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Science Thinking Books: Children talking, thinking and drawing their way into science

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Science Thinking Books:
Children Talking, Thinking and Drawing Their Way into Science
「科學思維小冊子」：啟發兒童討論、思考和用圖畫表達科學

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Abstract
This article presents the story of how as a science teacher I came to use Science Thinking Books as a tool for supporting children to explore and share their experiences, thinking and understanding of the world. As a key pedagogical tool in an emerging 'pedagogy of co-construction' I will share with you a story of how over time I constantly revised and fashioned my classroom teaching. By reflecting on what was going on in my classroom and with a desire to keep moving closer to a model of science teaching which privileged children's ways of thinking rather than mainstream scientific fact, this story is about a journey of discovery where as an alternative to the teacher's language of science the Science Thinking Book becomes the means for promoting their language of science.

摘要
本文作者敘述她在任教科學期間，使用「科學思維小冊子」作為教學工具，引導兒童發掘和分享經驗，並且思考和理解世界。作者將與讀者分享她使用這種「共同建構」的教學法時，怎樣不斷地修正和設計她的課堂活動。在過程中，作者不斷對教學活動進行反思，同時不斷摸索一種有利於兒童學習思考的科學教學模範，而棄用主流的科學教學法。透過「科學思維小本子」，教師會認識一種另類的科學教學語言。

Introduction to the *Science Thinking Book*

Science Thinking Books (*STB*) is a pedagogical technique I have used in recent years in my science teaching with children in classrooms and students in teacher education programs. In this paper I will present how I came to utilize the *STB* as the key tool for achieving a "pedagogy of co-construction". I will share with you how over a number of years and much revising, rethinking and reconstructing I have continually modified my science classroom pedagogy and practice in response to a desire to put children's science thinking at the centre of the classroom. Starting with discovery learning where I emphasized children's hands-on engagement with science materials through planned activities I then discovered constructivism. But as my story will reveal constructivism still had many limitations and didn't really provide for me the focus on child centered curriculum I hoped to achieve. Then along came Leonardo (the scientist and artist) and his amazing notebooks and the work of Karen Gallas and her focus on science talks, both of which became instrumental in providing a framework through which I came to design the focus of the *STB* and where a pedagogy of co-construction started to be realized. But I am jumping ahead let me start my story of curriculum change at the beginning.

Beginning with discovery

As a science teacher committed to the view that science should be fun and engaging I had always focused on a discovery hands-on approach to my teaching. I would put out materials and then allow children to play with these. A brainstorming or sharing time after the activities would then be the time where we would build concepts and ideas from their discoveries. The session would normally end with me addressing their questions by sharing with them the real 'answers'. The following images are from a discovery science program on light and colour. The first image (see image 1 below) is a colour activity. The children were provided with a number of pots of vegetable dyes, eye droppers and filter papers and then were free to explore how colours mixed, merged together and reacted with one another. To extend this activity the children were then given smarties (coloured sugar coated lollies) which they dropped water on and watched how the different colours on the smarties were made up of a number of colours which separated on the filter paper. The activity finished with a brainstorming session where we shared our experiences and I wrote up their

findings. When then concluded that colours are mixed together to create new colours but primary colours like red, blue and yellow are the base colours.

Image 1: Children exploring colour

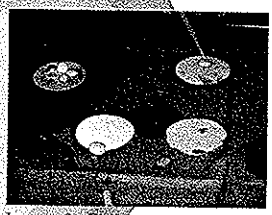

Image 2: Children extending colour exploration with smarties

But although the children were having 'fun' and seemed to enjoy the science activities I felt it wasn't enough. I was always aware that the curriculum content the questions we explored were my questions (or often the questions of science derived from science textbooks) and the activities although seemingly open ended were manipulated by me. Because of the nature of the materials and the questions I asked to tune the students into the activities I was organizing the learning environment with a view of the children arriving at a predetermined destination. It became clear that what seemed like supporting children to discover new ideas was really a staged process of delivering textbook science in a 'fun' way. This was confirmed after recently reading the paper by Appelbaum and Clark, "Science! Fun?: A critical analysis of design/ content and evaluation". It was clear I had been seduced (like the authors inferred in this passage) into using fun as a way of disguising or at least hooking the children into what I really wanted them to do - the real stuff of science:

> We worry about possibly dichotomizing (falsely) 'fun' and 'real science' content, and hope that there are many situations where this would not apply; but most of the sources we studied were based on the fun leading to the 'real' stuff of science, or preceding, it or getting the students interested so that they would then be able to do the 'real' stuff (Appelbaum & Clark, 2001, p.585).

Then along came constructivism

Then along came constructivism. I embraced it and tried to consider how to marry my focus on hands-on experiences and constructivist theories of science teaching. It certainly made sense that children came to the classroom with their own ideas about the world and that these understandings could be varied according to their unique lived experiences. In fact, I had often seen evidence of this when I had asked my students to share their findings in our brainstorming sessions. Children often told me stories about how they came to know specific information relevant to our science activities outside of those derived from the actual hands-on activities. Although I recognized that children had some prior knowledge and had seen the evidence of it, I never really knew what to do with this unless their conceptions fitted with 'real' science understandings I was trying to teach the children. I would find myself diverting the children's attention away from these prior knowledges: " that is interesting but what did you find out from the activities today?" I felt uneasy about this avoidance of acknowledging the children's prior knowledge because it seemed to contradict the way I worked in the social studies subjects. In social studies I focused on inquiry based learning and actually encouraged the children to feel empowered to 'generate their own knowledge' through project based investigations. That is, there was no real answer. Yet in my science teaching I came to see my focus was on giving children the right science answers (even though it was dressed up as discovery).

Constructivism seemed to open up new ways of thinking with its emphasis on finding out what children's alternative conceptions about science were and by using this as the starting point. But what happened after that still felt limited. Limited because it seemed to me it still emphasized or privileged one way of looking at the world – the traditional scientific way. I often asked myself why or how I had come to see science as having a set of truths or facts and consequently sat up the night before a class cramming all the information I could about the topic I was launching. I wondered why I felt I needed to be prepared for any 'hard' questions children might ask with clear scientific facts. I likened it to a handicapped race – the children were starting from all different points along the track (or off the track altogether), my job was to find out where on the track they were and then create a plan and the actions (the curriculum) that made sure they all arrived at the finish line at the same time and with the same understandings. Race finished, gold medals given

out, my job was done. Strange that in other topics (such as social studies) I was comfortable with not knowing the ' facts' (believing in the one true story) and was happy for children to bring to the learning environment an array of different understandings.

Nonetheless I continued on with this combined discovery-constructivist model for some trying to keep the classes as 'fun' and interesting as possible, always starting the class with a session on asking the children what they knew about the topic and then organizing a plan to scaffold their learning till I felt satisfied most of the children had 'got it'. That was until a colleague gave me a copy of Karen Gallas's books. But before I discuss the next step in my pedagogical changes in the classroom I will introduce how alongside of these changes – I was slowly introducing into my classroom the *Science Thinking Book.*

Beginnings of the *Science Thinking Book*

The initial idea of using a journal as a form for documenting science in my classroom came from my own personal use of visual journals as the means for combining my interest in science and art. When I went on holidays or out on field trips I would take my journal with me and draw and write about my discoveries. Plants, rocks, insects, fish all would find their way into my journals. I would write short commentaries and stories about my discoveries and identify questions that interested me to follow up at a later date. I used the journal as a documenting book but also as a means of extending my own science knowledge. For instance after a trip to the Cook Islands I had drawn a number of the plants I saw while walking along the mountain paths. When I got home I would use these drawings as the basis for finding out facts, like their scientific species and their relationships to plants in other countries. Image 3 is an example of a page from my Cook Islands visual journal.

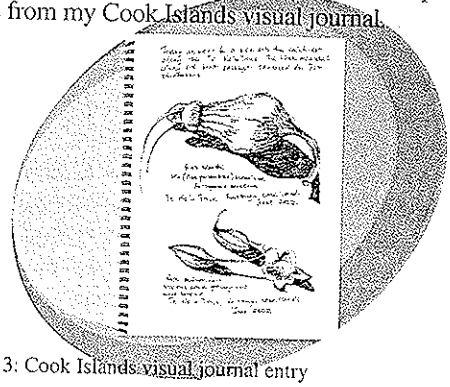

Image 3: Cook Islands visual journal entry

Also having had a long term affiliation with the work of Leonardo Da Vinci I had become inspired by the 13,000 pages of personal notebooks which documented his experiments and observations of the natural phenomena of the world (this inevitably lead me on a pilgrimage to Florence). Leonardo was the true Renaissance artist/scientist/architect/engineer who was obsessed with discovery, with exploring ideas to any questions through observation and experiment and documenting his thinking through his notebooks in an almost random fashion but integrated way. A sheet of writing on optics complimented by the sketch of a face, a brief treatise on the way to prepare a specific type of paint alongside the details of how the sun moved through the sky in spring. Big ideas and seminal questions about his world emerged out of his playful ramblings and imaginative stories and sketches. I had attempted to emanate this style of exploration in my personal journals and often brought the journals in for my students to look at. I came to recognize that Leonardo presented theory building as an irrational activity, a haphazard exploration of ideas, discovery was often accidental and not connected to the task at hand! This was not the clear cut objective science fact making I found in the science textbooks. Medawar's (1982, p.53) comments on the imaginative constructions of theory making really resonated with me at this time: "Scientific theories begin as imaginative constructions. They begin, if you like as stories, and the purpose of the critical or rectifying episode in scientific reasoning is precisely to find out whether or not these stories are about real life". I began to explore the idea of introducing this form of documentation into my classes. The idea of using journals in the classroom wasn't new to me I had used them with students in other areas of the curriculum but not in science. The idea of the journals also seemed a useful way to circumvent was seemed to me to be a growing dependency on using printed workbooks or mass produced photocopied worksheets with young children, of which I was adamantly opposed.

In the first instance the science journals were nothing more than a documenting tool. Students would engage in the discovery based activities and I would encourage them to write or draw the results of these activities in their journal. As my interest in

constructivism developed I also found the journals useful as a means for assessing how the children were progressing in the race and adjusting my teaching to scaffold their learning to make sure they got to my desired ends. I would ask them to answer questions at the beginning of our sessions in their journals, for example before a unit on living or non-living, I would ask them to draw a picture of what was living and was not living in the classroom or outside. This allowed me to evaluate the children's concepts and gave me a baseline for evaluating their success on achieving the theories of living and non-living when I asked then the same question at the end of our unit. The image below (Image 4) was taken from Sara's journal (I have inserted the words and line to make it easier to understand – these weren't in her original drawings).

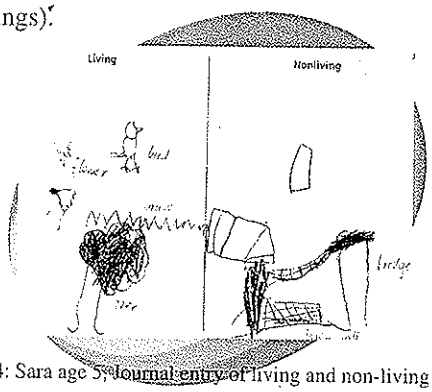

Image 4: Sara age 5, Journal entry of living and non-living at the start of a unit

It was at this time that I was introduced to the books of Karen Gallas (1994, 1995) and her pedagogy of co-construction.

Making thinking visible

Ben – *Well, see I have a question, this morning I saw a rainbow and I wanted to know do you know where they come from?*
Sally – *Yeah... I have seen a rainbow. They are so beautiful.*
Ben – *It went right across the sky and I saw lots of colours.*
Gloria– *Was it raining? When there are rainbows it is always raining.*
Sally – *Yeah but it is sunny too.*
Ben – *Yes, yes [very animated] the sun was shining and there was rain this morning. You know what I think, I think a rainbow is like made by the raindrops.*
Gloria – *My mum told me once that the raindrops are like diamonds. My mum has a diamond and sometimes I can see it make lots of colours on the wall just like a rainbow.*
Sally – *Yes, yes my mother's ring does that to.*
Murray– *You know there is a pot of gold at the end of the rainbow.*
Sally – *Gold and diamonds – a rainbow is a precious thing.*
Ben – *[turning to me] do you know what makes a rainbow?*

By making visible children's voices and thinking creates a landscape of imagination. In this conversation between the children about Ben's experience of the rainbow provides a platform for the children to share their knowledge and experiences. Theories are proposed and "children make attempts to support their theories either through analogy or fact, clarifying questions are asked, and the theory is revised or expanded" (Gallas, 1995, p. 38). Taking a step back from the curriculum topics and listening to children's ideas and questions – making their thinking visible – was my first step in creating a pedagogy of co-construction.

This short conversation between Ben and his classmates was the first in many 'science talks' that happened around the topic of light, colour and rainbows. Unlike my earlier light and colour sessions, I did not initiate the unit – it started from the children. Instead of focusing on 'teaching' children about colour and light we started with Ben's wish to find out what made a rainbow. By doing this I was guided by Gallas's ideas on how to utilize children's questions generated through science talks in the classroom while still continuing to cultivate a sense of wonder, imagination and awe:

> Generating seminal questions and/or synthesizing questions both involve an act of the imagination: The child take a point of curisosity or wonder and uses it to formulate a question. The act of questioning alone is a remarkable thing!... When the children I work with begin to ask their questions, whether the questions emerge as a beginning point for a study or as a result of a study, they are emanating from the creative imagination, from a point of wonder (1995, p.67).

I was also conscience that to readjust the power relationships of the classroom meant more than having a different starting point (the children's questions instead of mine) it was:

> When we begin to think of curricula as emerging from children's questions and employ both directed *and* unintrusive strategies of instruction, the science curriculum moves more naturally into the communal life of the classroom (1995, p.101).

By being interested in what the children are interested in, and how the children communicate this interest I began to see the science journals as having an even greater use in the science classroom. Although most of the children couldn't read or write in the early years the journal became the place where the children thoughts and ideas could be recorded through images and talk (the teacher acting as documentor). For many children the process of writing and drawing in their *Science Thinking Book* allowed them the space to ask questions, explore, experiment and document their thinking. It also became the focus of intimate conversations that I shared with the children about their creative, imaginative and irrational theory making activities. Their science language was being privileged and valued beyond textbook views of science that often postulate science as clear-cut, objective, factual knowledge:

> The ways that we expect children to talk, think, and write about science make a large assumption about what the language of science is and ought to be. That is, the language of science must be formed and articulated in a particular way, using previously established vocabulary and specific cognitive structures ... They speak and write metaphorically or in terms of the particular. The form of THEIR language of science does not orginally parrot the forms that we believe indicate real mastery of that subject matter (Gallas, 1994, p.97).

To support the collegial aspects of the science classroom I also keep my own *STB* where I included my ideas and thoughts about science and scientific knowledge. I also shared my *STB* with my students so we could compare thoughts.

To support the children's question posing about rainbows I had asked them what kinds of things they needed to be able to explore the idea of rainbows further. The list included sunlight or at least something that gave us light (we decided on torches), diamonds, raindrops, one of those big lights with the jewels hanging off it (chandelier) and a glass. The diamond and chandelier weren't so easy to come across so I gave the children a selection of prisms, crystals and glasses with water in them. The children then explored their ideas, talked up their theories and draw pictures of their stories in their *STB*.

The following image (Image 5) was taken from Ben's *STB* when he started to explore further the question of: 'where do rainbows come from?' which had emanated from the science talk by him. But how did he get there? In his *STB* Ben had drawn his theory of rainbows as a picture of a prism and the way the light diffracted into a variety of colours. He had only just drawn his image when I arrived with the camera so he insisted on getting the prism and showing me the colours – he later drew the colours in with his coloured pencils. The text is taken from him explaining his theory to me. I wrote this in his *STB* as a record of his thinking.

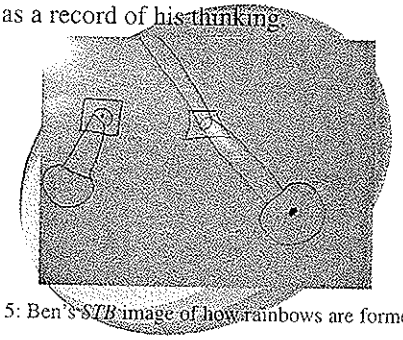

Image 5: Ben's *STB* image of how rainbows are formed

> *See when I shone the torch on the prism the light came out the otherside in all the colours of the rainbow. See that is how a rainbow happens the sunlight goes through the raindrops and makes lots of colours. Light is made up of lots of colours. But there isn't a prism in the sky – the raindrops are like diamonds that make the rainbow – Ben, age 7*

We see from Ben's explanation to me, he had constructed a theory of light as an dialogic messing together of his talks with others, his own explorations and his own lived experience. Toulmin (1972) describes this idea of a developing human knowledge as an 'epistemic self-portrait' where the developer

needs to articulate what they believe and then analyses the base from which that belief is anchored.

By studying the structure of children's thinking, drawing out their theories, letting them share their ideas and theories with others, creatively exploring their theories and then drawing and writing up their experiences in the *STB*, I was able to realize that the children's stories about science where very personal but they were also the product of an array of other experiences. Experiences of being in the world, talking to friends, parents, others adults, watching television, reading fiction and non-fiction books – a huge diverse pool of possibilities existed for Ben to draw on in his theory-building. A pedagogy of co-construction allowed Ben to bring to his theory building a range of experiences that weren't about making sure he found the 'correct' theory – but that by opening up his wonder and curiosity encouraged him to design his science theories and proposing a language of science that could be irrational and random. What is the focus in of a pedagogy of co-construction is on the practice of theory-making where the child is supported to develop an identity as a scientist.

Why a *Science Thinking Book?*

The *Science Thinking Book* is the space where children take risks, explore old and new ideas, generate and challenge their scientific theories. From my experiences of science talks and the content of *STB*'s with children in my science classrooms and now in my role as a teacher educator working with trainee teachers, I have come to realize we all have very sophisticated and deeply considered understandings and observations about the world we live in. Often, however, adults (particularly teachers) view children's (and adults) symbolic stories and images of science as naïve and simplistic – not stopping to listen to the logic and reasoning, not stopping to view the metaphors or analogies as creative devices for imagining complex thoughts and ideas. As Gallas (1995, p.101) states: "These images are not throwaway terms. They often help children 'make the intellectual leap toward theory' that they are not otherwise able to articulate using everyday language".

What the *STB* has enabled me to do as a teacher is to free myself and my students from the traditional conventions of science teaching that asks for clear, pure and concise theories and understandings of science that are congruent with scientist's constructions of mainstream science. The *STB* allows us to be creative, imaginative, playful and irrational in our theory building. Creative and collaborative processes that one might see as more aligned with the practices of artists, poets or writers are supported through experimentation and discovery in our classroom. Contrary to what scientists may have us believe, intuition, imagination and wonder are key to generating new ideas and we know scientists do work in these messy ways - even if what they present to the world seems rational and sanitized of human creativity. As the teacher the *Science Thinking Book* becomes the foundation of a shared conversation that in turn drives the designing of a pedagogy of co-construction that is intellectually challenging and acknowledges that science thinking happens in the story making of living in the world not when we 'do' science in the classroom, or as Karen Gallas so aptly states:

> Science instruction from children's questions requires teachers to attend more to the natural rhythm of children's intellectual development. Rather than studying science only in designated time periods over the course of a week, the children think, talk, and do science all the time! (Gallas, 1995, p.101)

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