the quickest way to reach the top. The toddlers A (1 years and 9 months) and B (2 years old) by using a game relevant with their physical development demonstrate an emergent scientific concept relevant with the table 1.1, presents at the next section.

The above were only two of the case studies we explore while observing children during this research study. These case studies demonstrate to us the correlation of free play activities with the scientific concepts within.

We used the same approach of seeing 'what is'. What actions were taken at what concrete of otherwise situation, using thematic analysis technique (Braun and Clarke, 2006), to read and read our observations until we decided on themes of activity.

We made observations, in accordance with full ethical practices of the organisations or families who allowed us to observe (BERA, 2018). We made field notes on paper and took photographs of items the children chose to use to remind us. Eleven play groups in England were observed regularly over three years, ranging from a Church mother and toddler group to state run child care centres and nurseries.

Results

From our observations and field notes we identified the following main themes in spontaneous play in a playgroup type of informal setting. We observed play in general and noted the way in which children tackled their play. This we decided was the practice of science, the beginnings of working scientifically, aspects of the nature of science, which are an instinctive part of the interactions of these emergent scientists with their environment and the things therein. We identified that there are two main categories of play activities.

- Play activities: children spontaneously choose the activity will be explored. Children play and act with it at the free choice activities. For the basic science experiences helpers need guidance link them with potential literacy, numeracy and social skills.
- Planned science activities: where children can investigate.

Our themes and analysis of main basic science ideas were compiled into a table (1.1) for the English Observations presented below where the activity, the scientific concept as well as the science in action are presented.

Activity	Scientific concepts	Science in action
Play in general	Nature of science	Observation, recognising data, recall

		of past experiences, analysis of issue, planning investigation, choosing what is needed, organising items, other children or adult, instructing, data gathering, recording, evaluation, reporting, communication, repeating investigations, changing variables. identifying patterns, and over time
Sand play	Forces, properties, feelings, mixtures, evaporation, friction, surfaces,	Filling, pouring, capacity, emptying, making tunnels, wet and dry sand.
Water Play	Mixing, currents, forces, gravity, ice- change of state, properties of water, absorption,	Using senses, hot, cold, tepid, Forces, gravity, buoyancy, measuring capacity, surface tension, light, colour, refraction,
Construction (emergent engineering)	Properties of materials, center of mass, stability, strength, energy, purpose, design	Making towers, bridges, homes for something, recognising shapes in buildings, fences, triangles, squares diagonals, rectangles, circles appropriate materials
Physical	Crawling, running jumping, rolling, Balancing, throwing, catching	How they move, what they use, what happens. <ul style="list-style-type: none"> crawling through tunnels, on floor, running, chasing, sitting, dancing, hopping, jumping. Weather effects on body e.g. wind forces, slipping, heat, aching,
Malleable Materials	Forces used to change materials, properties of material, plasticity, joining, drying	Twisting, pressing, cutting shies, modelling shapes, adhesion
Cooking	Change of state, chemical reactions, effect of heat and cooling, heat transfers, evaporation, mass, measuring. Forces in cooking, <ul style="list-style-type: none"> pushes, pulls, gravity 	Change of state, heating, melting, role of foods, origin of foods, sieving, mechanical mixing
Dolls	Metamorphosis, development,	Caring, re-enacting child care, life cycles, carrying and pushing doll, taking and develop a sense of communication with it.
Construction	Centre of mass, stability, balance	Balancing, fixing pieces together, replication, drawing, painting, origami
Wheeled activities	Forces, push pull, twists, taut, friction, construction, gravity,	Collecting items and carrying around

	speed acceleration, deceleration	
Role play		Simulating adult behavior and tasks, talking adult way of speaking, cooking, cleaning, shopping, organizing
Biology focused	Metamorphosis, classification, `Life cycles, adaption, habitats, ecosystems,	<p>Painting toy animals, identifying, recognising adaptations habitats, finding habitats for particular organisms.</p> <ul style="list-style-type: none"> • How animals move • How self-moves, • How plants move, <p>Parts of human body, same parts in animals, (knee of cat's back leg and human leg), parts of plants. Colours in nature, growing, seeds, fruits, foods what they eat and what are they biologically.</p>
Outdoor Play	Light, shadows, weather, earth science	<p>Soils, pebbles, stones, weather, rain, snow, hail, ice, appropriate clothing, sky, clouds, sun, recording weather, indicator species, variety of plants and particular habitats, .clothes for weather Flight, pets, how animals move, behave.</p>
Mud play	Forces, mixing, properties	As above and Role play
Climbing frames	Forces, muscle powered, actions, balance	Risk estimate, energy, climbing, hand eye, coordination/
Slides	Gravity, friction, rates of descent with different loads	Using slide, decreasing their friction by sitting on mat running up, running down wheeled vehicles, different sizes and loads, rolling balls down,.
Ball games	Forces, pendulum, centrifugal forces, co-ordination, speed,	Bat and ball, ball on string, yo yos.
Numeracy	Measuring forces, volumes, mass	Counting, matching, shapes, pouring an amount quantity, measuring an amount
Literacy	Listen to stories, identifying images, matching, speaking, and making symbols, writing. Drawing to communicate	<p>Orientation of using a book, recognising symbols Linking illustrations to text Interpreting illustrations Identifying problem, solving story issue Critiquing, redesign myth and reality predicting next event, scale</p>

1.1 Table: Early Years Science (STEM) Actions and Skills in Play (Western)

The Table 1.1 represents the observed activity which took place as well as the scientific concept and the science in action. Via this thematic analysis it is obvious that there are scientific concepts as well as science in action demonstrated by the play activities documented.

There is some literature written focused on kindergarten children and science but begins with considering relevant aspects of science learning in children of 5 years of age. We consider that this table can be used as an educational tool where the pre-formal school practitioners could note which play activities children spontaneously choose. Is there a difference between disadvantaged (establish by pupil premium) and non-disadvantaged, children in their approach in their spontaneous investigations? What do children play with and actions with it, of free choice and what is the basic science experiences they explore. Taking into consideration that personnel, of whatever genre, need guidance on this and further links to literacy, numeracy and social skills to be able to observe, record, evaluate and report on a learner's potential.

We believe that, if we as practitioners along with other practitioners, are able to recognise the science in action in free choice play activities they, in formal or informal, situations may be able to develop as appropriate an awareness in these emergent scientists. Furthermore, identification of such basic science in action activities may provide confidence to the many personnel in early years who do not have an identity, (Avraamidou, 2017) or confidence in their scientific knowledge.

Conclusion

The starting point for the learning of science, at this early age, is play. Bottrill (2018) states that play is one of the most misunderstood concepts. The diverse and important functions of play have made focus of interest in how children learn and how play can be deployed to augment other modes of learning (Wells, 2015). In such activities these early learners are making observations, asking questions and problem solving, albeit to themselves, devising their own strategies for eliciting an answer. Such working out by the children are them using 'hidden questions' to themselves even though in the earliest of years, thoughts are not verbalized. Thus, the only evidence, we, as, observers, have is we can see the actions of children which an expressed model of their science play- investigation are thus. Moreover, such learning occurs in the immediate environment of the child, in its community, with the people with whom children spend their time and begin long before any formal educational interaction. Starting children on their path in learning science as in other subjects is a community endeavor. These places of potential learning are where they live and the immediate environment outside. In these locations children witness everyday activities such as cooking, cleaning, washing, various activities with materials such as textiles, wood, clay, as well as identifying and being involved with basic life processes such as moving, breathing, eating, excreting and the human activities associated with the life processes and beyond.

Children are immersed in their environment, to include natural structures various amounts of technology, maths and science. Thus, can range from a simple cooking vessel being used on an open fire to mobile phones; from natural vegetation to a manicured garden and the everyday non-built areas. Moreover, the natural environment is comprised from physical, geological and biological matter and features of this, such as rocks, plants and watercourses

may be observed. Additionally, the culture and particular uses of science and technology by the community with whom the children live are evident and noticed, pointed out by members of the community, buildings, transport, water sources for instance. If children cannot play can they develop as scientifically literate beings, problem solvers, communicators?

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