The Journal of Emergent Science

Issue 22 January 2022

The Association for Science Education
Promoting Excellence in Science Teaching and Learning

why & how? PRIMARY SCIENCE TEACHING TRUST

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Publisher:
Association for Science Education (ASE) College Lane, Hatfield, Herts, AL10 9AA, UK

ISSN: 2046-4754

The Journal of Emergent Science (JES) is published by ASE in partnership with the Primary Science Teaching Trust (PSTT).

It is free to access for all.

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why& how?
PRIMARY SCIENCE TEACHING TRUST

Editorial

● Sarah Earle

The aim of the *Journal of Emergent Science (JES)* is to make research more accessible, both in its online open access format and also in the way that it presents short articles that are relevant and close to practice. A further element is to make publishing accessible to authors, whatever their educational setting. In this editorial, I would like to demystify the process of 'getting published' to encourage both budding and experienced authors to share their practice more widely. You can find the full author guidelines for submission at the end of this issue, but it is the 'hidden' process between receipt of an article and it being publishing online that will be explored here.

Prospective authors may start with some research/practice that they would like to share and then go looking for a journal to match, or start with the journal submission guidelines and consider how their research/practice could align to an article type and the journal's audience. Either way, the author needs to decide what they would like to share with the audience and write it in a way that matches the submission guidelines for their chosen journal. Looking at recent past issues will give the author a sense of tone and pitch to supplement the submission guideline instructions. A written piece can only be submitted to one journal at a time, to avoid copyright issues with multiple publications of the same work.

Once an article has been submitted to the journal (for *JES*, this can be e-mailed directly to the Editor), it will be checked to see that it matches the style of the journal before it is sent out for review. If it is decided that the journal and article do not match (a 'desk rejection'), then a different journal may be recommended. For example, practical pieces for teachers may be directed to ASE's sister publication *Primary Science*. Since *JES* is only published twice a year, articles may be held until nearer the deadline (usually October for the January issue and March for the June issue) to be sent out to reviewers in a batch.

Most academic journals send articles out for review to an editorial board or list of reviewers. For *JES*, the Editorial Board reviewers comment on:
the clarity of writing, analysis and conclusions;
the use of literature/data/professional reflection, as appropriate to the article type; and
the significance and/or implications for early years and primary practitioners.

Academic journal reviewers consider the articles in their own time and with little recognition. Therefore, I would like to take this opportunity to thank the current Editorial Board (Table 1) for their time in supporting feedback to authors and edits to articles. Do get in touch if you would be interested in joining the Editorial Board to support future issues of *JES*.

Table 1. Editorial Board for the *Journal of Emergent Science*

Once reviewers have considered the articles, comments will be collated by the Editor, with queries and suggestions communicated to the author who may be asked to update their article. Since *JES* is keen to publish 'Practitioner Perspective' pieces, the Editor may work closely with authors to support publication. Once articles have been accepted and all the photos/figures received, the copy editor (Jane Hanrott) and designer (Commercial Campaigns) produce the issue.

Further support for writing for *JES*:

See submission guidelines and recent previous issues.

A live webinar to support budding writers for *JES* and *Primary Science* is scheduled for 8th March 2022 – see the Primary Science Teaching Trust (PSTT) website for details the month before. Do get in touch via e-mail or Twitter @PriSciEarle.

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Early science research summary: Use of play and role of the adult

● Sarah Earle

Abstract

The aim of this article is to provide an accessible summary of recent research into early science to support both early years and primary practitioners. Starting from the viewpoint of the child, rather than the subject of science, provides an early years perspective on science education. This summary draws on international research in both science and early childhood (up to age 7) to provide an introduction to key areas of debate in the use of play and the role of the adult. This short article cannot provide exhaustive coverage, but the aim of this summary is to bring together a range of work to provide a starting point for those seeking to consider research into early science.

Keywords: Early science, early years, early childhood, science education

Introduction

Science in the early years may not be explicitly called 'science', which is perhaps why those outside the sector may not be familiar with the research in this area. In fact, even those reviewing recent research into early childhood education and care note a paucity that refers to science or scientific enquiry (Rose & Gilbert, 2017). In England, early science has come under the spotlight, with primary science leads responding to a perceived push from Ofsted (2021) to track back lines of progression into the younger years, provoking questions about the dangers of 'backwash', rather than meeting the children's needs. There continue to be debates around purposes, whether the early years should be considered in terms of how it prepares for the next stage or how it supports the child's current rights and interests (Nutbrown, 2018).

Different starting points provide some explanation for the separation and lack of connection between phases: science education research usually starts with the *subject* of science, whilst early childhood research focuses on the *child*. The importance of the latter has become increasingly recognised, with research providing evidence for the significant impact of early childhood education and care on children's learning and life chances (e.g. Sylva *et al*, 2004). In addition, cognitive psychology provides insights into the capability of young children to build foundational concepts, learning from their early explorations of the world around them (e.g. Goswami, 2015).

It is proposed that an accessible summary of recent and international research into early science could support dialogue between early years practitioners and colleagues focused on science education. Relevant literature was initially located via a keyword search for *'early years/early childhood'* AND *'science'* since 2010 in both early childhood and science education international journals, together with identification of relevant reports (grey literature) and books available in the University library. Two areas of contention concern the role of play and the role of the adult, and it is these topics that will provide the focus for this research summary, after further consideration of the place of science in the early years. This short summary cannot provide exhaustive coverage and it is not a systematic review, but the aim is to bring together a range of work to provide a starting point for those seeking to consider research into early science.

Why consider science learning in the early years?

Science is both endemic and implicit in the early years. Young children learn through their interactions with their environment and such playful interactions are cross-curricular; they have no subject boundaries (Boorman & Rogers, 2000). Such interactions with the world are inherently scientific; the first step in any science enquiry is exploration or play (de Boo, 2000). As well as the *'specific area'* of *'Understanding the World'*, the statutory guidance for England lists three characteristics of effective teaching and learning: '*playing and exploring; active learning; creating and thinking critically'* (DfE, 2021:16), any of which could arguably apply to scientific exploration. Thus science can be found in every area of early childhood education.

Yet such a 'science is all around us' ethos may not be widely held, with some practitioners finding it difficult to see the science in their settings. A range of factors may be at play, including a view that science teaching methods have been developed for older children (Fleer, 2009), perhaps compounded by a lack of pedagogical confidence or even 'fear' of teaching science (Jones & Spicer, 2019).

In their evaluation of a STEM professional development programme for early childhood educators across Australia, MacDonald *et al* (2020) found that practitioner confidence was supported by recognition that science can be found in everyday experiences. Science is not something that only happens in laboratories, as one practitioner in the study noted: *'It's like simple things that you do every day… it's everywhere'* (p.360). Practitioner confidence can also be supported by understanding that, in developing the science process and way of thinking about the world, the adult is not expected to have an answer for every question that a child asks. Fleer (2009) argues that adult mediation is needed to build scientific learning through discourse with the child, which requires the practitioner to 'see the science' to be able to support the child.

In the US, Morgan *et al* (2016) found a strong correlation between low general knowledge in kindergarten and later low science attainment in elementary and middle schools, with the gaps between children from high and low socio-economic status widening. They argue that increased early opportunities for science could help to break this persistent cycle. Kähler *et al* (2020) in Germany found a similar pattern, that, for children from socially disadvantaged homes or those speaking a different language, initial differences in science in kindergarten persisted into primary school. However, they also found that attending a kindergarten where there was an explicit focus on science supported a positive impact on science learning, so argued that early promotion of science could help to reduce the disparities.

Early science is more than just preparation for later. Eshach and Fried (2005) identified a range of reasons to expose young children to science: enjoyment of engaging with nature; to develop positive attitudes and scientific thinking; to support later understanding through experience of phenomena and language; and that they are capable learners who *'can understand scientific concepts and reason scientifically'* (p.319). Larimore (2020) argues that early science education is a right for children and that they are entitled to *'make sense of their world for the joy and satisfaction it brings as well as the useful information it has for functioning in life'* (p.706). Campbell and Speldewinde (2018) similarly propose that young children's learning may be 'impoverished' without the opportunity to engage in science (p.38). If it is accepted that science learning can be an important part of early education, it is appropriate to next consider how to support such learning, which in this summary focuses on debates around the role of play and the role of the adult.

Debates about the role of play

We experience the world through our senses, combining multi-sensory information to develop our understanding (Goswami, 2015). Young children learn through their bodies and their senses (Boorman & Rogers, 2000). In fact, embodiment is relevant to all ages; as living bodies interacting with the material and social world, embodied cognition is a growing area for research (Kersting *et al*, 2021). Such direct experience through our senses is the starting place of scientific observation. Concrete sensory experiences help children to actively make sense of the world (Forrester *et al*, 2021). The exploration is led by the child, the playful infant has no constraint on time when they repeatedly put a rattle in their mouth or pour water between containers (de Boo, 2000). Such **playful exploration** is the precursor to scientific investigation (Johnston, 2010), the scientific method beginning with close observation.

Although, Campbell and Speldewinde (2018) note that there is a limit to sole discovery, with the role of the practitioner also being important in aiding understanding, as will be discussed in the next section.

The *Creative Little Scientists* project (2011-14) explored early science at 48 sites across nine European countries. They found that playful exploration was key for young children's learning in science, with the hands-on experiences supporting the children to make connections between their thinking and the environment. The ***'hands-on, minds-on exploratory engagement'*** (Cremin *et al,* 2010: 415) describes both the opportunity for the child to engage agentically in exploration of a range of resources, but also the opportunity for them to think about and discuss their ideas with others.

Early science provides the basis for **positive interests and attitudes** towards science, together with supporting a range of 'science-enabling' and 'science-specific' behaviours (Russell & McGuigan, 2016). Examples of 'science-enabling' behaviours include general logical skills such as classifying and ordering, which feature in both mathematical ordering of numbers and classifying vocabulary development in literacy, whilst more science-specific behaviours may be seen in early explorations or enquiries where children seek to answer questions and predict what might happen next. Skalstad and Munkebye (2021), in their study of outdoor learning in eight Norwegian settings, found that open exploratory activities led the children to move from asking practical questions related to task completion, on to higher level subject matter questions.

The adult has an important role in providing an enabling **environment,** which some describe as the third teacher (Grimmer, 2018). Forrester *et al* (2021) describe the importance of exposure to a diverse and rich environment. This includes open-ended materials, such as heuristic treasure baskets for babies or bags for toddlers (containing objects rather than 'toys'), or 'loose parts' construction materials for older children. Diverse and 'open' materials promote exploration and child agency (Cremin *et al,* 2015). Examples of practice can be seen in the Primary Science Teaching Trust (PSTT) 'Play Observe Ask' early years section of the website (see link below).

Outdoor experiences promote a wide range of learning and development, including exploration and possibility thinking (Rose & Gilbert, 2017). The use of outdoor spaces is an essential part of early years provision, particularly for science where, for example, the natural world supports development of biological concepts, 'messy play' supports the development of ideas about materials (early chemistry), and playground or vehicular play supports early physics. Davies and Hamilton (2018) note the prevalence of indoor adult-initiated teaching in response to accountability pressures in Wales and call for more recognition of the outdoor space as a place for learning. Campbell and Speldewinde (2020) propose that the bush kinder environment (Australian forest school) enables children to experience and improve their understanding of a range of science ideas: for example, with changes in weather over time enabling new insights to emerge. However, the scope of children's learning may be dependent on the educator's ability to scaffold their experiences and learning.

Sensory experience of the world leads children to develop **early scientific ideas**, for example*: naïve physics* ideas about the cause and effect of pushing or dropping; and the *naïve biological* ideas about moving and growing or the naming of categories of animal (Goswami, 2015). Such experience supports development of 'precursor models' of scientific concepts (Ravanis, 2020). Klofutar *et al* (2020) in Slovenia found that, whilst vicarious experiences of plants (from books etc.) can support observation and identification, direct experiences of forest organisms led to higher level and more persistent learning, since it enabled the children to use multiple senses at once, observing the trees holistically and linking the parts of a plant together.

Areljung and Sundberg (2018) note concerns regarding 'schoolification' and subject-based teaching, which may threaten the role of play and multi-dimensional teaching in pre-school pedagogy. They propose that the wide range of pre-school teaching dimensions such as fantasy, storytelling and sensory experiences should be used to support emergent science learning, which encapsulates both science concepts and methods. Pyle and Danniels (2017) propose a **continuum of child to adult-initiated play-based learning**, with one step up from 'free play' termed 'inquiry play'.

Inquiry play is child-initiated, but could include practitioner-scaffolded extension, for example, to support children to find out how far their paper planes had flown. Playful explorations could also feature further along the continuum in 'collaboratively designed play', co-designed with the children, and 'playful learning' adult-initiated activities. Whilst each of Pyle and Danniels' (2017) types of play could take place in a science context, they note the importance of an open practitioner viewpoint about the role of play, not to see 'play' and 'learning' as separate constructs, but to embrace a continuum of child- to adult-directed play, with opportunities for learning at each stage.

Debates about the role of the adult

The role of the adult is a much contested area in education, with a feeling that the practitioner needs to be all things to all people at all times. For example, Rose and Rogers (2012) describe the *plural practitioner*, with seven different dimensions that are integrated and interactive: critical reflector; carer; communicator; facilitator; observer; assessor; and creator (planning). It is through formative assessment, through sensitive and responsive scaffolding (Stylianidou *et al*, 2018), that the practitioner moves between these roles, co-constructing ideas in partnership with the children (Rose & Hattingh, 2014). Nutbrown (2018) prioritises **listening to the child**, arguing the importance of the child's voice and rights, as well as actively communicating with the family for an awareness of home-life experience. Such listening to young children's 'voices' can also include observing their actions, actively listening to what the child is 'saying' in their explorations (Nutbrown, 2018:30) and in their gesturing (Samuelsson, 2019).

Fleer (2009) argues that the child may not 'discover' scientific knowledge from just the provision of materials; **adult mediation** is important, supporting discourse and 'minds-on' activity. This suggests that there is an ongoing balancing act between listening to the child and mediating the learning. Rose and Rogers (2012) propose that adult- and child-initiated activities can *'co-exist in continuous interaction'* (p.71), perhaps a more 'meddling in the middle' approach (Craft *et al*, 2012). Stylianidou *et al* (2018) note the importance of opening up everyday learning activities so that there is space for children's decision-making and creative exploration. Part of the balancing act is also giving space and time for the children to explore at their own pace; incremental experience is crucial for learning and knowledge construction (Goswami, 2015).

The Oxfordshire Adult-Child Interaction project (2010-14) carried out action research with 18 practitioners, including paired discussions of video from 120 episodes to consider features of **effective interaction** (Fisher, 2016). For the interaction to be deemed effective, it needed to be a positive experience for the child and one where they gained something that they would not otherwise have had: the learning was enhanced by interaction with the practitioner (p.15). Such effective interactions are based on effective observation of the child, building a relationship and attuning to the individual, showing interest and getting to know their *'own personal cognitive jigsaw of the world'* (p.71). Scaffolding is seen to be responsive and fading, with the gradual transfer of responsibility over to the learner.

The **development of vocabulary** and scientific language is a key part of learning in the early years. Learning in young children is socially mediated (Goswami, 2015:24) and the role of dialogue is critical; it enables children to: *'externalise, share and develop their thinking, consolidate their ideas and develop verbal reasoning skills'* (Cremin *et al*, 2015:407). Using person-centred questions, such as 'What *do you think* will happen next?' (Harlen & Qualter, 2014), can open out discussions with children. Fisher (2016) emphasises the importance of 'wait time' when asking questions, both after raising a question and after hearing an answer, to give the child time to add more to their thinking (p.154).

The role of dialogue is further developed by considering the concept of **Sustained Shared Thinking,** where prolonged interaction includes exploring children's ideas and co-constructing ideas together (Siraj-Blatchford *et al*, 2002). The concept of Sustained Shared Thinking emerged from the Effective Provision of Pre-School Education (EPPE) longitudinal study, which followed 3000 children from ages 3 to 7, providing strongly evidenced recommendations about the importance of pre-school provision, especially for those from more disadvantaged backgrounds (Siraj-Blatchford *et al*, 2002; Sylva *et al*, 2004). 'Effective' settings (in general, not science-specific) were found to encourage open-ended questioning, Sustained Shared Thinking, modelling and an equal balance of adult/child-initiated activities. Science exploration could provide a context for episodes of Sustained Shared Thinking, whereby two or more individuals 'work together', for example, to talk through a problem, clarify an idea or evaluate an activity (Sylva *et al*, 2004). Although, Furman *et al* (2019) acknowledge that this is particularly challenging for less confident practitioners, noting that the 'driving force' in one setting was 'teacher talk' rather than 'true dialogues' and high numbers of 'unproductive' questions acted as 'noise' and were counterproductive to learning (p.283). The EPPE team also found that sustained dialogue did not happen frequently and, even in the most 'effective' settings, only 5.1% of questioning was open-ended (Siraj-Blatchford *et al*, 2002).

The adult has a key role to play in the **development of concepts**, for example, in expansion of children's vocabulary, which is fundamental to content knowledge (Guo *et al*, 2016). Whether describing children's early scientific ideas as 'naïve' science (Goswami, 2015), 'restricted conceptions' (Boorman & Rogers, 2000), preconceptions/misconceptions (Kambouri-Danos *et al*, 2019) or 'working theories' (New Zealand Ministry of Education, 2017), the adult plays an integral role in supporting the development of language to explain such ideas. The adult can help to develop 'higher tier' vocabulary by modelling language use (e.g. see PLAN EYFS website link below) and playing in parallel with the child (Guo *et al*, 2016), for example in continuous provision areas like sand, water, construction or a 'mud kitchen'. Larimore (2020) argues that the most important content knowledge is that which comes from explorations and play-based experiences with phenomena that are part of children's daily lives, advocating a 'figuring out' rather than 'knowing about' list of content to cover. Although adult mediation remains integral, Fisher (2016) also notes the importance of consolidation, suggesting that practitioners should not feel that learners need to be constantly 'moved on' to their 'next steps', since they need time to practise, repeat, revisit and rehearse, as they assimilate such a huge amount of new information about how the world works into their current internal model (p.15).

Another contentious role is that of **documenting learning in science**. Digby (2014) argues that documentation should be more than a record of an event; it should support the learning process through active engagement of both practitioner and learner. New Zealand's Te Whāriki early childhood curriculum champions narrative learning stories, which involve families in a holistic process (Ministry of Education, 2017).

Russell and McGuigan (2016) argue that direct experience alone may not be enough to develop scientific conceptual understanding; they suggest that re-representing their experiences through drawing or speech develops a self-aware metacognitive dimension that supports learning. However, Areljung *et al* (2021) found that, despite pedagogical benefits of drawing to support understanding to become explicit, few of the thirteen Swedish practitioners in their study utilised drawing as a tool for communicating and learning science.

A function specific to science is that of **role model of positive attitudes** (de Boo, 2000), especially since there is often an uncertainty or lack of confidence around science in the early years (Forrester *et al*, 2021), with trainee-teacher research revealing their low science capital (Jones & Spicer, 2019). Campbell and Speldewinde (2018), in their study of bush kinder in Australia, found that the inclusion of science appeared to be dependent on the teachers' science understanding and philosophy of pedagogy.

They argued that building practitioner science knowledge would support the teacher to 'see' more science in the children's experiences and play, and so be able to integrate more science into bush kindergarten exploration. Avoiding a negative or gendered approach to science in the early years (Rippon, 2021), and including diverse representation of science, could help to build science capital, a feeling that 'science is for me', from an early age (Archer *et al*, 2020; Nag Chowdhuri *et al*, 2021). Crompton (2020) also highlights the importance of a child's context, proposing that we cannot make children interested in science, but need to take time to understand their interests and the 'funds of knowledge' that they bring (Chesworth, 2016).

In conclusion

The literature explored in this summary provides an argument for the importance of science in the early years, building foundational concepts, language and interest in the world. It is argued that early science can be seen as a form of playful exploration, with a 'hands-on, minds-on' approach providing shared experiences, especially for those from disadvantaged backgrounds, supported by dialogue with an interested adult. As noted at the outset, a short summary is only able to introduce the issues rather than fully explore the literature. Nevertheless, the breadth of research into science and early childhood presented above indicates that there is a range of studies and publications that can be utilised to inform practice and further research; it just may take a broader view of science in the early years to find them. The *Journal of Emergent Science* welcomes future articles in which to discuss the issues further and to present new insights and research.

Acknowledgements

Thank you to colleagues across the early years sector for their suggestions and advice in the preparation of this article.

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Balancing play and science learning: Developing children's scientific learning in the classroom through imaginary play

Marilyn Fleer

Abstract

Models of teaching of science in the early years such as Discovery learning, Process approach and Guided Enquiry often begin with consideration of the science concept. But what if we want to begin with children's play? In this paper, we will look at a model of teaching science that begins with imaginary play. Through a case example of children playing being characters in the story of Robin Hood of Sherwood Forest, we explore how imagination in play supports imagination in science. The model presented is called a Conceptual PlayWorld for the intentional teaching of science and was developed from ten years of research in Australian early years settings. The five characteristics that make up a Conceptual PlayWorld are: selecting a dramatic story; designing an imaginary space; planning entry and exit; planning the science problem; and considering the role of the teacher. The pros and cons of beginning with the science concept or beginning with children's play are explored, together with a discussion of how to balance play and the learning of science in the early years.

Keywords: Play, science learning, early childhood, Conceptual PlayWorld

Introduction

Young children are curious about their world and express their wonder through active exploration and play. Evidence of this can be seen when children are outdoors digging for treasure, acting 'as if' archaeologists. Harnessing this active exploration and motivation for play to bring forward science learning is the goal of early years and primary teachers. But how do we do this in a way that preserves the child's desire to play, while systematically deepening their explorations to support science learning?

This dilemma can be split into questions about starting points and models of teaching, which will then be considered in turn:

1: *Do we plan in relation to everyday exploration and thinking that attracts the attention of the child, or do plan with science concepts in mind?*

2: *Do we draw on models of science teaching that begin with play or do we use a model that is oriented more to the science concept?*

Starting points for children's thinking in science

A synthesis of longstanding research into children's thinking in science across the globe (O'Connor, Fragkiadaki, Fleer & Rai, 2021) shows that studies either focus on the phenomenon, such as how a spinning top works, or the concept, such as what is the physics that keeps the spinning top moving?

Balancing play and STEM (Credit: Lara McKinley).

The former brings in children's interests in things in their everyday lives, such as their toys, whilst the latter is more oriented to planning for the scientific concept. Two examples of phenomena and their associated science ideas are shown in Table 1. The key question arising is: do we begin with the phenomenon or do we begin with the concept? There are many scientifically oriented phenomena

Table 1. Do we begin with the phenomenon or do we begin with the concept?.

The phenomenon that is of interest in the early years	Science topic	Children's ideas: What very young children might think
Rainbows (Siry & Kremer, 2011)	Light (e.g. Ravanis, Christidou & Hatzinikita, 2013)	Young children think about darkness rather than light. Being bathed in light during the day means that children do not notice the light. Some children think that beams of light are emitted from their eyes (often depicted in cartoons). Children do not necessarily think about the light going in straight lines, that it can be blocked (shadow), reflected with a mirror, absorbed by a dark surface or coloured cellophane, and refracted (rainbow).
Spinning top (Samuelsson, 2018)	Force (e.g. Klaar & Øhman, 2012)	Stored energy as we see in the spinning top, and the forces acting that bring the top to a standstill. Children experience force as they slide quickly down an icy slope. Children do not think about all the forces acting to stop motion, or when it is equally balanced (object is at equilibrium), such as when something is stationary.

Table 2. What are the pros and cons for beginning with the phenomenon or the concept?

Beginning with the phenomenon		Beginning with the science concept	
Pros	**Cons**	**Pros**	**Cons**
Connected to the life of the child.	Is more difficult to transfer the knowledge of the phenomenon to other contexts.	Big ideas in science give explanatory power to children, are predictable explanations, and can be used in different contexts.	Science concepts are complex, and focusing on concepts may not be personally meaningful to the child.
It is of interest to the child and therefore the child is more likely to want to understand the science that explains the phenomenon.	The science to explain the everyday phenomenon may be too complex for early years.	Having knowledge of scientific concepts helps children to navigate their world and make scientifically informed decisions.	The concept might not be relevant to the cultural community in which the child lives.

Jumping into the story (Credit: Lara McKinley).

that are of interest to young children and these can be brought into the learning of science concepts. Table 2 (on p.14) gives a snapshot of the advantages and disadvantages associated with making a decision about where to begin.

Models of teaching science in the early years

There are many ways of teaching science in the early years, such as:

1: Discovery learning: Provision of materials for self-learning, separate to the teacher, such as a science table or display in a pre-school

2: Process approach: Development of scientific skills, such as observing, classifying, inferring, etc. For example, giving children hand lenses and inviting them to observe something specific, such as a seed.

3: Guided enquiry: The teacher guides the learner while giving some aspects of decision-making during the enquiry process to the children: for example, setting up a problem for small groups, such as how to make dirty water clean.

4: Conceptual PlayWorlds for the intentional teaching of science: Creating an imaginary play situation where problems arise, which draws on specific conceptual knowledge from science, technology, engineering and maths (STEM) to keep the story narrative going, such as in the story of Robin Hood, who needs help with getting into the castle but does not know about the mechanics of drawbridges.

If we consider the spread of pedagogical models of play and science learning that already exist in the early years' and primary classrooms, they can be represented as shown in Figure 1. This figure shows, on the far left side, children's play activity that is not oriented to science. On the far right side is represented science learning where no play is featured. The graduations between these two extreme ends show either more play activity or more formal learning of science with minimal play.

In the early years, children engage with others and their world through play. Spontaneous play and exploration (left side of Figure 1) may not result in deep science learning. For example, in discovery learning, placing magnets and a range of materials on a science table may lead to children thinking that cold things are attracted to magnets.

In the more recently developed models of teaching science in the early years, such as guided enquiry or Conceptual PlayWorlds for intentional teaching, both play and learning are considered. We will look at two case studies from the perspective of the continuum of play and scientific thinking using science concepts.

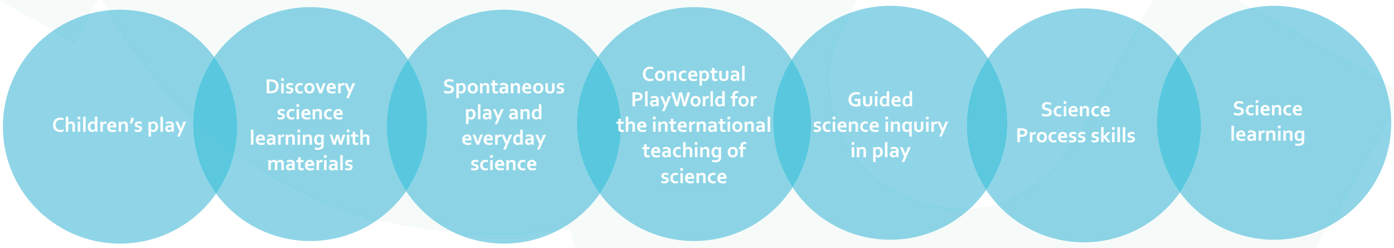


Figure 1. A continuum between play and science learning – where do you sit? (Figure 1 copyright Conceptual PlayLab).

Case example of forensic science – beginning with the concept

Howitt, Lewis and Upson (2011) used a guided scientific enquiry model that began with science concepts. They introduced forensic science to early years children by leaving footprints in the classroom and inviting children to work out who left them.

Their planning was stepped as follows:

1: Determining guided scientific enquiry process.
They worked with these guided scientific enquiry process skills:

- Students ask questions;
- Students are actively involved in finding answers to their questions;
- Exploring and investigating phenomena through using materials; and
- Making observations and developing explanations.

Focus	Learning activity	Making connections	Science process skills
Lesson 1: Discovering bear footprints in the classroom.	Who left these footprints? An evidence board is prepared.	Make cutouts of own footprints and compare those to the footprints found.	Making comparisons – my footprint is smaller/bigger.
Lesson 2: Planting fake fur around the classroom.	Using gloves, tongs and ziplock bags, children find and bag the evidence.	Class code pictograph is prepared, and children categorise hair colour.	Making comparisons – compare and discuss.
Lesson 3: A messy pawprint is found (honey is on the print).	Using cotton buds, the children take samples of the messy substance.	Children make own fingerprints using inkpads and paper.	Observations – using magnifying glasses, the children look at their fingerprints.
Lesson 4: Who left the evidence?	Children look at the evidence board and draw pictures of who they believe left the footprint/fur/messy pawprint.	Children plan an investigation. The research question was 'What foods can we make fingerprints from?'	Using evidence to make predictions.
Lesson 5: Undertaking an investigation.	Children carry out the investigation previously planned. Visiting the outdoor area as a group, going on a bear hunt and finding more evidence. Then finding a bear cave and discovering a note from the bear.	Fruit is placed on to 5 plastic sheets. The children press their fingers onto the fruit and then onto a plastic sheet to leave a trace. Children look at the fingerprints using magnifying glasses. Using a worksheet, the children match the fingerprints to the fruit.	Observations – using magnifying glasses, the children look at their fingerprints. Use observations as evidence. Represent and communicate their results.

Table 3. The plan for the forensic science programme studied by Howitt, Lewis and Upson (2011).

2: Understanding the principles of forensic science. They determined that forensic science involved:

- Application of systematic scientific process and knowledge to a legal problem; and
- Every contact leaving a trace (e.g. fingerprints, hair, fibres, soil, pollen, etc.).

3: Making connections between everyday ideas and scientific concepts within the forensic science programme. This is shown in Table 3, Column 3:

Part of guided scientific enquiry is the teacher supporting the children as they try to make sense of the phenomena under study – such as the principles of forensic science. The beginning point is the science enquiry skills and the science concept.

Case example of Robin Hood of Sherwood Forest – beginning with imaginary play

The second case study example begins with children's play. The context of the play is introduced through a book or storytelling, where problems arise that need scientific solutions. For instance, the story of Robin Hood from Sherwood Forest sets up social problems of poverty and the need to retrieve the treasure from the castle and redistribute the wealth to the villagers. Creating an imaginary situation by being players in the story of Robin Hood, and meeting problems during the play – such as how to get the drawbridge up – drives the children's play and amplifies the science learning opportunity.

The Conceptual PlayWorld for the intentional teaching of STEM involves five characteristics

Selecting a dramatic story (Credit: Lara McKinley).

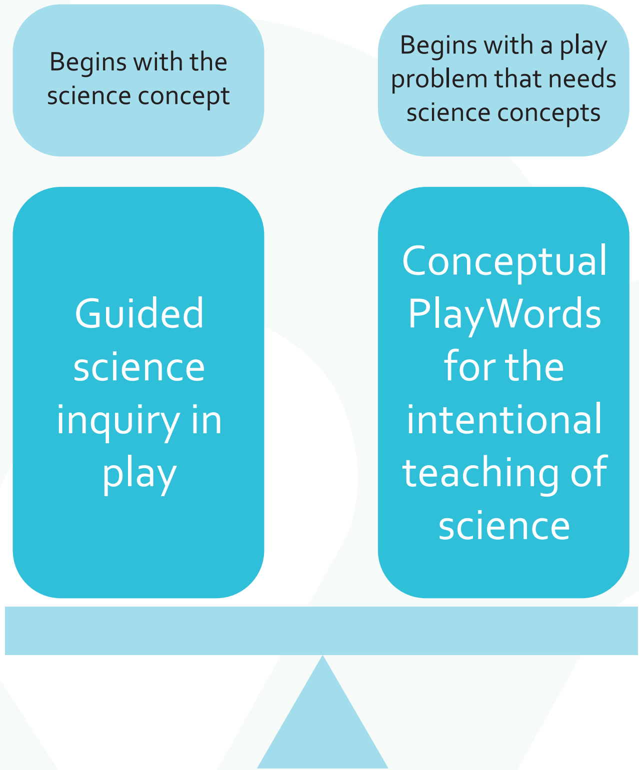
that are thoughtfully planned and implemented. They are shown in Table 4. Developing children's imaginary play (Robin Hood) and imagination in science (how to get the treasure out of the castle) is supported through the five characteristics of a Conceptual Playworld for learning science (simple machines and how they work). The imaginary play situation can last a morning, or it can take place over a whole term. This example of Robin Hood took a full term.

Characteristic	Details
1. Selecting a dramatic story	The story of Robin Hood was selected because it is full of drama and excitement – social problems arise because children want to help the villagers, who are poor. There are many different kinds of adventures (chapter books) or storylines that children or teachers can introduce so that the imaginary play situation can be dramatic and last for days, weeks or even months.
2. Designing an imaginary play space	The outdoor area with its play equipment becomes Sherwood Forest. The climbing equipment becomes the castle, where a drawbridge with a double pulley can be secured.
3. Planning the entry into the Conceptual Playworld	The fort becomes the time machine that takes the children back into the time of Robin Hood. Entry into the time machine has a countdown and children are taken back in time. Children return to the classroom through the time machine.
4. Planning the problem that needs science concepts	**Problem 1:** How to get into the castle to rescue the treasure to give back to the villagers who are starving. **Research:** Find out how drawbridges work. Make prototypes of castles and drawbridges. Study *YouTubes* about the science of drawbridges. **Problem 2:** Designing an escape plan to quickly escape and then to hide in Sherwood Forest. **Research:** Look at Google Earth to see castles, the children's school, their neighbourhood. Parent shows the children how to draw from a bird's eye view, front view, cross-sections – to help them design their plans. Look at books containing pictures of castles with cross-sections. **Problem 3:** Friar Tuck goes into the time machine and visits the children, carrying a letter from the Dragon who is stuck in the dungeon and needs help. **Research:** After visiting the Castle Engineer back in time, the children plan a simple machine to use to retrieve the treasure. Children look at *YouTubes* of cranes, and the science surrounding cogs and wheels. **Problem 4:** How to design a simple machine to retrieve the treasure. **Research:** The children use a pulley system, role-play being links in a chain, cogs and wheels, and make, with support, a prototype of their simple machine.
5. Planning the role of the teacher	The teachers are characters in the play, taking on a role and role-playing together with the children. Sometimes they ask for help, sometimes they give help, and sometimes they do things equally together. The different roles allow the educators to model or support the asking of questions, the investigation process, predicting, planning and trying out ideas, gathering evidence, discussing the evidence, presenting and communicating their ideas, etc.

Planning a Conceptual PlayWorld for the intentional teaching of STEM (Fleer, 2020).

Table 4 shows how imaginary play is used for the teaching of STEM concepts. For the children's play to continue, they need to do some research. They take back into the play their ideas, such as their escape plan, which they take to the Castle Engineer for advice. Similarly, children take their hand-held devices and record how the castle drawbridge works, and then return with their data to the classroom, and discuss how to build a prototype of a drawbridge. As the children learn more about drawbridges, simple machines and design drawing, their play is enriched with science in the imaginary Conceptual PlayWorld of Robin Hood. Further examples are shown as videos in the resource list below.

Figure 2. An invitation to consider the balance in your context for beginning with a science concepts or beginning with children's play.



Conclusion

In this paper, two case studies of science teaching were presented. One approach began with the science concept and the other with children's play. Table 5 presents some pros and cons of both ways into science learning. Figure 2 invites you to consider the balance of play and science learning in your programme.

As teachers, we need to make decisions about what approach will work best for the particular children and the setting that will draw on individual pedagogical beliefs about how children learn and develop. For example, in providing opportunities for a child to go outside and look for slaters (woodlice), they are building ideas of the play area as a habitat, looking for a species under its food source of rotting logs. In this example, the child has built a rudimentary relational model of a core concept of an ecosystem (habitat – structural features of a species – food source). This is the kind of scientific thinker that we hope will emerge in the early years.

This paper invited you to consider how to preserve the child's wish to play and systematically deepen their explorations for the learning of science concepts. We investigated beginning with the phenomenon, a play problem or the scientific concept. There are many pros and cons associated with making decisions about teaching and learning

Beginning with play		Beginning with the science concept	
Pros	**Cons**	**Pros**	**Cons**
Children are highly motivated in play. When they want to help the character to solve the problem, they are really in tune with the science concept.	Children may not be interested in bringing science concepts into their play.	The science concept and the process skills drive the learning activities. There is more confidence that the science is being covered.	Children may not be motivated to focus on the science or the process skills.

Table 5. What are the pros and cons of beginning with the play or the concept?

in science in the early years. What is key for effective learning is planning a programme that brings to children not just scientific lenses for understanding their world, but a passion and motivation for scientific activity and thinking.

Further information and resources

Go to the project website for a wide range of examples and supporting materials, including a planning proforma to design your own Conceptual PlayWorld for the intentional teaching of science: https://www.monash.edu/conceptual-playworld/early-childhood-educators/playworld-starters-for-educators

Early years in school: The Secret Garden

Overview: https://youtu.be/Uou55FDiu88
Characteristic 1: Select a story: https://youtu.be/_fZ2PVNQaDY
Characteristic 2: Design the space: https://youtu.be/ArS_-F-EoVw
Characteristic 3: Plan entry and exit: https://youtu.be/kXykFMxeKUA
Characteristic 4: Plan the play inquiry: https://youtu.be/NtVrL2x_6OM
Characteristic 5: Plan teacher interactions: https://youtu.be/S47u8W5r4jU

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A deeper layer of enquiry: Using the Heuristic Investigation Delayed Evidence (HIDE) approach to evaluate how students select evidence

● Mason Kuhn

Abstract

It is widely emphasised in contemporary science teaching that students should engage in practices of enquiry similar to actual scientists. In an attempt to meet these expectations, many teachers have turned to 'hands-on' lessons that can be fun for students but may serve as a faux proxy to meet the expectations and rigour that the authors of reform-based standards intended. In an attempt to meet the expectations of these standards, the Heuristic Initiative Delayed Evidence (HIDE) method was created. The method starts with students using experience to learn instead of being told how things work, followed by teachers waiting to provide vocabulary and information about the science content after students explore the phenomenon. In this study in Grade 6 (age 11) in the United States, we evaluated how students selected evidence before and after they were taught using the HIDE method and compared that to students who were taught by a teacher who used a more traditional method.

Introduction

It is widely emphasised in contemporary science teaching that students should engage in practices of enquiry such as planning investigations, analysing data, and engaging in argument from evidence (Alexander, 2017; Bråten, Muis & Reznitskaya, 2017; Windschitl & Stroupe, 2017). This research has resulted in new science standards in Australia, Europe and the United States (see Australian Curriculum, Assessment and Reporting Authority [ACARA], 2009; UK Department for Children, Schools and Families [DCSF], 2009; Next Generation Science Standards [NGSS Lead States], 2013; Promoting Inquiry in Mathematics and Science Education across Europe project [PRIMAS], 2013). A common call made by science education researchers is that teachers should focus on the content and process of science (National Research Council, 2012). One practice with which professional scientists frequently engage is evaluating the strength of evidence, considering conflicting ideas, and deciding which source they should trust when they ultimately decide which claim they support (Oreskes, 2019). The urgency to teach enquiry to students is highlighted in the Association for Science Education's (2018) list of 'best practices' for science teachers, citing such benefits as '*developing problem-solving skills, working with independence, developing skills to think like a scientist, and effectively communicating their understanding of the content'* (p.2). However, there are critical aspects of enquiry that are typically left out of 'school science', including pedagogy that promotes creative thought, considering multiple solutions to a problem, and evaluating the strength of evidence.

To accomplish this goal, teachers need to adjust their role from being a 'gatekeeper of knowledge' to someone who manages student uncertainty (Manz, 2015). Recently, Chen and Benus (2019) evaluated how teachers approach this challenge and found patterns of *raising*, *maintaining*, and *reducing* uncertainty. Their work comes from the view that science is a base of knowledge built from communities of experts who pursue endeavours to understand our natural world better. In actual science, uncertainty is raised when ongoing phenomena lack a proper explanation and require further enquiry; it is maintained as scientists seek evidence and argue its merits with peers, and is reduced when a clear set of evidence is deemed satisfactory, and the community takes a position (Kuhn, 1962). With those ideas in mind, the Heuristic Investigation Delayed Evidence (HIDE) method was created to take those aspects of uncertainty management and develop a practical classroom-based approach. The term HIDE was developed from the pedagogical pathways that teachers are encouraged to take. The method starts with students using experience to learn instead of being told how things work. Delayed evidence refers to teachers waiting to provide vocabulary and information about the science content after students explore the phenomenon, and designing instruction where students continue with the enquiry process as they figure out which evidence should be trusted. In the following sections, we will describe HIDE in both general terms and an example in the context of light.

Heuristic Initiative (raising and maintaining uncertainty)

The HIDE method begins with an exploration of a phenomenon (see Figure 1) where students are not front-loaded with vocabulary but, instead, they discuss what they observed with their peers and then engage in dialogue about what they think it means. Phenomena can be anything that teachers imagine, but examples that we have seen include stations of materials related to light and sound to kick off an energy unit, videos of strange weather patterns to support thinking about climate, a nature walk to a nearby park or playground to support thinking about the symbiotic relationship of plants and animals, or any type of activity that elicits wonder about a topic and asks students to share their understanding.

Next, teachers ask students to take what they know about the phenomenon and co-create a 'Big Idea' for the unit with the teacher. The concept of the Big Idea was borrowed from the work by Hand and Keys (1999), which asks teachers to shift teaching from traditional methodology such as memorising facts to focusing on argumentation as a means to learn about concepts, or Big Ideas, at a deeper level (Cavagnetto, Hand & Norton-Meier, 2010; Martin & Hand, 2009; Yore, Bisanz & Hand, 2003).

In this context, a Big Idea is a simple statement that connects the various aspects of phenomena exploration and serves as a starting point to pique student interest (Akkus, Gunel & Hand, 2007). The Big Idea should be considered a launchpad that gives students a foundation from which to start, but requires the students to participate in a more detailed investigation and subsequent research to understand the concepts at a deeper level.

As part of the Heuristic Initiative, the teachers we worked with in this professional development

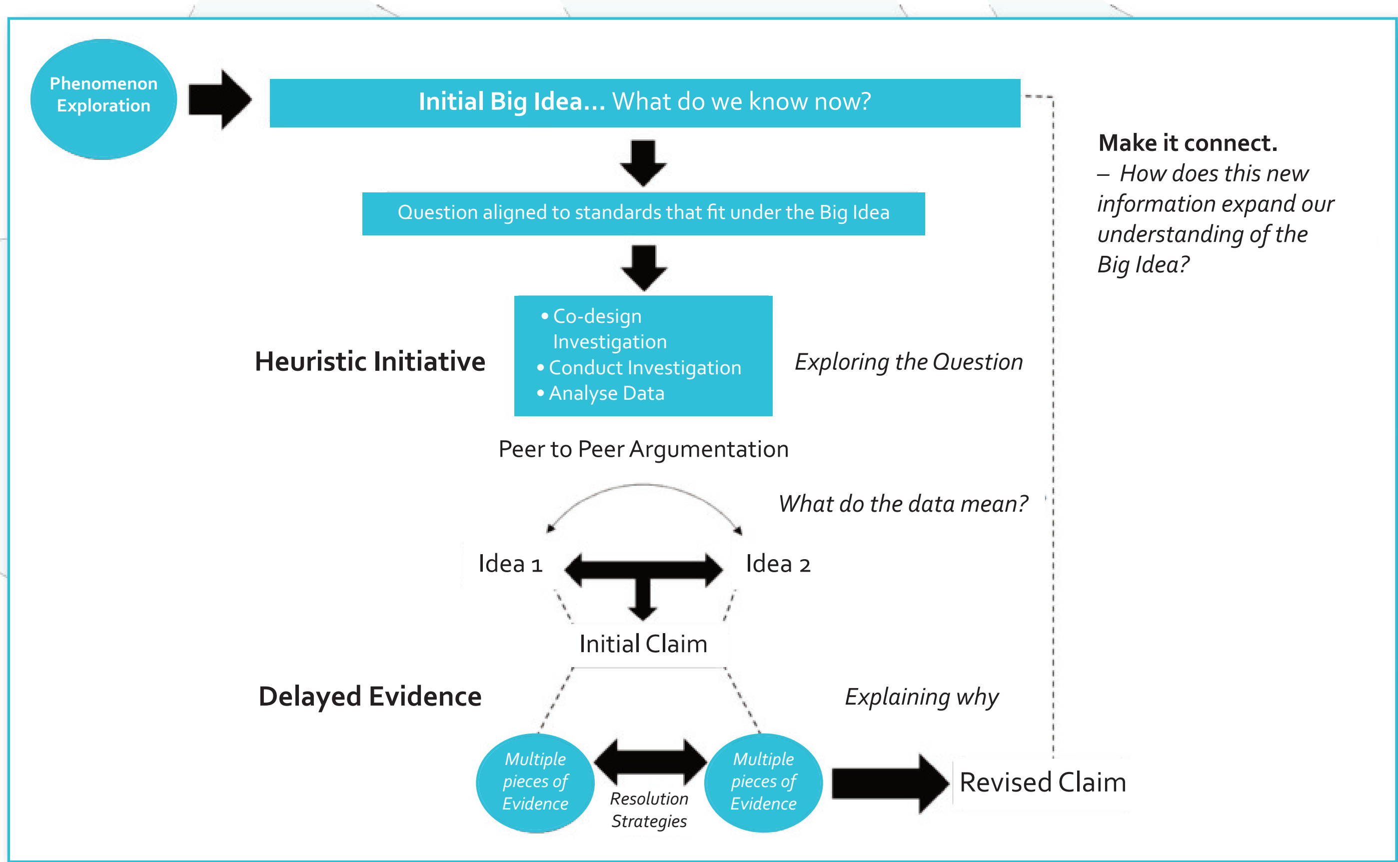


Figure 1. Flow chart of the HIDE Approach.

research project asked their students to answer the following questions:

- How do we write a testable question?
- What is the best type of investigation?
- What are the independent variables, dependent variables, and what variables do we need to attempt to control (if conducting an experimental design)?
- How are we going to collect the data?
- How will we analyse the data?
- How do these data help us answer the research question?
- How do these data help us better understand the Big Idea?

The flow chart of the HIDE method in Figure 1 shows how uncertainty is raised and maintained by setting up a phenomenon for students to explore, developing a Big Idea to guide the investigations, and generating multiple questions and investigations related to the Big Idea.

For example, if primary students were investigating light, teachers could set up stations with mirrors, prisms, cups of water, magnifying glasses and translucent items at the stations (see Figure 2). Next, the teacher would provide students with flashlights and have them take turns rotating around the stations using their flashlights to explore the phenomenon. After the students finish making their observations, the teacher would gather them in a whole-group discussion about how the light interacted with the objects.

At the end of the discussion, the teacher would co-create a Big Idea with the students about light and how we use it to see. The Big Idea for this standard would be *'Light interacts with objects and we need it to see'.* After that, the teacher and students would make a list of questions to investigate. The teacher would allow the students to develop their own questions in which they are interested and multiple questions could be investigated at once, but the teacher would include the question *'How do we use light to see objects?'* to make sure that the enquiry covers the content in the standards.

Finally, the teacher would ask students to design an investigation where they would use the materials available to them to answer the question, followed by an informal argumentation lesson where students would make tentative claims based on the evidence collected during the investigation.

Delayed Evidence (maintaining and reducing uncertainty)

After students conduct the investigation and collect data, the teacher asks the class to explain what the data mean and how they help them to

Figure 2. Stations that the teacher used for the Heuristic Initiative.

answer the question. At this step, the teacher would still maintain the uncertainty by asking students to explain why the data came out the way they did without telling them the answer. In the HIDE method, teachers are asked to allow students to raise competing ideas of what the data mean; however, the teacher should come prepared for this lesson with at least two competing ideas if the students do not create them on their own. One of these ideas should be supported by science, and the other idea should represent a common misconception or a plausible explanation that is ultimately wrong.

For example, if primary students were investigating the phenomenon of how our eyes interact with light in order to see, the competing ideas might be:

1. We see objects when light reflects off the object and enters our eye.
2. We see objects when light enters our eye and then we shoot it out.

At this point in the investigation, the teacher should allow students to choose which idea they support and argue with each other about why one idea should be supported over the other. The teacher would ask the students to think about what reasons they have for supporting the idea and explain why they do not support the other idea. After more peer-to-peer discussion, the students would write out a formal explanation of their understanding using a Claims-Evidence-Reasoning format, where they state their claim, provide evidence to support it, and then engage in reasoning by thinking about how they will figure out if their idea is correct or incorrect (See Figure 3). Teachers should emphasise that everyone should remain open-minded at this point, and teachers should also emphasise that more research needs to be done to work out which idea should be supported (see Figure 3). An advantage of using this approach is that the teacher can see if the student has a misconception about the content. For example, in Figure 3 you can see that the student thinks that our eyes work like flashlights or headlights. This information could be helpful during the next lesson when students engage in argumentation, because the teacher could lead the discussion by asking their students: 'Do our eyes work the same as flashlights?'

Next, the teacher will attempt to reduce uncertainty by providing multiple pieces of evidence for the students to read (or watch) that is grade-appropriate and would give the students the correct answer to the question that they are investigating. With lower primary grades, we have created lessons that have students read a passage that has the correct answer. For upper primary students, we have created lessons that provide multiple pieces of strong evidence to support the correct idea and pieces of weak evidence for the incorrect ideas.

For example, if we continue with the phenomenon of how light behaves, we can have teachers creating the following pieces of evidence:

- A document explaining how light travels, written by a scientist (terminal degree in physics and conducts research with other experts).
- A second document written by another expert and providing multiple examples of how light can be reflected, refracted, or absorbed.

Next, we have worked with teachers to create weak evidence for the competing idea that light enters your eye and then shoots out. Some examples of weak evidence include:

- A video produced by a non-expert (i.e. a middle-school student) claiming that our eyes work like a laser, shooting to the spot we want to see, but only offering their opinion without providing any evidence.
- A blog post written by an anonymous author who claims that our eyes work like the headlights of a car, but only offering their opinion without providing any evidence.

There are multiple ways to vary the strength and weakness of the evidence, including sourcing, claim-evidence link, and statistical significance of data. However, some of those examples are too complex for primary-age students (especially lower primary grades). In the examples in this section and the research project that we will describe in this paper, we focused on sources of evidence but, in other projects, we have helped teachers to design weak evidence examples that include mathematical errors and claims that violate logic fallacies. Since knowing which source to trust is such an important aspect of how lay people interact with science, this study includes a student task related to the trustworthiness of evidence.

Figure 3. Picture of a student explaining their initial interpretation of the phenomenon.

Question: How do we see objects?

CLAIM *Remember your claim is your answer to the question.

I think that….

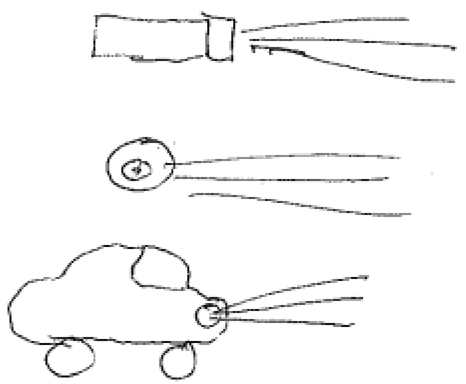
The light goes in our eye and then we shoot it out to see

What is your **evidence**? *Remember evidence is the information that supports your claim.

Our eyes work like a flashlight

or a car

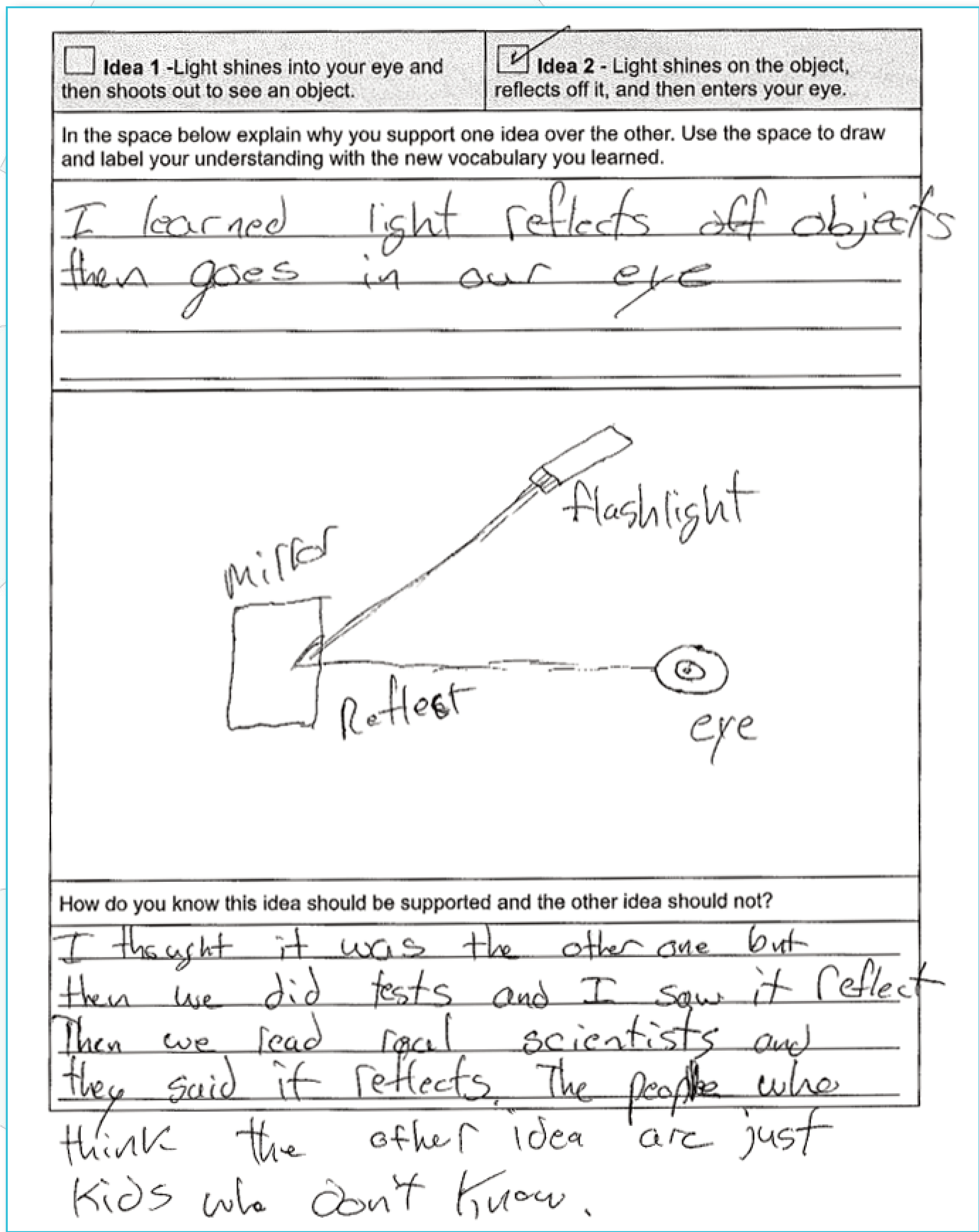
Use the space below to explain your answer through drawing



Reasoning *Remember reasoning is thinking about all the ways an idea might be right or wrong.

How will you figure out if this idea is right?	Why might this idea be wrong?
I will read about it	If light goes into our eye.

Figure 4. An example of a student's revised claim after reading the multiple sources of evidence for each idea.



☐ **Idea 1** -Light shines into your eye and then shoots out to see an object.	☑ **Idea 2** - Light shines on the object, reflects off it, and then enters your eye.

In the space below explain why you support one idea over the other. Use the space to draw and label your understanding with the new vocabulary you learned.

I learned light reflects off objects then goes in our eye

How do you know this idea should be supported and the other idea should not?

I thought it was the other one but then we did tests and I saw it reflect Then we read real scientists and they said it reflects. The people who think the other idea are just kids who don't know.

Figure 5. A summary of the HIDE method and how it helps teachers to raise, maintain and reduce uncertainty.

The Heuristic Investigation Delayed Evidence Method		
Raise Uncertainity	*Maintain Uncertainity*	*Reduce Uncertainity*
Phenomena Exploration *–Ask students to share their understanding. And develop a Big Idea based on their prior knowledge.*	**Initial Argumentation and Claim** *–Ask students to analyse the data collected and describe in their own words what they think happened.*	**Reliable Resource** *–Include a discussion about why a resource is reliable or have students search for information and vet the source they find.*
Design Investigations *– Ask students to think about how they will investigate the phenomena and how to design a fair test.*	**Competing Models of Understanding** *– Present two ideas to the students and have them engage in scientific argumentation (Claim, Evidence, and Reasoning) to present their understanding at this point in the lesson.*	**Revise Claim and Include New Vocabulary** *– Ask students to revise their claim and either explain why their initial idea was wrong or expland their understanding by including newly-learned vocubulary.*

Research question

What is the relationship between teachers' use of the HIDE method and how their students select evidence for their claims?

Method

In the study, two 6th grade teachers and their students (n = 217) in a large metropolis school district in the southwest United States served as the participants. One of the teachers in the study had finished the first year of an optional multi-year professional development designed to help teachers to create a curriculum using the HIDE method. The second teacher did not attend the professional development and used a traditional approach to instruction that relied on teacher lectures and demonstrations. Both teachers agreed to record five 45-minute lessons: specifically, lessons completed after students finished an investigation and before the teacher explained the science behind the activity. To further evaluate the instructional differences between the two teachers, the author and a graduate assistant evaluated the videos using the Reformed Teaching Observation Protocol (RTOP, Sawada & Piburn, 2000) after they were formally trained in how to score the tool.

The RTOP is a commonly-used observational instrument that has been utilised frequently in research to assess the degree to which mathematics or science instruction in grades K-12 (ages 5-16) is reformed (Sawada & Piburn, 2000). Possible scores range from 0 to 100 points, with higher scores reflecting a greater degree of use of reform-based instructional practices (Sawada & Piburn, 2000). A Cohen's κ was conducted to determine if there was an agreement between the two reviewers, and a high level of agreement was found ($\kappa = .791$, $p < 0.001$).

Finally, each student in the teachers' classes was given two modified versions of the Illinois Critical Thinking Test (Finken, 1992) in the autumn of 2018 (before any science instruction) and in May 2019.

The Illinois Critical Thinking Test was chosen to measure the quality of the students' argument and the evidence used to support their argument, because the rubric for the assessment uses a claim, evidence, reasoning framework similar to Toulmin's (1958) argument framework.

Before administering the assessment, teachers provided a prompt of '*Please read the question at the top of the page, think about your answer, read the available evidence and then write the best scientifically-based answer you can that explains the reason why you support your idea over others*'.

We designed a task where students were asked to write an essay about a topic, and they were provided with eight documents of evidence (four supporting the topic and four against it; see

Table 1) written by fictitious authors. The evidence documents were designed to have varying degrees of trustworthiness by assigning the epistemic trust (ET) characteristics of expertise, integrity and benevolence to each 'author' (Hendriks, Kienhues & Bromme, 2015). In the autumn, students were asked: 'Do you think violent video games make kids act violent?' and, in the spring, students were asked: 'Should we invest more money in space exploration or focus on problems on Earth?'. The key aspects of ET mentioned earlier were considered when assigning attributes to each author (see Table 1). It is important to note that we were not concerned with which position the students took on the topic. Instead, we were more interested in how the students selected evidence to back their claims.

Results

Teacher 1 (who attended professional development and used the HIDE approach) scored significantly higher on the RTOP than Teacher 2. Specifically, Teacher 1 had a mean score of 74 for the video lessons they submitted, and Teacher 2 had a mean score of 29. Ebert-May *et al* (2015) created categories based on aggregate RTOP scores and, according to their rating, Teacher 1's instruction would be described as *'Active student involvement in open-ended enquiry resulting in alternative hypotheses, several explanations, and critical reflection'.* Using the same criteria, the videos submitted by Teacher 2 would be described as *'Lecture with some demonstration and minor student participation'* (Ebert-May *et al*, 2015, p.4). These additional data were helpful because they show

Source 1 *Peer – 6th Grade Student*	**Source 2** *Middle School Principal*	**Source 3** *Former Researcher who works for a Video Game Company*	**Source 4** *Scientist at a Major Research University*
Synopsis of Article (E1 - Pro) Explained how they play violent video games and they are not violent. (E2 - Con) Explained how they had a friend who started getting into fights after they started playing violent video games.	**Synopsis of Article** (E1 - Pro) Explains how they have observed more office referrals from students who self-reported to play violent video games. (E2 - Con) Explains how there is an after-school video game club at their school. Sometime kids play violent games at the club and they have never had issues with violent behaviour with those students.	**Synopsis of Article** (E1 - Pro) Explains that their research shows that violent video games do not cause violence and even improve academic performance. (E2 - Con) Explains that they have research that shows violent video games cause aggressive behaviour, but education video games (produced at the company he works for) improve academics.	**Synopsis of Article** (E1 - Pro) Empirical evidence suggests that violent video games might increase short-term violent behaviour. (E2 - Con) Empirical evidence (from actual peer-reviewed articles) suggests that there is no correlation between violent video games and violent behaviour.
Low Expertise/ Integrity No degree, no collaboration with experts, anecdotal evidence, and no citations or referencing professional organisations.	**Low Expertise/ Integrity** No degree, no collaboration with experts, anecdotal evidence, and no citations or referencing professional organisations.	**High Expertise/Integrity** Terminal degree in the field, recognised and publications from peer-reviewed articles.	**High Expertise/ Integrity** Terminal degree in the field, recognised international expert, and citations from peer-reviewed articles.
Low Benevolence Promotes a specific video game (either violent or non-violent) and asks readers to follow them on social media.	**High Benevolence** Explains how the aim of their article is to help students be more informed so they can be better students.	**Low Benevolence** Lost their job at the university because it was discovered they were being paid by a video game company to publish articles that promoted the type of games the company made.	**Low Benevolence** Explains how the aim of their article is to provide the most accurate information to readers so they can make informed decisions.

Table 1. Description of each source of evidence that students in the study could choose from.

some clear differences between the instructional practices of the two teachers and that Teacher 1 implemented the HIDE approach in a way that was commensurate with the professional development they received the previous summer.

Finally, Table 2 has the results of how the students in the study selected evidence. The results highlight a significant difference between the students taught by Teachers 1 and 2. Students taught by Teacher 1 saw a 33% increase in selecting the evidence written by the fictitious author who had high expertise/integrity and benevolence. Those same students selected the fictitious author who had low expertise/integrity and benevolence 12% less at the end of the year than they did at the beginning of the year. The students taught by Teacher 2 had almost no change in the authors they selected for their evidence. In fact, those students selected the author with high expertise/integrity and high benevolence 2% less at the end of the year when compared to their essays at the beginning of the year.

Summary

The data from the study are encouraging because there was a clear difference in how the students selected evidence. The main result was that the students who were taught by the teacher using the HIDE method selected evidence from the source that would be considered more epistemically sound. It is important to note that the results of this exploratory study need to be considered with a degree of hesitancy due to the small sample size of two teachers. However, the main finding was the shift in how their students selected evidence to support their claims after a year of two very different approaches to instruction. This study would need to be replicated with more teachers and students to increase the confidence in its findings.

In the introduction to this paper, we mentioned that science teachers had been called upon to teach both content and process of science. One aspect of the process of science that is overlooked in science education is how scientists determine if the evidence they encounter is high enough quality to be considered in the construction of their knowledge.

However, most science curricula spend little to no time discussing why the evidence that supports scientific knowledge is reliable, or how the process

Evidence Sourcing	Source 1 *Low Expertise/Integrity Low Benevolence*	Source 2 *Low Expertise/Integrity High Benevolence*	Source 3 *High Expertise/Integrity Low Benevolence*	Source 4 *High Expertise/Integrity High Benevolence*
Students for Teacher 1 Pre-Test Selection	21 (16%)	35 (27%)	31 (24%)	41 (32%)
Students for Teacher 1 Post-Test Selection	4 (4%)	19 (15%)	8 (6%)	84 (65%)
Change in Evidence Selection	△ - 17 (-12%)	△ - 16 (-12%)	△ - 23 (-18%)	△ + 43 (+33%)
Students for Teacher 2 Pre-Test Selection	18 (16%)	31 (27%)	30 (26%)	37 (32%)
Students for Teacher 2 Post-Test Selection	12 (10%)	35 (30%)	34 (29%)	35 (30%)
Change in Evidence Selection	△ - 6 (-6%)	△ + 4 (+3%)	△ + 4 (+3%)	△ - 2 (-2%)

*Note– Teacher 1 Student *n*=107; Teacher 2 Student *n*=110.
*A student's essay could receive more than one code and the aggregate score and percentages reflect how many students within that category had the same coded response.

Table 2. How the students in the study selected evidence in their essays.

of science evolves over time. This topic has become paramount in recent years, with so many people finding scientific information online and the massive amount of misinformation being spread over those formats (König & Jucks, 2019).

In this study, we were focused on the instructional practices of teachers and whether these influenced student choice of evidence. We were interested in collecting data to determine if these types of learning environments would change students' proclivity to select quality evidence for their claim. We believe that promoting evidence quality evaluation is a worthy aim of science instruction and can be accomplished by adjusting a few key pedagogical choices.

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Science-based books: task or pleasure?

• Patrick Egan

Abstract

This article examines data gathered in a study of using non-fiction and fiction science-based books as a basis to stimulate interest in learning about science to primary school children in Ireland. The data gathered were part of a project with four schools that were involved in a doctoral study thesis. As a result of this, the researcher established a school-based reading challenge for children aged between 6 and 10 years to read science-based books, centred in their school and home environments. Prior to undertaking the project, a survey was conducted where teachers helped identify children's reading habits as well as their knowledge of the science process. After the time allotted to the challenge had ended, participating teachers completed questionnaires and a sample group from each school were interviewed. Evidence relating to reading for pleasure was identified, extracted from the data set and analysed, and more positive attitudes resulted from taking part in the project. Contemporary science-themed books were found to be, in themselves, a source of pleasure. The study concluded that it is possible to differentiate between the pleasures of fiction and non-fiction science books: the types of pleasure that can be differentiated, and that different types of pleasure derived from reading science-based books can also be differentiated, ranging from extrinsic to intrinsic and including sensory to aesthetic.

Keywords: Reading, fiction, non-fiction, science information story books, aesthetic

Introduction

'Somerset Maugham once said that all intelligent people over twenty read nothing at all. Nowadays, all intelligent people over twenty read nothing that's not assigned' (Gore Vidal, 1993).

Many will concur with Vidal's assertion that most people, particularly in the school environment, only read to further their studies. Doris Lessing furthered this with:

'Books, literature...should be seen as pleasure, full of surprises and paths leading to whole worlds of delight and never a sort of agenda or requirement of the adult world' (Lessing, 1998, p.49).

While reflecting on these views, we can be certain that both these writers felt that children's pleasure in reading may be harmed by adults who deem reading as 'assigned' or as 'a requirement'. Can the same be assumed of science-based books? Until recently, reading in the USA has focused on fiction to help to learn science. However, the Common Core State Standards and the Next Generation Science Standards both emphasise the reading of non-fiction texts to gain specific skill sets for analysing information (Job & Coleman, 2016).

Science is viewed as a cross-curricular approach whereby children are encouraged to explore, observe, and find out about different things pertaining to the world around them (DfE, 2014). Finding things out for scientific purposes is usually achieved through enquiry-based activities, which develop children's enquiry skills such as observing, asking questions, and looking for patterns (Sackes *et al*, 2009b). These skills lend themselves well to early years settings as they lay down the foundations for developing scientific skills and attitudes needed for later school life (Sackes *et al*, 2009b). Cremin *et al* (2015) indicate that there is a synergy between science education and creativity in the early years, which allows teachers to contextualise children's investigative and exploratory engagement in meaningful ways.

Therefore, children's literature, whether it is fiction or non-fiction, is deemed an effective pedagogical tool that gives children a context for exploring concepts in the science classroom (McLean *et al*, 2015). The availability of such tools offers a solution to the lack of resources that teachers have for implementing practical enquiry-based instruction to develop children's enquiry skills (Sackes *et al*, 2009b). Sackes *et al* (2009a) recognise the difficulty in teaching science to young children and advocate that literature offers a solution for teachers, as books are an instrument that they feel confident in using. It is important to utilise teachers' familiarity with stories to *'foster inquiry-based pedagogical approaches to science'* (McLean *et al*, 2015:49).

Researchers recommend lists of books, criteria against which to choose from available books, and pedagogical approaches to using books to teach several science concepts (Sackes *et al*, 2009a: 415), suggesting that they enhance early years science education. However, several limitations, which could lead to misconceptions, have been identified within fiction books, including inaccurate illustrations (Trundle & Troland, 2005), fantasy (Ganea *et al*, 2014) and anthropomorphism (Waxman *et al*, 2014).

Sackes *et al* (2009a,b) contend that children's literature is becoming more popular for teaching science as it fosters positive attitudes and interests towards learning. Books can stimulate students on both the emotional and intellectual level, and children can readily identify with their *'imaginative illustrations, engaging storylines and the warm emotions that surround their reading experience'* (Ansberry & Morgan, 2007:1). Children are more likely to engage with ideas, because literature also supports children's ability to learn difficult science concepts as the content knowledge is laid out in the form of a narrative that aids their growing understanding (Sackes *et al*, 2009a). Bannister and Ryan (2001:75) found that conceptual connections are *'carried by the narrative links'*, which indicates that there is a strong correlation between using stories to teach and children's increased learning. Horton (2013:38) argues that children are able to retain more information when it is presented in the format of a story. She found that this is partly due to *'the structure of stories which are familiar and accessible'*. Children, especially in the early years, have a familiarity with stories, as they permeate their day-to-day life and thus it seems reasonable to introduce science concepts this way (Sackes *et al*, 2009a).

However, researchers warn that teachers should be aware of the possible scientific misconceptions contained in children's fiction books (Ansberry & Morgan, 2007), as they *'present the most serious obstacles to learning scientific concepts'* (Sackes *et al*, 2009a: 416). For example, in *The Very Hungry Caterpillar* by Eric Carle, children might be led to believe that caterpillars eat a variety of food including cherry cake, lollipops and ice cream. If we are using books to teach children specific science concepts, we must ensure that these are represented accurately. Trundle and Troland (2005) analysed popular storybooks about the Moon; the books were chosen because of their easy accessibility for teachers. The most prominent inaccuracies found were the depictions of the Moon; they were often pictorially inaccurate and there were inconsistencies about the Moon's phases, amongst other things. By using literature that contains inaccurate facts, educators may unintentionally introduce misunderstandings that render that book redundant by the fact that it has provided children with false ideas about science. Although, Cavendish *et al* (2006) emphasise the fact that stories can be used as starting points, because children enjoy them and this will enhance their inclination to listen.

Methodology

This article draws on data gathered at various times over two years as an extension of a doctoral study. The aim of the research methodology was to understand not the enquiry but the product itself, and further look at the lived experience of primary schools (Gall *et al*, 1999). Within this study, qualitative research was used to look at the lived experience regarding the use of fiction and non-fiction books to facilitate the teaching of science (example books are listed in Table 1). Semi-structured interviews were conducted with 10 staff members from 4 rural primary schools. This comprised 7 teachers who were mainstream teachers, and 3 teachers who actively taught in the primary school but also held posts of responsibility for science within the school. As part of the recruitment process, teachers from 4 rural primary schools in the mid-west of Ireland were invited to take part. In order to concretise results, a triangulation system, in line with Stenhouse's pioneering (1975) introduction to curricular research and development, is utilised. This will incorporate many aspects of education including motivation, desire and imagination.

Study ethics

The research adhered to the British Educational Research Association's (BERA) code (2011) addressing informed consent, confidentiality and secure data storage. Ethical sensitivities included a possible sense of obligation to participate and abuse of trust, ownership, issues of privacy, long term anonymity and special insights possible only to those deeply on the inside of the institution (Costly, Elliott & Gibbs, 2010). As such, BERA (2011) is the governing system for this work and, following approval from the school's Board of Management, written informed consent was acquired from teachers who partook in this research.

Data collection

Pre- and post-study questionnaires were completed, as well as semi-structured interviews that were conducted to determine the perceptions of teachers regarding aspects of the reading intervention programme. Participants were interviewed by the study researcher via Zoom while adhering to Marton's phenomenographic approach to identifying the perceptions of participants' lived experiences (Marton, 1988). The interviews were recorded to support analysis.

Data analysis

Following Marton's method of phenomenographic analysis, all questionnaires were uploaded to Google Drive and an Excel spreadsheet was formed to document and compare the results. Once all the interviews were conducted and recorded, they were each transcribed into a Google docs file. This involved a series of steps in which the data were categorised and sub-categorised into codes and themes, which included familiarising with the data, honing and refining the lower-level codes, and organising these into thematic clusters. After this was completed, a qualitative thematic data analysis was undertaken for the purpose of *'identifying patterns or themes, within qualitative data'* (Delahunt, 2017, p.3352). In 2018, the General Data Protection Regulation (GDPR) came into force in the European Union (EU). At all times, GDPR guidelines were followed and respected and the information gathered was kept securely.

Results

The post-project interviews and questionnaire showed that 98% of teachers considered the project to be very enjoyable, with many pedagogic benefits that impacted on the success of the

Book	Author
The Inventor's Secret	Suzanne Slade
Welcome to our Neighbourhood	Shaun Sheehy
Papa's Mechanical Fish	Candace Fleming
I Love this Tree	Anna Claybourne
Bacteria Book	Steve Mould
The Lighthouse Keeper's Lunch	David Armitage
What Makes You YOU?	Gill Arbuthnott
The Boy Who Harnessed the Wind	William Kamkwamba
Eye Benders	Clive Gifford

Table 1. A selection of books related to the project.

intervention. One teacher interviewed stated that: *'The books chosen really orientated the children to science activities and encouraged them to explore and discuss their books further. The books seemed to serve as a basis to various lessons and not just science, for example the book about women in STEM led the children to discover further women in history and modern history'.*

The project also yielded a good response to the teachers' and children's sense of wonder about the various books that they read. A second teacher stated that: *'As I teach in a multi-class setting, I was fortunate to give 7 of my older children all the same book. I was fortunate to also be able to elicit the children's conceptions and build my science class around the books, which led to a more collaborative and informed approach'.*

A different teacher in the project had also observed the children discussing the books with their peers and he integrated the books actively into an oral language paired activity, in which he asked the children to tell one another about the science book that they were reading and what science experiments could be undertaken based on the book. He commented that: *'This method was extremely useful for two children in my class for whom English is their second language. By encouraging them to discuss their books, they also built on their spoken language as well as their scientific language'.*

Prior to discussing the above findings in further detail, it is prudent at this stage to discuss the limitations of the current research that has yielded these results. One concern was that the saturation of science-based books would overload the children and somehow 'turn them off', but the various fiction and non-fiction books and the introduction of these over a year did not seem to deter either the teachers or the children. One teacher commented that: *'The drip-feeding of the books was very cleverly organised and, even though there was a scientific element attached to them, the children never seemed to get bored; for example, such books as 'The Pebble in my Pocket' and 'Cloudy in the Sky with Meatballs' were a stark contrast to 'My Book of Quantum Physics' and 'How Things Work'.*

On a personal note, one limitation that the researcher experienced was how time-consuming the research was, particularly when trying to complete another study in tandem. Also, as this study is small-scale, it must be remembered that this only offers a small-scale view of what teachers think but, in order to overcome this issue, *'triangulation in regards to imagination, desire and motivation, was considered to be crucial because, in essence, it is difficult to create rogue summaries when different components yield the same results'* (Stenhouse, 1975).

Discussion

Many pedagogic findings arose during the study, which impacted on the success of the programme. The project not only introduced children to the collaborative learning approach for science, but also to the joy of reading fiction as well as non-fiction science books. It seemed to help that the chosen books, such as *Eye Benders: the science of seeing and believing* by Clive Gifford, were beautifully illustrated. The findings in the project corroborate with those of other studies on how to promote reading for pleasure. Cremin *et al* (2014) recommend encouraging informal book-talk and creating a social reading environment as pedagogical strategies that foster enjoyment.

Many science information books lend themselves to being looked at by a couple of children together, which very naturally facilitates discussion and book-talk. Often, fact-intriguing snippets of information are presented that are easily read and remembered; information is usually in chunks and does not need to be read in linear fashion; and readers of varying reading ability can find a page that interests them and negotiate their way around it, chatting to a fellow reader as they do so (Alexander & Jarman, 2015). Children said that they liked to talk about the books that they had read with their friends and family. There was evidence that boys especially liked to pass on facts that they had learned to their peers.

Throughout the duration of the project, children usually undertook book-related activities. These included designing a cartoon strip of a scene from their book; shared reading activities with their guardian; designing and displaying science information posters or writing; and directing and producing a short film. Some contributed to group oral presentations, themed as 'big up your book'.

Such activities were optional and self-selected. The reading was not to facilitate the task, but rather to foster pleasurable associations with literacy. During the interviews, children spontaneously reported benefits from these ancillary activities, which they positively associated with the actual experience of book reading.

Even though there were many benefits from the project, it is clear that teachers should be aware of the possible scientific misconceptions contained in some factual books, as these can present the most serious obstacles to learning scientific concepts. Evidence reviewed from Sackes *et al* (2009a) concluded that anthropomorphism was not a *'specific or substantial problem with science learning'*; however, they suggest that language and illustrations in children's literature may present a source of misconceptions. Ganea *et al* (2014:4) investigated the effects of both anthropomorphic imagery and language and found that anthropomorphised language increases children's tendency to *'attribute anthropomorphic traits to animals'.* Therefore, information books may be the best choice to foster the development of children's scientific concepts, as they are a written format of scientific discourse. When presenting the argument in relation to information books to the group of teachers, six of them disagreed, as they believed that many non-fiction texts fail to address content in a meaningful way, indicating that fictional texts are also believed to be significant for the teaching of children. Furthermore, it has been noted that children acquire more scientific language when it has been taught through fictional stories, as this helps to master unfamiliar and abstract terminology. Books also support vocabulary as well as reinforce it through a combination of practical tasks and language games, which can be a useful strategy for noticing children who misuse language, and consequently address misunderstandings.

Books are an important way to bridge the gap between children and the content of science. Books give us a sense of who we are and put meaning into context. It was clear that, during the project, children engaged and were enabled to develop both reflective and communicative skills that could allow them to develop essential life skills of collaboration, problem-solving and critical thinking. From the project, it is clear that the books also helped to teach tricky concepts such as the shape and structure of the body's organs. Children need to investigate their stories to see how things all fit together, so teachers should allow time for children to think and encourage the expression of all ideas.

Acknowledgement

To the teaching staff at the four schools in the mid-west of Ireland where this project was undertaken.

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Science through stories

● Nicola Connor

Abstract

This article considers three case studies of practitioners and primary pupils using narrative or creative outputs to share their science learning. It looks at using stories as a stimulus to engage pupils with science learning and teaching within Scotland's Curriculum for Excellence (Scottish Government, 2010) across the early years (Early level) and primary (First and Second level) age range. The study considers examples of practitioner planning sequences, to demonstrate what such an approach looks like in practice. The story stimulus and learning outcomes for pupils are explored, together with feedback from teachers. The study found that allowing pupils to choose how to share their knowledge and understanding of science in creative ways can help to support developing their literacy skills, not just in the genre of report writing.

Keywords: Storybooks, communicating learning, story stimulus, practitioner research

Introduction

I am a class teacher from Peel Primary School in West Lothian, currently seconded out of class as part of the Raising Aspirations in Science Education (RAISE) programme (see weblink below). I have been supporting teachers and schools across West Lothian since taking part in the SSERC primary cluster professional learning programme in 2016-2017 (see weblink below).

Whilst working as RAISE Primary Science Development Officer during the COVID-19 school closures, we considered an agile approach to learning, with child-led project-based home learning and teacher as facilitator. Whilst considering what an agile approach would look like in practice, I was challenged 'to create a wordless text' with my STEM hat on. I created a short animation, sharing a science experiment through a story. You can view my learning journey and final video here:
https://sway.office.com/EBgSMkPQkvjeajtk?ref=Link

After developing the idea in theory, I then considered how this could be put into practice with pupils.

All teachers and classes involved in this project were part of the planning and discussion before and after the lessons. This was to ensure that science topics covered were part of the teacher/school's curriculum framework and planning for the term, so that it was not seen as an 'add-on'. This small 'test of change' research project will be of interest to staff considering creative ways for children to recount science lessons, or how pupils can apply literacy skills through a relevant science context.

Rationale

Stories and picture books have always been a great hook for starting a science lesson and allowing pupils to see the relevance of the context in which they are learning. However, often the literacy follow-up to a science investigation would be to support report writing. Whilst there is a place for pupils to learn the genre of report writing, and tying in with science lessons is a great opportunity, I wondered if there was an opportunity for pupils to develop other literacy skills and genres through science lessons. The purpose of this research project was to consider how pupils could recount their science investigation and outcomes through stories, or a child-led creative output, rather than writing a standard science report.

Science communicators use stories as a meaningful context and an effective way to communicate with an audience, as stories are integral to all cultures. Studies such as Walan (2019), Walan and Enochsson (2019) and Coulter *et al* (2007) indicate that stories help audiences to process and recall new information. Within Curriculum for Excellence literacy experiences and outcomes (Education Scotland, 2018), 'recounting' involves students orally reconstructing a story, where teachers can use recount to assess how well students comprehend and can support pupils to develop a deeper understanding of what they have read. Using recount within a science lesson, this project sought to find out if pupils could recount their investigation and outcomes, ensuring that they included the important details and in the correct sequence.

For this research project, classes of around 20-30 pupils from each of Scotland's Curriculum for Excellence levels in three schools were used – Primary 1 (ages 4-5, Early level), Primary 3 (ages 6-7, First Level) and Primary 6 (ages 9-10, Second level) – to show how this could be developed across a school and the progression of skills used.

Case study: School 1 – Kirknewton Primary

The project started at Kirknewton Primary, which has 190 pupils. Primary 6 were learning about energy and forces, Primary 3 about suitable materials linked to habitats, and Primary 1 were starting to learn about forces. For the research project, picture books were selected to consider if and how these can be used from P1-P7 for different purposes.

Primary 6 listened to a story called *When a Leaf Blew In* by Steve Metzger; they were asked to consider the sequence of the story and how to describe the 'chain reaction' of events. The children were then asked to create their own chain reactions, with the challenge of only using what they could find in their classroom. The chain reaction of events needed to have a purpose, similar to the 'Goldberg machines', of completing the chain by putting a ball into a cup. They worked in small groups to make their chain reaction and then to create their recount. Some children chose to write instructions using procedural writing on how to set up a chain reaction. Some groups created news reports, filmed on a device, recounting their investigation. These groups took it in turns to say what their chain reaction was, if it worked or didn't, and why. They also included reflections such as *'the material we used wasn't suitable so we changed it'*, *'we had to problem-solve how to build a reaction around a corner, I'll hand over to X to explain how we achieved this'* and *'we worked well as a team as we listened to each other's ideas'.* These reflections on their collaborative process may not have been discussed or highlighted if writing an individual report.

Primary 3 listened to the story *Hibernation Station* by Michelle Meadows, linking to an investigation around natural/human-made materials to make the best habitat for a hibernating dormouse. For Primary 3, it was decided to give them a story starter to help support their narrative writing: *'Dotty the Dormouse was looking for materials for her shelter to keep her warm during hibernation. She…'*. Children wrote a plan for their story in groups or pairs, discussing the investigation that they had carried out. This writing was also continued in their literacy lesson time for the following day. Children supported each other in the recount of the investigation and, technically, in the writing/phonics of the story too. However, whilst looking through the books created, two pupils had written an index page for their narrative piece. This highlighted to the class teacher that some aspects of features of a fiction/non-fiction text needed to be revisited or consolidated at a later stage. This would not have been highlighted through a report writing session.

Primary 1 listened to the story *And Everyone Shouted Pull* by Claire Llewellyn. As there was a play-based pedagogy approach in this classroom, an adult-initiated, open-ended challenge was posed. Could children create a cart that could be pushed or pulled using loose parts in the classroom? Pupils used a storyboard template to draw/write the recount of what they created and how it worked, making sure that they included a beginning, middle and end. This would help pupils to recount their learning process, but also to tie in narrative writing skills, considering in a story what happened at the start, middle and end.

Feedback from across the classes showed that almost all of the children said that they felt the story helped them with their investigations. One Primary 6 pupil stated that *'they thought about the story as they created their chain reaction'*. They all enjoyed recounting their investigations in different ways, using their 'own voice'.

Case Study: School 2 – St. Anthony's Primary

The project then moved onto St. Anthony's Primary, which has 223 pupils and is in Armadale, West Lothian. Primary 6 were learning about sustainable energy and forces, Primary 3 about space and the movement of the Sun, and Primary 1 were starting to learn about forces. Whilst working with classes on this project, I was also supporting the whole school staff through staff professional learning around practical science at all levels.

Primary 6 listened to a story called *The Boy Who Harnessed the Wind* by William Kamkwamba and Bryan Mealer. Classes discussed sustainability and creating wind turbines (Figure 1) and harnessed their energy to power a mechanism– in this case a basket on a thread to pull up. Both Primary 6 teachers decided to take the series of lessons forward themselves, without remote teaching support. This allowed them to carry out the lessons over the series of afternoons. The teachers' feedback included: *'Throughout the activities the children were engaged and on task'* and *'We were more than impressed with the final products that the children produced'.* Feedback from the children included: *'I enjoyed the story about how William made a wind turbine'* and *'I liked investigating how the angles of the blade affected the rotation when we blew on it'*, showing not only that their literacy but also numeracy skills were being applied within their learning process.

Primary 3 listened to the story *The Black Rabbit* by Philippa Leathers. The classes discussed what caused shadows and what might make them change shape/size. The investigation carried out was to explore what made shadows change shape. This was carried out using small torches and a classroom object, recording the shape/size of shadows as the torch moved. Pupils could choose one object, the position of the torch, and the distance of the torch from the object. The object was the variable that remained unchanged as they investigated moving the light around it. From this, pupils created cartoons or shadow puppets to recount what they found in their investigations. Teacher feedback included that they thought the

Figure 1. Wind turbine.

subject content, student engagement and participation were excellent. They thought that it was *'very beneficial giving children the choice of how they write up their experiment'* and that they had learned *'to consider using stories as a stimulus, it really got the children talking and thinking'*. Pupil feedback included that it was great to choose how they shared their learning and what they discovered.

Primary 1 started to learn about forces and listened to the story *And Everyone Shouted Pull* by Claire Llewellyn (as above). The class teacher led the lessons and this class decided to work in teams to plan, design and create a cart from the story, which they could push or pull. They then shared their designs, creations and orally retold their process with the rest of the class, ensuring a beginning, middle and end (Figure 2).

The teacher feedback included the positive approach to different literacy skills being applied and developed, not just recounting but also communication and presentation skills.

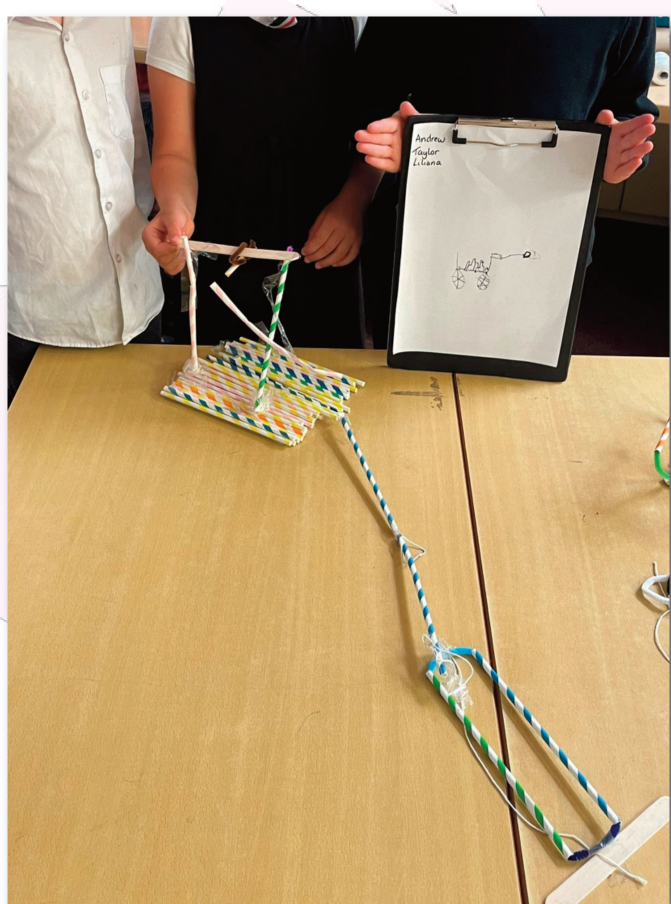

Figure 2. Designing a cart to push and pull.

Case Study: School 3 – Peel Primary

Peel Primary School has 416 pupils and they decided to run the project as a whole school small test of change, rather than focusing on just 3 classes. I met with almost all stages within the school to help discuss their plans/ideas and offer ideas for resources and books to use. For this case study, however, I have kept the results of Primary 1 and Primary 6 to keep this case study consistent with the other schools' results.

Figure 3. Shadow puppets.

Primary 1 focused on electricity. They carried out a scavenger hunt at home on a seesaw to find out what they knew about electricity. They read the story *When Charlie McButton Lost Power* by Suzanne Collins and talked about what would happen if the electricity went off. A play pedagogical approach was used in this Primary 1 classroom and the child-led approach meant that the pupils decided they would use torches to create light, and they explored making shadow puppets (Figure 3). They also designed a light box and some characters to show what they would do in the dark. These scenes were shown in the dark box to look at and use for storytelling orally. Key vocabulary utilised within the story and investigations was evident in pupils' storytelling and used within the correct context.

Primary 6 started their learning by reading *Jack and the Giant's Peach*, a twist on *Jack and the Beanstalk* from Jules Pottle's *Science through Stories* book (2015). Primary 6 were learning about the life cycle of flowering plants, pollination and fruiting. Instead of narrative writing a recount, they decided to use procedural writing. This had been a focus in writing lessons, so they decided to apply their writing skills in the new context of their science learning. The pupil feedback said that they liked the way the story introduced the science topic, allowed them to explore the life cycle through drama and linked to the art they carried out. The teacher's reflection was that she would like to refer back to the story, possibly through a display, getting the pupils to make a display of the life cycle stages with story bubbles of what was happening in the story at that time. She would use these series of lessons again, adding in her reflections as a next step with future classes.

Impact

Due to COVID-19, these lessons were supported remotely. This meant that I worked in different ways with each class, whether remotely supporting the teacher with planning or remotely with the class and team teaching a lesson through Microsoft Teams.

This study highlights where appropriate science investigations can be retold in a creative, child-led way. I found that the approach could help highlight gaps in learning and so be used to inform formative assessments. For example, in Kirknewton's Primary 3 class, pupils mixed up the features of a fiction/non-fiction text, allowing the teacher to revisit at a later stage. Using storyboards in Primary 1 helped to see whether pupils could sequence in the correct order and include a beginning/middle/end, developing their skills in retelling and narrative writing. The teacher of Primary 6 using chain reactions felt, during the news reports, that knowing her learners, they gave more detail and clarified thinking than if asked to write it down. Thus, in this project, I found that using stories as a stimulus can help to both engage pupils initially with the concept and, by retelling a science investigation, they can also develop their literacy skills in a relevant, meaningful context.

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Referencing examples:

Book

Russell, T. & McGuigan, L. (2016) *Exploring science with young children.* London: Sage.

Chapter in book

Johnston, J. (2012) 'Planning for research'. In Oversby, J. (Ed) *ASE Guide to Research in Science Education.* Hatfield: Association for Science Education.

Journal article

Reiss, M. & Tunnicliffe, S.D. (2002) 'An international study of young people's drawings of what is inside themselves', *Journal of Biological Education*, **36,** (2), 58–64

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