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目錄  Contents

編者序言
Editorial
成子娟、Nicola YELLAND、伍瑞顏
CHENG Zi Juan, Nicola YELLAND & NG Sui Ngan Sharon ......................................................... 3

Young Children’s Abstract Mathematical Thinking
幼兒的抽象數學思維
Douglas H. CLEMENTS & Julie SARAMA ................................................................. 5

聚焦「科學思維」：幼兒科學教育的新取向
Focusing on “Scientific Thinking”: A New Trend in Early Childhood Science Education
張俊．ZHANG Jun ............................................................................................................. 11

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
Karen MALONE ............................................................................................................... 15

促進兒童的數學思維及解決問題之能力
Enhancing Children’s Mathematical Thinking and Problem Solving Skills
黃敏・WONG Mun Amanda .......................................................................................... 21

一些值得推薦的早期科學和數學活動──學員習作分享
Scientific and Mathematical Activities in Early Childhood: Sharing from Students’ Assignments
成子娟．CHENG Zi Juan ............................................................................................ 23

Teaching Mathematics in Hong Kong: A Comparison Between the Pre-primary and Early Primary Years
比較香港幼教及初小的數學教學
NG Sui Ngan Sharon & Nirmala RAO．伍瑞顏、劉麗薇 ........................................ 30

Becoming A Mathematical Thinker in New Times
在新世代培養幼兒的數學思維能力
Nicola YELLAND & Anna KILDERRY ......................................................................... 37

透過創意數學教學培養兒童的高階思維能力
Develop Pupils’ High Order Thinking Abilities via Creative Teaching Approach
黎耀志、黃德華・LAI Yiu Chi & WONG Tak Wah .................................................... 43

Children’s Autonomous Approaches to Problem Solving
讓兒童自發學習解決問題
Sudha SWAMINATHAN ............................................................................................. 47

小小幾何板
Tangrams for Children
梁興強・關樹培・LEUNG Hing Keung & KWAN Shi Pui ........................................ 53
專欄 Features

中國幼教先行者所走過的路：幼兒教育領域的辛勤跋涉者和領航者——趙寄石教授
**Early Childhood Education in China Through the Eyes of Pioneers**
唐淑、虞永平 · TANG Shu & YU Yong-ping ............................................................ 57

崇真會美善幼稚園暨幼稚園（馬鞍山）簡介
**Tsung Tsin Mission Graceful Kindergarten & Nursery (Ma On Shan)**
郭婉儀 · KWOK Yuen Yi ................................................................. 60

學前兒童「一對一」閱讀輔導之經驗分享
**Paired Reading – Student Teachers Reading to Preschoolers**
陳莉莉 · 余陳惠玲、姚芷茵 · CHAN Lily, YU CHAN Wai Ling & YIU Chee Yan .............. 62

書評：《操作式學前數學》
**Book Review: Operational Learning in Pre-school Mathematics**
王小鳳 · WONG Siu Fung ................................................................. 65

豐富的網絡世界：幼師網中尋寶——數學／科學新知
**Using the Internet**
韓重惠 · HAN Chung Wai Christina ................................................................. 67
編者序言

數學和科學思維的發展是兒童認知發展的重要方面，也是21世紀教育領域的重要課題之一。因此，我們第七期的《香港幼兒學報》專以兒童數學和科學思維為題，輯錄了十篇文章，以饗讀者。前五篇為學前階段的研究，另有兩篇屬跨學前和小學兩個階段的研究，後三篇則是小學階段的研究。這些文章的作者分別來自不同的國家和地區，彼此社會文化背景各異，所從事的職業也各不相同，其中有大學的學者，也有幼稚園的教師，很具有代表性。這些文章所論及的課題也頗具廣泛性，讀者不難發現，其中，有的文章重點論述了抽象思維在兒童早期數學學習中扮演的重要角色，有些文章集中討論了學前數學和科學的基本定義及教學理念，有些文章探討了學前和小學階段數學與科學教學的各種方法和途徑，還有的文章則就如何運用現代資訊科技創設理想學習環境提出了自己的見解。

本期專欄刊登了介紹趙詩石教授的文章，我們希望讀者能從中分享幼教先行者所走過的路。從幼稚園和幼兒中心欄目可以見到崇真會美善幼稚園暨幼兒園的辦學風格和教學理念。本期向讀者介紹的研究專案，是「一對一」閱讀輔導經驗分享。在書評欄目中讀者可以更多瞭解《操作學前數學》的教學理念和實踐意義。在豐富的網路世界中，專欄編輯幫助讀者網中尋寶，提供了一則與數學和科學有關的網站資訊。

執行編輯
成子娟、Nicola YELLAND、伍瑞顏
Editorial

Mathematical and scientific thinking are an important aspect of children’s cognitive development and are also the focus of a great deal of concern in the education realm since they are an integral part of life in the 21st century. Therefore, the theme of mathematical and scientific thinking for the seventh edition of Hong Kong Journal of Early Childhood is very timely and significant. We have published ten articles in this edition, which will extend the horizon of all readers. The first five articles are concerned with children in preschool settings, then follow two articles focusing on both preschool and primary school, and finally the three remaining articles refer to studies carried out within primary school settings. A broad and rich contribution from authors of varying background and culture has enabled the presentation of a range of points of views and field experience from both university scholars and kindergarten teachers. Furthermore, a wide range of issues are covered by these articles in which some discuss, for example, the important role of abstract thinking in the development of early childhood mathematical learning; and other articles consider both the basic direction and teaching ideas of preschool mathematical and scientific activities. In particular, some articles explore the teaching methods and techniques in relation to preschool and primary school mathematical and scientific education and illustrate the writer’s view of how to harness modern Information Communication Technology (ICT) to create more effective learning environments.

In addition, the Features section of this edition includes an article to introduce Prof. Zhao Ji-shi. We hope that our audiences will enjoy the shared experiences from this early childhood education forerunner. For the section on Early Childhood Institutions, readers can share the vision and ethos of Tsung Tsin Mission Graceful Kindergarten & Nursery (Ma On Shan). The research project introduced in this edition is “one-to-one tutoring in reading”. The Book Review, of Operational Learning in Pre-school Mathematics, lucidates some ideas for teaching effectively. Finally, we present a review of a useful website that is full of resources on mathematics and science ideas which readers will hopefully find useful for their teaching.

CHENG Zi Juan, Nicola YELLAND and NG Sui Ngan Sharon
Edition Editors
Young Children’s Abstract Mathematical Thinking
幼儿的抽象數學思維

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Abstract

Educators often promote “concrete,” rather than “abstract” experiences for young children. Whether goals or experiences that involve abstract thinking are appropriate, however, depends on how we define “abstract”. In this article, we distinguish between different kinds of concrete and abstract experiences and understandings. We discuss the kinds of abstractions that are critical to young children’s development of ideas about both number and arithmetic. In both these areas, we draw implications for teaching and learning. Finally, we discuss the role abstraction plays in general development and learning.

Thinking about Abstraction

People define abstraction in different ways. One meaning is “generalizing from concrete experience.” Other meanings reflect a belief that abstractions are sophisticated ways of thinking more appropriate for adults than children. For example, “abstract” might connote “not useful” or even “difficult to understand”. These ways of thinking often bias early childhood educators to avoid abstractions. They wish to provide young children with experiences that are “concrete” or “hands-on” rather than “abstract, paper and pencil activities.”

We need to re-think such biases. We do want children to “generalize from concrete experience”. As a simple example, to know “red”, children have to abstract the idea from many objects, such as red apples, clothes, or sunsets. We even want them to understand ideas that are more abstract, such as “fairness” or serving others.

In this episode, we see that Leah thought about numbers, at least very small numbers, in an abstract way. She could assign 1, 2, and 3 to the three engines, or she could assign 1, 3, and 5 to the same engines. Moreover, she could count the numbers; that is, she applied counting, recursively, to counting numbers. Such abstractions allowed her to play with numbers while she played with the engines. In this article, we consider the role abstraction plays in young children’s development of mathematics.

1 Note for article: Time to prepare this material was partially provided by a National Science Foundation (NSF) grant, ESI-9730804, "Building Blocks – Foundations for Mathematical Thinking; Pre-Kindergarten to Grade 2: Research-based Materials Development" and an Interagency Educational Research Initiative grant (IERI; NSF, DOE, and NIH), REC-0228449, “Scaling Up the Implementation of a Pre-Kindergarten Mathematics Curriculum: Teaching for Understanding with Trajectories and Technologies.” Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author and do not necessarily reflect the views of the NSF or IERI.
Different Kinds of Abstract and Concrete

In summary, we want children to gain certain kinds of abstract knowledge. To determine what kinds are appropriate, we need to distinguish between different kinds of concrete and abstract experiences and understandings (see Clements, 1999).

Most early childhood educators agree that many types of hands-on, concrete experiences are good for children. However, “understanding does not travel through the fingertips and up the arm” (Ball, 1992, p. 47). Children need to abstract ideas from working with concrete objects. You can point to a chair and cup for the meaning of each. While you can point to 3 chairs and say “three” and you can point to the numeral “3” and say “three”, but neither one of these is indicating the referent for the idea of the number three. Children have to abstract the idea of the number three by generalizing from many experiences. When they do, paradoxically, it seems like they have a “concrete” idea of number. For example, a child might say, “I thought of 3 in my head and 1 more is 4.” Numbers seem like real objects to such children. This makes more sense when we understand that there are different types of abstract and concrete knowledge.

- Children have Sensory-Concrete knowledge when they need to use sensory material to make sense of an idea. For example, at early stages, children cannot count meaningfully unless they have actual things to count.
- Children build Integrated-Concrete knowledge as they learn. It is knowledge that is connected in special ways. This is the root of the word concrete – “to grow together”. What gives sidewalk concrete its strength is the combination of separate particles in an interconnected mass. What gives Integrated-Concrete thinking its strength is the combination of many separate ideas in an interconnected structure of knowledge. Some of these ideas are concrete examples, and others are abstract ideas. When the two are connected, children have Integrated-Concrete knowledge (Clements, 1999).

Depending on what kind of relationship you have with the knowledge, it might be Sensory-Concrete, or Abstract (only – that is the kind most of us try to avoid – verbal definitions and rules without meaning), or Integrated-Concrete. “Fourness” is no more “in” four blocks than it is “in” a picture of four blocks. The child creates Integrated-Concrete knowledge of “four” by building a representation of number and connecting it with experiences with collections of four concrete objects. When children have that integration of concrete and abstract knowledge, when they take a number as a mental “thing” – a well-known thing they can mentally manipulate – that is when they are masters of their own knowledge.

Children’s Abstractions of Number

Number

Let us make this concrete for ourselves with an example of children’s development of number concepts. From birth to first grade, children develop increasing abstract and flexible ideas and strategies of number and counting.

Three pictures hang in front of a six-month-old child. The first shows two dots, the others one dot and three dots. The infant hears three drumbeats. Her eyes move to the picture with three dots (Klein & Starkey, 1988).

Babies are sensitive to quantities almost from the day they are born. By 8-12 months of age, they can tell which of two very small collections is more or less than another (Clements, 1984a). Research on human brains suggests that, like some animals, we seem to possess neurons that respond to three, whether it is three sounds or three light flashes. Human’s behavior, as young as infancy, reflects an abstract number module in the brain, developed over eons of evolution. However, babies’ knowledge of number is probably in the form of an estimate, although with very small numbers, that suffices. Nevertheless, they begin the long process learning complex ideas about number.

Thus, babies have some built-in ability to abstract quantity from very small collections, but it is not an
exact representation. A significant development is made about age 2, when they engaging in symbolic exercises such as symbolic play. At his age, they can represent numbers with “mental pictures” of objects. This allows them to represent numbers exactly. One toddler put out two plates, turned, got two spoons, and placed one on each plate. This shows an early abstract mental representation, even if the mental symbols he used are more like pictures than words. Even infants’ numerical representations are abstract enough to apply to different situations and different types of objects (Wynn, 1998).

Representations are critical. In our introductory story, Leah incorporated counting into her play to keep track of her train engines. Early concrete experiences form the basis for mathematics, but they are not yet mathematical until children learn to represent them. Young children represent their ideas by talking, but also through models, dramatizations, and art (Edwards, et al., 1993).

Thus, number words become increasingly important. At the earliest ages, children may not realize that number is an important attribute. Number words help them recognize that you can classify collections by number. They bring number to the child’s conscious awareness. For example, a girl was sitting with her dog when another wandered into the yard. She says, “Two dogs”. She then asked her mother to give her “two treats” and gave one to each. This is an important abstraction. As we said previously when talking about the chairs: “Two” and “three” are abstract concepts, mental relationships.

Soon, children build on these early ideas by developing their counting abilities. They string some of these words together and begin to learn to count. This is the beginning of an extended, complex process. Children learn to abstract five principles for counting (Gelman & Gallistel, 1978).

The stable order rule. Counting words must be said only once, and in a consistent order.
The one-to-one rule. Each counting word must be paired with one and only one object.
The cardinal rule. The last counting word indicates “how many” of the collection.
The order irrelevance rule. Objects can be counted in any order.
The abstraction rule. Any kind of objects can be collected and counted.

Even though young children find it hard to follow the rules, their behaviors indicate a developing understanding of them. Let us look at an example for each.

1. A child counts, “1, 2, 3, 4, 5, 6, 8, 7...” each time he counts. He is not completely correct, but is consistent.
2. Many 4-year-olds will make mistakes like skipping an object... but will catch similar mistakes when others make them.
3. If you ask a child who is just learning to count how many she just counted, she may re-count. But as they learn to name ever more collections without counting them, and then count them, they abstract this rule and find that the last number word is not an attribute of the last object counted, but an attribute of the collection as a whole.
4. Children will say, “I can make this marble ‘one’, the count is the same.”
5. Children will count jumps or number of dog barks. Both the description and the name of the abstraction rule indicate clearly – Early counting is an abstract, principled activity.

The development of number words and counting allows children to build abstract number comparison as well. For example, after age 3.5 years, most children can accurately compare two collections of dissimilar objects, such as a collection of blocks and a collection of chips. They can also accurately compare collections that they do not see at the same time, such a collection of marbles with a sequence of drumbeats. Between 4 and 4.5 years, children can compare collections that are each composed of a mixture of different objects. Thus, they have increasingly seen number as an abstract idea that does not depend on the size or nature of the objects counted.

Counting develops even beyond these
understandings and skills. Tonya was asked to count six marbles into an adult’s hand. When she did, he covered them up, showed 1 more, and asked how many he had in all. She said one. When the adult pointed out he had 4 marbles hidden, Tonya said adamantly, “I do not see four.” For Tonya, there could be no number without visible things to count (Steffe & Cobb, 1988). Months later, Tonya could point to four locations on the teacher’s hand, counting “1, 2, 3, 4” then point to the visible marble and say, “5, 5 in all!” She had learned to meaningfully count abstract objects that she could not perceive. This takes us to the domain of arithmetic, which we discuss next.

**Arithmetic**

Although counting becomes an important tool for solving addition and subtraction problems, very young children have nonverbal arithmetical competencies. For example, infants are surprised if adding an object to a very small number of objects behind a screen does not result in the correct number once the screen is revealed (Wynn, 1992).

By age 4, children synthesize their counting and arithmetic knowledge. They invent arithmetic counting strategies (Steffe & Cobb, 1988). For example, told that someone had 3 toys, then got 2 more toys, and asked how many in all, children might put out 3 fingers on one hand, then put out 2 fingers, then count the fingers to figure out the sum of 5. Of course, this involved concrete objects. However, using fingers concretely to solve the problem is not still an abstraction. At least, children understand that whatever number results from combining x fingers and y fingers will also be obtained when combining x toys and y toys. As further evidence, we only have to note that languages of some cultures can express “3 chickens and 2 more chickens are 5 chickens”, but cannot express arithmetic abstractly. That is, they cannot say, “3 and 2 is 5”. Children who do that are already at an impressive level of abstraction (Nunes, 1992).

The level of abstraction increases as children invent new counting strategies. For example, 4- and 5-year-olds, given multiple experiences, can invent counting on. That is, they realize that they do not have to count out 3 fingers; they can just put out 2 fingers, starting counting at “three”, then count on, “four, five ... five!” In the story that began this article, Leah counted counting numbers. This usually occurs in the early school grades, when children learn they can figure out the difference between 8 and 11 by counting, “9 is one, 10 is two, and 11 is three. Three!”

Children’s counting strategies initially closely model the problem situation, such as in the “3 toys plus 2 toys” example. Primary grade children will abstract the structure of problems, seeing that a problem such as “10 cars take about 8 cars” can be solved more easily but counting up from 8 to 10. At 5 years, Abby Rose said, “I just figured something out. 2 + 2 is 4, and 2 + 3 is 5. Her mom said, “That is right, but you have known that for a long time.” Abby Rose replied, “No, what’s interesting is, 2 and 2 is 4, and if you make one part 1 bigger, then you get one more...5!” Mom said, “Oh, So, if you know 5 and 5 is 10…” Abby Rose interrupted and finished, “... then 6 and 5 is 11!”

By first grade, children who are encouraged to think about and invent mathematical ideas and strategies can start to create and understand one of the most abstract fields of human endeavor: algebra. For example, research shows they can make such algebraic statements as any number plus zero is that number (x + 0 = x), or adding two numbers then subtracting one of them results in the other number (x + y – y = x).

We focused on number and arithmetic here, but abstractions are involved in all mathematical topics (Clements & Sarama, in press). Children’s informal mathematics is more fully developed and powerful than many have realized. Children make increasingly sophisticated abstractions that are the foundation of mathematical thinking.

**Beyond Mathematics: All Learning Involves Abstraction**

Children learn substantial mathematics through abstraction. In addition: All significant learning involves abstraction. What does this mean? Jean Piaget said there were different types of abstraction
(Kamii, et al., 2004). One type, physical abstraction, involves learning and generalizing from experiences with the physical world. For example, children might touch clay and find that they can poke a hole in it. They gain that physical knowledge about the clay. They might then manipulate different types of clay and find some types are easier to poke holes in than others. They create the idea of being more or less malleable – "soft", "squeezeable", or whatever they name it – that cannot be given directly by the clay. It is a relationship between the different types, and thus involved reflective abstraction. That is, children reflect on their actions of poking and the result of their actions in two types of clay, compare the effects of their actions, and so build a new mental relationship, creating logicomathematical knowledge.

So, a logicomathematical experience happens when children think about the actions they perform on objects and their effects. Piaget tells of his friend's childhood experience: At about 4 years of age, he was sitting and counting pebbles. He placed them in a row and counted them to 10. Then he counted them in the other direction. It was the same. He "found this marvelous." He placed them in a circle and counted yet again. Still the same (Piaget, 1953).

Children learn about number, not through direct physical experience, but by considering their own actions. The child first notices one of his own actions, the repeated counting. The effect – always the same count – surprises and interests the child. Then, the thought about the pebbles is reflected, as in a mirror, from the "plane of action" to the "plane of thought" – the child abstracts the idea from the concrete pebbles to ideas about counting in general. It is reflective in another way – the child "stood back" from the activity and reflected, or thought, about it. He thinks that if he gets the same number when counting, they be always be the same number. There must be a "numerical equivalence" – no matter how objects are arranged, the number of objects does not change. The child abstracted and reflected on his actions to build a new idea about number – he reinvented the conservation of number for himself.

Again, it is not so much words and symbols that promotes such reinvention. It is making mental relationships (Kato, et al., 2002).

Could someone teach the child this idea? Many researchers have studied this. Most studies show that simple reinforcement is not effective, but helping children focus on the idea of number, rather than length, or describe the verbal rule, has been effective with some children (Clements, 1984b). We do not know much about the effect of such "training" outside the laboratory, however. Piaget would probably claim that the effect on overall thinking was minimal. In any case, the bottom line is that children seem to need certain mental structures to benefit from the "nudge" that teaching can provide. Ultimately, children have to put the ideas together for themselves. As Piaget's collaborator Hermine Sinclair says, "... numbers are made by children, not found (as they may find some pretty rocks, for example) or accepted from adults (as they may accept and use a toy)."

That does not mean we have to talk about or teach every idea. Importantly, much reflective abstraction, especially for the young child is not conscious. Still, conscious reflection is important in education. In mathematics, for example, we do not really build a solid concept until we can talk about it – until we can use the language of mathematics. Children develop the counting strategies and algebraic ideas we described as they talk to teachers and friends.

Conclusions
To criticize mathematics for its abstraction is to miss the point entirely. Abstraction is what makes mathematics work. If you concentrate too closely on too limited an application of a mathematical idea, you rob the mathematician of his [sic] most important tools: analogy, generality, and simplicity (Stewart, 1989, p. 291).

Number may be one of the fundamental ways our brains interprets the external environment. Inborn in infants, then, is a brain “module” that lays the foundation for even young children to abstract mathematics from their world. We build upon those foundations as we help children develop increasingly sophisticated ideas. Even for young children,
abstraction is important for understanding. Children’s ideas, from birth to school, become increasingly sophisticated and abstract. From the first year of life, they use the power of abstraction.

References


聚焦「科學思維」：幼兒科學教育的新取向
Focusing on “Scientific Thinking”: A New Trend in Early Childhood Science Education

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摘要
幼兒科學教育在當前的一個重要轉向就是從過去的「以知識為中心」轉向「以探究為中心」。科學思維的培養應該成為科學教育的新焦點。科學思維是一種建立在事實和邏輯基礎上的理性的思維方式，它既是對傳統教學觀念和方法的挑戰，也是對幼兒年齡特點的挑戰。因此教師不僅要改變傳統的教學方式，還要充分考慮到幼兒的年齡特點，才能在幼兒的心靈中埋下科學思維的第一粒種子。

Abstract
It is an important trend of early childhood science education today to change from “knowledge-oriented” to “exploration-oriented”. The training of children’s scientific thinking should become the new focus of early childhood science education. Scientific thinking is a way of rational thinking on the base of facts and logic, which is a challenge not only to traditional teaching ideas and teaching methods, but to children’s age characteristics. Therefore, only when teachers take children’s age characteristics into account as well as they change their traditional teaching methods, can they sow the first seed of scientific thinking into children’s minds.

一、科學教育應該給幼兒甚麼
在科學教育不長的發展歷史中，對於「科學教育應該給幼兒甚麼？」這個核心價值問題的回答，卻已經有了多次轉向。無論在西方還是在中國，都大致經歷了從重知到重技能、再到重興趣的發展過程。也許在10年以前，還會有很多幼稚園教師把傳授科學知識作為科學教育的主要目標，而在10年後的今天，相信很多人都會認為，培養幼兒對科學的興趣和好奇心比讓他們了解一些科學知識重要得多。

這一變化實際上是科學觀的變化。也就是說，我們對科學的看法已不囿於「科學即知識」這樣一種傳統的解釋，而賦予其更為豐富的內涵。完整意義的科學，應該是由科學知識、科學方法和科學精神組成的一個三維的立體結構。而探究則是這個結構的核心。因為，科學知識是探究活動的結果，科學方法則是探求知識的方法並貫穿於科學探究過程之中，而科學精神的內核無疑應該是人類天生具有的探究心。

現代科學教育理論無不將科學探究作為科學教育的中心。美國《國家科學教育標準》(1996) 明確「科學即探究」的觀點，我國的小學《科學課程標準》(2001) 及《幼兒園教育指導綱要》(2001) 也都很強調科學探究在科學教育中的地位。

從過去的「以科學知識為中心」到今天的「以科學探究為中心」，科學教育關注的焦點開始從外在的、客觀的科學知識轉向幼兒的學習活動，轉向生動而豐富的科學探究過程。這也是本文提出科學教育要聚焦「科學思維」的背景。

甚麼是「科學思維」？顧名思義，科學思維就是用科學的方法進行思維，它是科學方法在個體思維過程中的具體表現。反過來，我們也可以把科學本身看成是一種思維方式，科學探究過程就是用科學的思維方式獲取知識的過程。因此，科學探究和科學思維在本質上是相通的，前者更側重於科學知識獲得的過程，而後者則側重於學習者內在的思維過程。在教學實踐中，科學探究和科學思維更是無法分開。科學教育的過程要真正體現科學探究的本質，就必須把焦點置於科學思維方式的培養。

簡單地說，科學思維就是一種實證的思維方式,
一種建立在事實和邏輯基礎上的理性思考。具體包括以下內涵：
- 相信客觀知識的存在，並願意通過自己的探究活動去認識客觀世界的。
- 對於未知的事物會做出猜想，並知道主觀的猜想是需要客觀事實來證明的。
- 相信事實，只有在全面地考察事實之後才會做出結論。
- 通過對事實進行合乎邏輯的推論而得出結論，並知道任何結論都是暫時性的，它需要更多的事實來證明，結論也可能被新的事實所推翻。

聚焦於科學思維的教育，應將以上諸點滲透於教學過程之中。其面貌當和傳統的聚焦於科學知識的教育大不相同。我們可以從以下幾方面將二者作一比較：

<table>
<thead>
<tr>
<th>教學重心</th>
<th>聚焦於科學思維</th>
<th>聚焦於科學知識</th>
</tr>
</thead>
<tbody>
<tr>
<td>科學觀的基礎</td>
<td>科學是不斷探究的過程</td>
<td>科學是一個固定和權威的結論</td>
</tr>
<tr>
<td>教學目標</td>
<td>重視過程，即重視幼兒的思維過程</td>
<td>重視結果，即重視科學知識</td>
</tr>
<tr>
<td>教學方法</td>
<td>較多採用探究的方法</td>
<td>較多採用講授的方法</td>
</tr>
<tr>
<td>教師角色</td>
<td>是幼兒探究的合作者、指導者，引導幼兒提出問題、解決問題，和幼兒一起尋找問題的答案</td>
<td>是知識的來源，引導幼兒得到最後的結論，或者直接地把結論告訴幼兒</td>
</tr>
<tr>
<td>幼兒角色</td>
<td>提出問題，解決問題，進行主動的探究和思考</td>
<td>接受確定的科學知識</td>
</tr>
<tr>
<td>教學結果</td>
<td>幼兒透過探究過程獲得對科學的個人的理解</td>
<td>幼兒透過記憶獲得科學知識，但也許並不理解</td>
</tr>
<tr>
<td>對幼兒心理發展的長遠影響</td>
<td>幼兒享受思維的樂趣，在科學探究的過程中獲得自信和滿足</td>
<td>難以給幼兒留下深刻的印象</td>
</tr>
</tbody>
</table>

下面我將通過一個案例「烏龜冬眠嗎？」來具體說明二者的差別：

某中班在進行「動物怎樣過冬」的科學活動時，教師和幼兒討論哪些動物是冬眠的。大家都認為烏龜是冬眠的，唯獨一位幼兒站起來說：「烏龜是不冬眠的，我家裡養的兩隻小烏龜到現在也沒有冬眠……」

這是在一個課堂上所遭遇的真實場景。幼兒在課堂上提出不同的看法並不奇怪（甚至我認為他是很有勇氣的），我們要關注的是：教師如何應對這一「突發事件」？

就這一問題，我徵詢了很多幼稚園教師的意見。結果大多數教師堅信烏龜是要冬眠的（這對於生活在北方的人來說並沒有錯），也堅信自己有責任將這個正確答案告訴幼兒，甚至是不惜一切代價（包括犧牲幼兒的尊嚴）來維護「真理的尊嚴」。如：全班的孩子齊聲說出正確的答案，請一個「能幹」的小朋友來告訴他；拿出《百科全書》來唸一段權威解釋，以至直截了當地否定這個孩子的錯誤……記得我曾向某位教師提議，是否可以請這個小朋友把家中的烏龜帶到幼稚園來，大家一起來觀察，看看結果會如何？她想了想回答我說：「不行！如果這隻烏龜真的不冬眠，我如何向孩子解釋呢？難道書上寫的不對嗎？」

以上所述的觀點代表了一種「以知識為中心」的科學教育。教師被籠罩在知識權威的陰影之下，幼兒更無法倖免。更可悲的是，為了維護知識的權威性，教師甚至可以忽視事實，放棄檢驗事實的機會，更不用說問題的探究了。

換個角度來看，知道「烏龜是冬眠的」這個結論對幼兒來說真的有那麼重要嗎？如果我們把科學理解成是對周圍世界的探究過程，那麼，我們完全可以和幼兒一起去探詢這個未知的問題。幼兒需要的並不是一個具有普遍意義的結論，他們更需要親身經歷科學的
過程、觀察、發現、猜想、驗證……讓我們來設想一下這樣的情景：

在小烏龜到來之前，大家就可以進行討論：「它真的不冬眠嗎？」——這個問題並不算難，只要注意觀察烏龜的行動就可以發現事實真相。當然，觀察可以讓幼兒得到有關烏龜活動的很多細節，這可是書上所沒有的哦！

如果大家發現烏龜真的沒有冬眠，「這又會是為什麼呢？」——幼兒可以進行各種猜想。但是，只有可以驗證的猜想才是真正有價值的哦！

某某幼兒提出，也許因為教室裏有空調，溫度不夠冷，所以烏龜才不會冬眠。那麼怎樣才能證明你的猜想有道理呢？「我們把烏龜放到一個冷一點的地方試試看吧！」——這不就是科學實驗嗎？

果然烏龜到了室外就一動不動了，看來它真的冬眠啦！「我們終於找到答案了！」——得出了結論，幼兒們一定很開心。不過，別以為真的找到了烏龜冬眠的祕密，說不定，別的烏龜還有更多有意思的冬眠趣事呢！

在這樣的活動中，教授不是直接把科學知識和結論交給幼兒，而是為幼兒開闢了更豐富的探究空間。在這其中，隨處可見科學思維閃爍的光芒，而與傳授知識的教育大異其趣。

二、如何培養幼兒的科學思維

通過上面的比較，我們可以感受到，只有將科學教育聚焦於科學思維的培養，才能觸及到幼兒科學教育的靈魂所在。幼兒科學啟蒙，最根本的就是思維方式的啟蒙。從小對幼兒的思維方式進行塑造，養成其科學的思維習慣，對他們的一生都很重要。那麼，如何培養幼兒的科學思維呢？

在討論具體的教學策略之前，我們必須對幼兒科學思維發展的可能性做一估價。他們有可能獲得一種真正的科學思維嗎？幼兒會面臨甚麼樣的挑戰？

主要是針對幼兒對周圍世界的探究熱情而做出的評論，其中多含表揚鼓勵的成分。而作為一個認識者，幼兒思維能力的發展離嚴格意義的科學思維還有很大的差距。這裏不妨舉一例予以說明：

教師問：你摸到的棒棒糖是甚麼樣的？
幼兒：硬硬的、圓圆的……
教師：你能不能用手摸出你的棒棒糖是甚麼顏色呢？
幼兒：我摸出我的棒棒糖是綠色的。
教師：你是用手摸出來的嗎？
幼兒：是的。我能摸出來。
教師：那你把棒棒糖拿出來看看，是不是綠色的呢？（結果幼兒拿出了一粒紅色的棒棒糖。）
幼兒：是紅色的了。原來它是綠色的，可我一拿出來，它就變成紅色的了！……

幼兒的這番話，也許會讓許多成人感到匪夷所思。然而這正是幼兒的思維特點！我們通過下面的表格將幼兒思維的特點和科學思維的要求做個簡明的對照：

<table>
<thead>
<tr>
<th>項目</th>
<th>幼兒思維</th>
<th>科學思維</th>
</tr>
</thead>
<tbody>
<tr>
<td>相信自己的「信念」，甚至無視、歪曲事實</td>
<td>相信事實</td>
<td></td>
</tr>
<tr>
<td>物我不分，常常混淆主觀的想法和客觀的事實</td>
<td>分清猜想和事實，對主觀性的猜想要客觀性的證明</td>
<td></td>
</tr>
<tr>
<td>缺乏邏輯規則約束的編織式的推理，跳躍性的結論</td>
<td>通過對事實進行合乎邏輯的推理而得出結論</td>
<td></td>
</tr>
</tbody>
</table>

從上表可見，科學思維的兩個基本要素，即尊重事實和遵循邏輯，恰恰是幼兒難以做到的！這正是科學思維對幼兒所構成的挑戰。

如何看待這一問題，又如何應對這一挑戰？我們認為，幼兒思維發展的狀況，既指明了幼兒科學教育的起點和方向，同時又說明了幼兒科學教育的特殊性質。這是幼兒科學教育所必須堅持的辯證觀。
幼兒缺乏科學的思維能力，這就給教育提出了要求。我們對幼兒進行科學教育，一個重要任務就是給予理性的啟蒙，將科學思維的種子播撒在幼兒的心靈中。幼兒科學思維的培養，有三個關鍵性的實踐要點：

第一步是對問題的猜想。

即使沒有教師的提示，幼兒也會對問題有自己的猜想，只不過他會用猜想代替進一步的探究，從而省略地得出結論。教師引導幼兒進行猜想的意義在於，我們可以從幼兒己有的認識水平出發，將他們引向科學探究的過程。

猜想本身就是一種思考。教師要追問幼兒「為甚麼這樣猜想」，這樣做的作用就是可以有效地鼓勵幼兒進行有根據的猜想。他們會主動地運用己有的經驗，來思考當前的問題。

對於幼兒的各種猜想，教師都要加以重視，並啟發幼兒如何證明它。幼兒的有些猜想的確是荒誕的，沒有依據的，而且也無法驗證，教師可以采取保留的態度，既不肯定，也不否定。

第二步是事實的實驗。

對幼兒的任何想法，都要引導其通過事實來實驗。觀察是直接的獲取事實的途徑，對於較大的幼兒來說，實驗則是更有力的證明。

無論事實和他們先前的想法是否一致，對幼兒來說都是很有意義的。如果幼兒發現事實證明了自己的想法，他們會得到一種驚喜的感覺，而當他們發現了和自己想法相反的事實，也許會感到很意外，但這種意外能使他們留下深刻的印象，並衝擊其固有的想法。

教師要不斷地強化幼兒這樣的價值觀：相信事實！

第三步是理性的思考。

也許這對幼兒來說是最為困難的，因為他們還沒有助於掌握理性思維的工具。但是幼兒天生具有一種理解的願望，希望得到對現象的解説。我們可以啟發幼兒對客觀事實進行進一步思考，或提出質疑從而引

發新的問題，或將有關聯的事物聯繫起來，以尋求它們的內在關係。

最後需要提及的是，幼兒科學教育的任務，是在幼兒的心靈中埋下科學思維的第一粒種子。科學思維在幼兒時期的培養，應該是建立在幼兒的好奇、發問和好奇思維想像的基礎上。科學思維在幼兒時期的培養，應該是建立在幼兒的好奇、發問和好奇思維想像的基礎上。
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規範，而棄用主流的科學教學法。透過「科學思維小冊子」，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 class rooms 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.

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.

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 them 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 curiosity 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.

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 diffraction 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.

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”.

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)

References
Enhancing Children’s Mathematical Thinking and Problem Solving Skills

Abstract
In this article I discuss how children’s mathematical thinking and problem solving skills are enhanced through cooperation with others in different social settings – peers and teachers. This article also presents examples showing how children construct mathematical concepts and actively involve in problem solving activities.

小時候，筆者上數學課時總是看不見老師的臉；他常常面向黑板，很用心的示範運算方法。每當老師示範完畢，便會讓我們做數學練習。同學遇上困難，老師便在練習簿上再示範一次運算方法；但老師從來也沒有讓學生思考不同的運算方法，也沒有讓大家發問或討論問題，數學好像是一個簡單的示範及模仿的過程。老師看重的是答案是否正確，而不是運算的過程。結果，學生只機械式的模仿老師的運算程序，而沒有主動思考問題及主動尋求解決方法的機會。

吳慧鳴指出因靠成人的講解或抽象符號的記憶，兒童不能真正理解數量概念或形成數學概念。吳慧鳴指出兒童須透過動手操作物件，以刺激思考，形成外部動作向內部思索活動的轉化。兒童累積不同的感官探索經驗，能整理數學表象，主動領會及建構數學知識體系（吳慧鳴，1995）。

Hoover (2003) 的研究證明幼兒對物體數量的理解有賴於他們動手操作物體。Hoover設計了一個適合五歲幼兒之小組遊戲（三人至五人玩），由成人扮演銀行職員。孩子輪流揩骰，然後依數目取適當的硬幣。當兒童收集了七個分錢（pennies）後，可向扮演銀行職員的成人換取一個分錢（dime），集齊十個十分錢（dimes），可換一元（dollar）。Hoover的研究結果顯示，透過生活化的遊戲情境可有效幫助孩子明白不同錢幣之價值及關係。例如：一位兒童在投擲三次骰子後已搜集了七個分錢，他主動的告訴成人他只需要三個分錢便可換一個十分錢。他接着擲出一個數目字4，
買賣遊戲

一群五歲的孩子在班房內玩買賣遊戲。扮演售貨員的莉莉大聲的向同伴說：「果汁買二送一。」引起扮演客人的小明和小迅的注意。

小明對莉莉說：「是不是買兩盒橙汁送一盒橙汁？」
小迅搶先回答：「兩盒橙汁送一盒提子汁也可，只要是果汁便可以。」
小明問：「那麼可不可以買一盒橙汁，一盒提子汁，再送一盒檸檬汁？」

從以上例子可見，透過程生活化的模擬遊戲，五歲的兒童能主動分析不同的數學概念，明白 \(1 + 1 + 1 = 3, 2 + 1 = 3\) 等於 3。他們也通常把物件歸類，明白果汁是不同種類的統稱。遊戲中學習數字概念，比在練習薄上進行機械式運算來得有趣生動。買賣遊戲能提供一個生活化的運算情境，使抽象的數字變得具體和有意義。

以上提出了兒童主動建立數學概念之實例，但老師的角色也很重要。有效的師生互動可提升兒童解題之能力 (Faivillig, Murphy, & Fuson, 1999; Vygotsky, 1978)。Faivillig (2001) 提出要促進兒童的數學思維發展，老師須引導兒童建立系統的比較和綜合不同的解決問題方法。老師不應示範單一的解決問題方法，而應該鼓勵孩子主動思考不同的方法，培養兒童表達他們的想法。老師須多鼓勵兒童共同解決問題，透過兒童間之討論，互相補足及延伸別人的想法。老師也可從兒童的說話，具體理解兒童的想法。以下分別即說明社交互動如何能促進兒童深入的分析問題。小孩子到了大約六歲便開始換牙，兩位五歲的孩子主動對這現象作出分析：

小茜：「哥哥昨天掉了一顆牙。」
小迅：「他一定是沒有好好的擦牙。」
小茜：「不是啊！哥哥每天也有擦牙。媽媽說每人也要換牙。舊牙脫了，會從新生長新的。」
小迅：「祖母也掉了好多牙，但並沒有再生新牙。」

五歲的兒童能適當的提出理論來支持自己的想法。小茜和小迅對脫牙的原因有不同想法。小茜知道哥哥正在換牙，但她認為人可不停換牙。小迅指出長者掉牙後不會再生牙齒，指出了小茜的想法不足之處。但小茜也正確的道出小迅每天換牙的人也會有牙齦的情況。他們的討論正好刺激他們從不同觀點去思考事物。Faivillig (1999, 2001) 提出老師應把握機會教

學，引導兒童有系統的比較和綜合不同的意見，以開放式的問題來引發兒童進一步思考問題。老師可對小茜和小迅說：「小茜的哥哥六歲，而小迅的哥哥已七十歲，那麼小童和長者的脫牙情形又會否不同？你們有何想法？」

以上各種活動的特點在於說明有意義的及個人化的數學活動，如何有效促進兒童的思維發展 (Faivillig, 2001; Cobb, Wood, Yackel, & McNeal, 1992)。兒童須透過動手操作物件來理解數量關係或形成數學概念 (Hoover, 2003; Copley, 2001; 吳慧鴻，1995)。老師應給予孩子充足的發言機會，並鼓勵他們試圖提出理論來支持自己的想法。當然老師也應進一步鼓勵他們透過實物操作去尋找答案。老師也邀請更多兒童加入討論，但必須維持一個開放及融洽的討論氛圍。老師應鼓勵孩子在討論過程中，每人的想法未必完全正確，但最重要的是各人說出自己的想法，集合大家的想法便可深入了解事物和有效解決問題 (Faivillig, Murphy, & Fuson, 1999)。

參考書目
吴慧鳴 (1995)：操作法的原理及其在幼兒數學教育的應用，《學前教育研究》6，頁43-45。
一些值得推薦的早期科學和數學活動
——學員習作分享

Scientific and Mathematical Activities in Early Childhood:
Sharing from Students’ Assignments

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摘要
本文匯集了幼稚園教育證書課程 (2003-2006) 14F2班三位教師學員的習作，分析了他們的一些經驗和做法，以說明早期科學和數學活動的一些重要特徵。

Abstract
Assignments from three student-teachers in the class 14F2 of Certificate in Kindergarten Education Programme (2003-2006) class were collected and presented in this article. Basing on their practices and experiences, the work showed some important characteristics of scientific and mathematical activities in early childhood.

如何設計和實施早期科學和數學活動，使科學和數學活動能夠有效地綜合並引起幼兒的活動興趣、激發幼兒的探索和思考？如何適應幼兒的年齡特徵和個別差異設計和實施這類活動？幼兒教師如何在科學和數學活動中發揮導架作用，促進幼兒的新發展？這些一直都是學前教育有關課程引導學員重點探討和實踐的課題。本篇文章引述香港教育學院幼稚園教育證書課程 (2003-2006) 14F2班三位學生的習作，這些習作中的經驗和做法對於以上課題會給予一些重要啟示。

物體在水中的浮沉現象是學校經常開展的幼兒科學活動內容之一。黃少芬和薛思琪的習作就是圍繞這個主題進行的連續三天的活動。

一、活動目的分析

<table>
<thead>
<tr>
<th>黃少芬</th>
<th>薛思琪</th>
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<td>幼兒班：3-4歲幼兒</td>
<td>高班：5-6歲幼兒</td>
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<td>活動目的</td>
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<td>了解和掌握浮沉的概念及影響浮沉的重量因素；學習實驗記錄方法及預測方法；掌握估量概念：輕重、空滿、多少；進行單屬性分類，並製作成簡單的統計圖</td>
<td>在已有知識經驗 (物體重量影響它們在水中的浮沉) 的基礎上，認識物件形態與浮沉的關係；能用量度單位 (克/g) 稱量物件的輕重，並按照由重至輕或由輕至重的順序排列物件。</td>
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以上兩個年齡階段的活動目的同時融合了科學和數學元素；這些目的適合幼兒已有經驗和認知水平，比如：探索影響浮沉的變量由簡單到複雜，即由單一的重量變量到重量和形狀的複合變量；對重量的把握由單一的估計到用量度單位進行測量，即由估量概念到測量概念 (咸子娟，2004)。
二、活動過程分析

黃少芬 幼兒班：3-4歲幼兒

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<th>教師的作用</th>
<th>兒童的反應</th>
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<tr>
<td>• 感知及觀察浮沉的現象*</td>
<td>有些兒童能辨認5字，知道每次只容許5人玩。有些兒童以一一對應辨別，如沒有圍群便不能玩。</td>
</tr>
<tr>
<td>首先，通過問題，引導幼兒使用浮及沉的詞彙來標識生活情境中的浮沉現象；其次，觀察圖片，提出「有甚麼物件會浮在水上？有甚麼物件會沉到水下？」的問題，考察幼兒是否理解浮及沉的概念。</td>
<td>船、水泡、鴨、潛水員</td>
</tr>
<tr>
<td>• 提供直接經驗*</td>
<td>有些兒童能辨認5字，知道每次只容許5人玩。有些兒童以一一對應辨別，如沒有圍群便不能玩。</td>
</tr>
<tr>
<td>請兒童到「探索園地」的水池運用玩水物料插水、「探索園地」每次能容納多少兒童？</td>
<td>船、水泡、鴨、潛水員</td>
</tr>
<tr>
<td>• 激發幼兒在玩中的思考*</td>
<td>有些兒童能辨認5字，知道每次只容許5人玩。有些兒童以一一對應辨別，如沒有圍群便不能玩。</td>
</tr>
<tr>
<td>玩的過程教師提問：甚麼物件浮在水面？甚麼物件沉下去了？</td>
<td>船、水泡、鴨、潛水員</td>
</tr>
<tr>
<td>• 引出新的刺激*</td>
<td>有些兒童能辨認5字，知道每次只容許5人玩。有些兒童以一一對應辨別，如沒有圍群便不能玩。</td>
</tr>
<tr>
<td>教師出示猩猩手偶說故事內容：小猩猩很苦惱，猩猩大王要小猩猩把一堆物件分成浮和沉（出示實驗物）兩類，並記錄在紙上（出示記錄表）。但小猩猩不懂分辨，希望小朋友幫忙。</td>
<td>船、水泡、鴨、潛水員</td>
</tr>
<tr>
<td>• 假設、實驗、分類和記錄*</td>
<td>有些兒童能辨認5字，知道每次只容許5人玩。有些兒童以一一對應辨別，如沒有圍群便不能玩。</td>
</tr>
<tr>
<td>請兒童跟着記錄表次序介紹各種實驗物件，每介紹一物件後，請兒童猜物件是浮還是沉再自行將物件放入水中，看看結果，在適當的格上印／號記錄，記下實驗結果。然後將浮在水面或沉下去的物件分類放在兩個盤子上。</td>
<td>船、水泡、鴨、潛水員</td>
</tr>
<tr>
<td>兒童齊聲說可以幫忙。</td>
<td>船、水泡、鴨、潛水員</td>
</tr>
<tr>
<td>放入水中看看。</td>
<td>船、水泡、鴨、潛水員</td>
</tr>
<tr>
<td>有位兒童指着魚缸上的浮字說在這裏是浮，指着沉字說在這裏是沉。</td>
<td>船、水泡、鴨、潛水員</td>
</tr>
<tr>
<td>大多數兒童能觀看實驗結果後，正確說出物件是浮還是沉，並正確印上／號，記下實驗結果。兒童經記錄步驟後，能快速地將物件分類放在兩個盤子上。</td>
<td>船、水泡、鴨、潛水員</td>
</tr>
<tr>
<td>教師的作用</td>
<td>兒童的反應</td>
</tr>
<tr>
<td>------------</td>
<td>------------</td>
</tr>
<tr>
<td>• 比較和計數 *&lt;br&gt;猩猩大王還要小猩猩說出浮和沉的數量及多少。&lt;br&gt;教師協助兒童把浮和沉的物件逐一放到格子上，把物件變成一行一行的，並排在一起。我們來看看這些物件，你們覺得哪一行比較多？哪一行比較少？</td>
<td>1、2、3、4，有4個；1、2、3，有3個。&lt;br&gt;浮的多，沉的少。&lt;br&gt;船在海上行駛，所以浮。&lt;br&gt;車不懂游水，在馬路行，所以沉。&lt;br&gt;膠波細小，所以浮。</td>
</tr>
<tr>
<td>• 分層次探索影響浮沉的重量因素 *&lt;br&gt;根據實驗結果，與兒童討論物件為何會浮？為何會沉？&lt;br&gt;• 根據幼兒的以上反應，使問題具體化 *&lt;br&gt;為何膠波會浮，鐵珠會沉？&lt;br&gt;再嘗試果汁瓶和空水瓶（讓兒童拿着感受，粗略測量輕重）。&lt;br&gt;• 引導幼兒將感知演變為實驗 *&lt;br&gt;還想不想玩小實驗試試是否重的物件會沉及輕的物件會浮？與兒童一起看實驗小書，選一些簡單而兒童感興趣的「輕重變量實驗」，與兒童一起嘗試做，協助兒童更具體感受影響物件浮起沉的重量因素。</td>
<td>船在海上行駛，所以浮。&lt;br&gt;車不懂游水，在馬路行，所以沉。&lt;br&gt;膠波細小，所以浮。&lt;br&gt;鐵珠好重，膠波較輕。&lt;br&gt;果汁瓶好重，空水瓶輕。</td>
</tr>
<tr>
<td>實驗：預備一瓶果汁和木瓜，請兒童放到水中先試試。然後，如何把它變成浮？發現它會沉下。&lt;br&gt;把果汁倒出。&lt;br&gt;切開木瓜，還有不要肉，變船形。&lt;br&gt;(兒童記得實驗小書的活動步驟。)</td>
<td>發現它會浮在水上，兒童很興奮。</td>
</tr>
</tbody>
</table>
哪一個木瓜重？
哪一個木瓜輕？
再放進水裏看
哪一個沉？
哪一個浮？

從具體操作中認識重的物件會沉及輕的物件會浮。

實驗：請兒童放紙船，然後給兒童每人一種顏色的磁
石貼（十粒）。

猩猩買了很多貨物要運往自己的國家，誰能幫猩猩？

你們的船能載多少箱貨物？
船載貨後會不會沉啊？
請兒童一起試，把磁石貼（貨物）慢慢放到紙船上。

載多少個才會沉啊？
我們再試一次。

數數放多少貨物，船會下沉？

船會浮在水上

我們有船運貨
（第一天的討論經驗）
一 約6, 10個，5個，8個
一 不會
一 發現船會逐漸往下沉

一 不知道
一 兒童把磁石貼（貨物）慢慢放到紙船上，
一 看到船沉便停止加貨。
一 兒童在水中取出自己的貨物，放到數數格上，數數
看放多少貨物，船會下沉。

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

*10以內數量與數字的對應
關係（成子娟，2004）
（兒童在[10]以內數數，會
出現數字亂跳的情形，活
動中物件對照數格數數的
過程，兒童對於數與量的
應對已漸有概念。）

*讓兒童知道船承載的貨物
（重量）太多，便會沉入水
中。從具體操作中認識重
的物件會沉。

薛思琪
高班：5-6歲幼兒

教師角色及提問

- 瞭解幼兒的現有水平

出示「浮沉圖片」及字咭，請幼兒把「浮」、「沉」、「半浮
半沉」字咭貼於適當的位置上，在透明膠箱面畫上
浮、沉和半浮半沉的位置線，從而把握幼兒能否辨別
物體在水中的三種形態。

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老師問幼兒：「為甚麼有些物件在水中會浮；有些會沉；有些會半浮半沉呢？」

- 在幼兒的已知水平上刺激他們新的思考
  請幼兒檢視他們先前的推斷，即，重量影響物體在水中浮沉。
  - 首先，學習用「g」（克）的磅秤稱量幾種不同食物，其中，老師指導幼兒學習：「g」即「克」，是一重量單位，而磅上的每一小格即代表5克。利用先前已掌握五個一數的概念進行計量，並將結果記錄下來。將這些重量不同的食物，由重至輕或由輕至重作排列。

- 其次，幼兒輪流把食物放進盛有水的透明膠箱中，並作記錄。

- 有目的地引導幼兒觀察和發現：影響物體浮沉的因素除重量外，還有形狀因素 *
  - 提問引起幼兒新思考*
    老師提出新的問題：「為何蘋果較重會浮；而獅子狗較輕則會沉呢？生菜、魚片、蟹柳及白蘿蔔同是重25克，但為何它們有不同形沉浮形態呢？它們當中有甚麼不同呢？」

  - 與幼兒同驗證物件形狀，是否會影響其浮沉狀態 *
    老師請各幼兒用磅量出20克的泥膠，及搓出不同的形狀，並繪畫這些造型於記錄表上。

老師問：「泥膠的形狀改變了，其重量都會改變嗎？可用甚麼方法得知？」
請幼兒預測這些泥膠造型於水中的形態。

幼兒都認為物件輕會浮，重會沉，而不太輕和重的就會半浮半沉

有幼兒說看到「g」字，數字，及一格格等。觀察時，有幼兒說刻度較小，較難看清楚。於是他們提出用放大鏡以助觀察。

幼兒能夠在磅秤上5個一數，將稱量的結果記錄下來

幼兒都很驚訝，他們大多認為蘋果200克應沉的；而獅子狗20克應是浮的，但結果卻相反。

在討論時，有幼兒就說：「原來有些重的食物也會浮的，而有些輕的也會沉」。有幼兒看到它們的形狀是不同的。於是大家皆認為可能是形狀的不同，而影響其浮沉的結果。

幼兒分別搓出類似生菜的碗形、蟹柳形、魚片形、牛丸形及獅子狗形。

這時幼兒都提出可用磅再量度一次，並作記錄，結果是泥膠的重量沒有改變。
請幼兒驗證以上的預測，並作記錄。

- 把幼兒發現的「密度」問題，簡化為可以觀察和具體操作的實驗。

與幼兒討論，「牛丸和泥膠球都是20克的球體，但為何一個是浮，一個是沉？它們又有甚麼不同？」

於是，老師採用與幼兒一同在課室搜尋不同物質的球體，看其浮沉的狀態，從而讓幼兒認識到雖然形狀相同，但物質不同也會影響其浮沉。

（實際上是物質的「密度」影響其浮沉，但由於該概念太深，所以只與幼兒說物質。）

活動是從幼兒發現的問題出發，而有些活動則是由教師設計問題情境，引導幼兒進行探索和思考。無論哪種情況，都需要教師的設計和引導作用。最終這些設計和引導過程能否激發幼兒探索和思考，而不是用教師思考代替幼兒思考。

以上活動重點是教師設計問題情境，當教師學員確認活動的起點之後：

- 幼兒班教師學員的做法是有目的地引導幼兒觀察和發現影響物體浮沉的重量因素。其具體做法是：提供重量上差異懸殊的兩個物體：膠紙和鐵紙球，以及裝滿果汁的瓶子和空瓶，並附以具體化的提問，如：「為甚麼膏會浮，鐵球會沉？」和引導幼兒用手掂量。在這一系列體驗和思考之後幼兒發現了影響浮沉的重量因素。教師學員進一步引導幼兒去驗證重量如何影響物體的浮沉。難能可貴的是，這些小實驗的做法不是教師直接展示，教授的，而是教師引導幼兒在閱讀中掌握的。試想：幼兒把他們自己在閱讀中得到的小實驗做法親手做出來，這對於他們的自主性、自信心和閱讀興趣的培養會有哪些意義呢？這是不難回答的。

- 高班教師學員的做法是有目的地引導幼兒觀察和發現影響物體浮沉的重量因素，除重量外，還有形狀因素。從幼兒的一系列活動中我們發現了教師的精心構想：這一系列活動的選擇，是有目的的讓重量和形狀因素對比突出顯現，即，幼兒經過稱量把幾種食物分成三種重量的類別，當幼兒把把它们放到水裏試一試的時候，卻發現這個結果與幼兒的已有經驗相矛盾。幼兒都很驚訝，他們大多認為蘋果重200克應該是沉的；而獅子狗重10千克應該是浮的，
但結果卻相反」。教師學員在幼兒面對困惑的時候，緊接著提出的是十分具體而有價值的。所謂具體就是，這個問題能夠把幼兒注意力引向重量和形狀的框架內，再將重量變量固定，而集中於形狀方面作出觀察：「從何處較重要？而猴子狗較輕則會沉呢？生菜、魚片、蟹柳及白蘿蔔同是重25克，但為何它們有不同的浮沉形態呢？它們當中有甚麼不同呢？」。所謂有益價值就在於這個問題可以造成幼兒在認知上的衝突，而刺激幼兒新的思考和探索。[調適] （Piaget, 1977）：幼兒很快就發現可能是形狀不同，而影響其浮沉結果。接下來活動也是十分有針對性的，即：幼兒用磅量出20克的泥膠，分別搓出類似前面所用的生菜的碗形、蟹柳形、魚片形、丸牛形及獅子狗形。再經一試，幼兒肯有自己的推論。

第三、迥避一些抽象的問題，引導幼兒在能夠直接感知實驗結果的水平上進行探索。許多時候，幼兒提出的問題，教師是難得用語言來解釋的。比如，以上高班幼兒驗證了物體形狀會影響它們在水中的浮沉之後，又發現了新問題，教師學員認識到這個問題與物體【密度】有關。由於幼兒是無法直接體驗把握物體的密度，所以這個概念對於幼兒來說就是十分抽象的。教師學員迴避密度概念，而把這個概念直觀化為【不同材料】的探索，這種引導幼兒能在直接感知實驗結果的水平上進行探索的做法是可取的。

第四，在科學活動中自然地融入數學元素，並使這些內容能夠恰如其分地配合幼兒的數學發展水平。很明顯，以上兩個階段的活動是以科學活動為主體，而在必要環節恰當溶入數學內容，引發幼兒的數學思考。比如，在幼兒班識字數與數目的對應，即，根據數字「5」確定到活動角遊戲的人數，根據浮沉因素將物體進行分類，數量不同類別的數量，比較多少，在估量的水平上掌握物體的輕重，並進一步學習新知識——10以內數量與數字的對應關係；而高班幼兒則學習新的計量單位、5個5個計數的測量方法，並學習把測量的結果用由10-200的數字表達出來。可知，這些活動均分別照顧了3、4歲和5、6歲幼兒已有的知識經驗，又在這個基礎上有效地指導幼兒提升到新的數學思考和數學學習水平。

三、結論和提示

從以上活動目的和活動過程分析中，我們看到：科學和數學探索的環境不只是常換不換的石頭、貝殼和放大鏡，而是根據幼兒興趣所在和探索需要而設置，並要常更換常更新；不同年齡階段幼兒可以從事同一種類的科學和數學活動，但是根據幼兒成長需要，活動變量需要逐漸複雜和深化；同一年齡階段幼兒不只是從事同一水平的活動，而是在各自的水平上得以發展：教師不只是被動地跟在幼兒提問的後面，而是處於主動的地位，除了要分析幼兒的問題，在必要的時候更要提出新的問題，刺激幼兒思考和設置可供思考的具體操作情境；科學和數學活動的內容和達到具體的目的，不是教師的想當然，而是首先瞭解幼兒的已有水平，並以此作為活動設計的重要參考因素之一；科學和數學不是相互的附屬物，而是活動中相互互聯的重要組成部分；科學和數學活動不只是讓幼兒獲得一些技能和瞭解一些事實，而是思維方法、閱讀和學習興趣、自信心和主動性的培育。

從對以上活動的分析中，也提出一些值得進一步思考的問題。這些問題是：為甚麼把食物或其他的物品作為浮沉的實驗變量？它與幼兒的生活現象有何關係？如果我們很難在現實生活中找出這些做法的意義，我們不妨將這些做法帶入幼兒的幻想世界。在回答這些問題的時候，教師學員梁荔紅著作中的一些做法可以暫時把這篇文章劃上句號。

梁荔紅的著作是關於磁鐵的實驗。通過三次活動，使幼兒探索磁鐵的吸附性、穿透性和傳介力。「本來，科學角的磁鐵無人問津，因為孩子們已經熟視無睹了，當我們將磁鐵變身成[磁鐵超人]時，他們立即興趣大增。」在這個[磁鐵超人]的幻想世界中和磁鐵超人的刺激下。「年輕的磁鐵超人」，[幼兒發現了直徑或馬蹄型[磁鐵超人]的不同能力]，幼兒更發現摩擦次數與磁力的關係：「一定要摩擦一百下以上才能吸住萬字夾」……從這個例子中我們可以看到，教師把幼兒對磁鐵的探索活動帶入了幼兒的幻想世界中。

如果把前面所分析的浮沉活動更密切地與幼兒的生活實際聯繫起來，或者在幼兒的幻想世界中將它們編排出，或許幼兒能更加深刻體驗這些活動的意義。

參考文獻

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