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## *Research Note*

# Crystallography and the Kindergarten – a correction?

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**Abstract:** *Christoph Meinel attributed the shift in chemical thinking required by the introduction of organic chemistry in the latter half of the 19th century to the influence of model making. He argued that this was enabled by the widespread availability of construction toys for children, based in the educational work of Friedrich Fröbel. I suggest that Fröbel's ideas about toys were influenced by his own experiences in chemistry, most particularly by his time as assistant to the foremost crystallographer of the day, Christian Samuel Weiss. I base this on the startling similarity between illustrations in one of the most important crystallography texts of the 1820s and in Fröbel's Pedagogics.*

## The chemistry

Christoph Meinel, writing on the history of chemistry and its approach to visual representations (2004, p242), remarked that the dominant thought changed in the 1860s from abstract and verbal to constructivist and pictorial, stimulated by the rise of organic chemistry, and the advent of a new theory of chemical structure in the late 1850s. John Dalton in 1808 thought molecules were composed of atoms with relative positions determined by a binding force, but without specifying the spatial arrangements of the atoms in the molecule. The belief that knowledge of true spatial arrangements could allow the linking of chemical behaviour to physical characteristics was announced by van't Hoff in 1874. Meinel argued that the change was led not by theory but by modelling of these new chemical spaces; the synthesis of new substances, the ideas forming the new stereochemistry, and even social space were thus demonstrated and their social and cultural messages were more easily understood and therefore accepted by younger chemists. This active construction of space was part of a more comprehensive change in perceiving the world and making it one's own, seen in cultural domains from pedagogy to architecture.

## The models

The form chemical models took began with rudimentary balls and pins as used by Dalton. In 1862, Hofmann introduced wire frames supporting cubes representing atoms which could be substituted for each other in molecule structure (Hofmann, 1862). These "moulds" were then used in the pedagogy of chemistry lectures. Meinel suggested that the choice of model and the language used disclosed a modeller or architect approach – in this case, architectural templates or moulds, used to show how to make something. These were not however meant to represent the physical arrangement of the atoms, but to give a pattern so that chemical operations of elimination and substitution could be classified. In 1866, the sales catalogue of J J Griffin offered a kit of 60 biscuit ware cubes, two inches square, and painted in various colours, to illustrate the atomic "various chemical doctrines by equations" (Griffin 1866, p194-5; Gee and Brock 1991; Meinel 2004,p 247).

In 1861, Alexander Crum Brown developed a graphical way to represent molecular constitution, and published it three years later. Inspired by this James Dewar, also a student of Lyon Playfair, prepared a model kit using narrow thin brass bars which could be clamped together in pairs to form an X shape, with the arms adjustable to different angles. This represented a carbon atom; coloured discs were used to be hydrogen and oxygen atoms. In 1865, Hofmann took Crum Brown's ideas to a new level by using coloured table croquet balls instead of circled letters as atoms, with tubes and pins to join them together. Still not intending to show spatial arrangements, Hofmann delivered a stunning Friday Evening Discourse at the

Royal Institution using these models to present the chemist as someone able to manipulate matter at will, and build new worlds from chemical material.

The lecture was widely reported (and illustrated), and commercial kits were rapidly available. However, their value as pedagogic tools in chemistry was questioned – even the advertisement for the set warned they might be mistaken for toys, and secondly, that incorrect ideas might be induced. However some eminent lecturers did use them – Frankland in London, and Schorlemmer in Manchester. They did not become popular on the Continent, but one notable exception was Kekulé, who had worked with Frankland and Hofmann. He introduced "bread roll" models for atoms, with the length of the roll giving the number of affinity units the atom possessed. Through the late 1850s and 1860s Kekulé used these models in his organic chemistry, but it was 1867 when he modified the atom balls to be three dimensional – carbon became a tetrahedron. This made the representation of double and triple bonds a lot easier, and later the same year the models were used as research tools in a paper showing the synthesis of trimethyl benzene. Two years later, two of his students used models to argue for the existence of previously unrecognised isomers. So by 1874, van't Hoff was able to build on an existing tradition of building 3D models as didactic devices, and also as aids to deriving stereochemical consequences from them.

## The toys

In relating this sequence of events to wider structural thinking, Meinel referred to a debate from the late 1860s concerning the construction of St Pancras Station in London. He then moved to the sale of 1850s construction kits for children, allowing them to create polygonal structures using peas and sticks, and linked them to Kindergarten pedagogy introduced by Friedrich Fröbel. In an almost throw-away sentence, Meinel commented "trained as an architect and later a student of physics, chemistry and mineralogy, Frobel was an assistant to Christian Samuel Weiss, the founder of modern crystallography, before he abandoned science and turned to pedagogy." (Meinel 2004, p267). He opened the first Kindergarten for early years' education in 1837, whence it spread through Germany, and after 1848 to Britain and the United States.

One of the foremost educational aids Fröbel used were geometric toys, supporting the child's self-activity in exploring the world. The simplest were spheres and cubes, with the child moving gradually up to brick boxes containing a number of cubes, cylinders and so on, in a carefully staged way. These kits were widespread from the 1840s, with manufacturers in Britain and the United States producing them in the1850s. In 1875, the aeroplane pioneer Gustav Lilienthal and his brother Otto invented a process for making artificially coloured stones for brick boxes in a precursor of today's Lego (Meinel 2004, p268).

Meinel remarked that although his readers do not need to assume Hofmann and his fellow chemists took children's toys as their source of inspiration, at the time it would have been almost impossible not to be familiar with their existence and meaning. The spread of construction thinking in Europe was demonstrated by the huge number of assembly kits during the second half of the nineteenth century, and both the Frobel and the molecular models were part of this movement (Meinel 2004, p269).

## The correction?

I suggest that Meinel has missed an early part of the history here. The illustrations of the kits in Fröbel's *Pedagogics of the Kindergarten* show a truly marked similarity to the illustrations of crystal shapes used in Haüy's *Treatise on Crystallography* of 1822. The stepped model of Fröbel's plate IV no 19 (Figure 1) in particular is presented in identical style to Plates 2, 3 and 4 in Haüy's *Treatise*, Vol 5, the Atlas of Illustrations (Figure 2). I therefore argue that the inspiration for the Kindergarten toy may well have come from Fröbel's experience of crystallography – he served as Weiss's assistant for nearly two years, working on the specimen collections, and would have been familiar with the crystallographic and mineralogy texts of the day, including and particularly the newly printed Haüy treatise. Further ideas of this kind are formulated in Elkins (1999, p19).

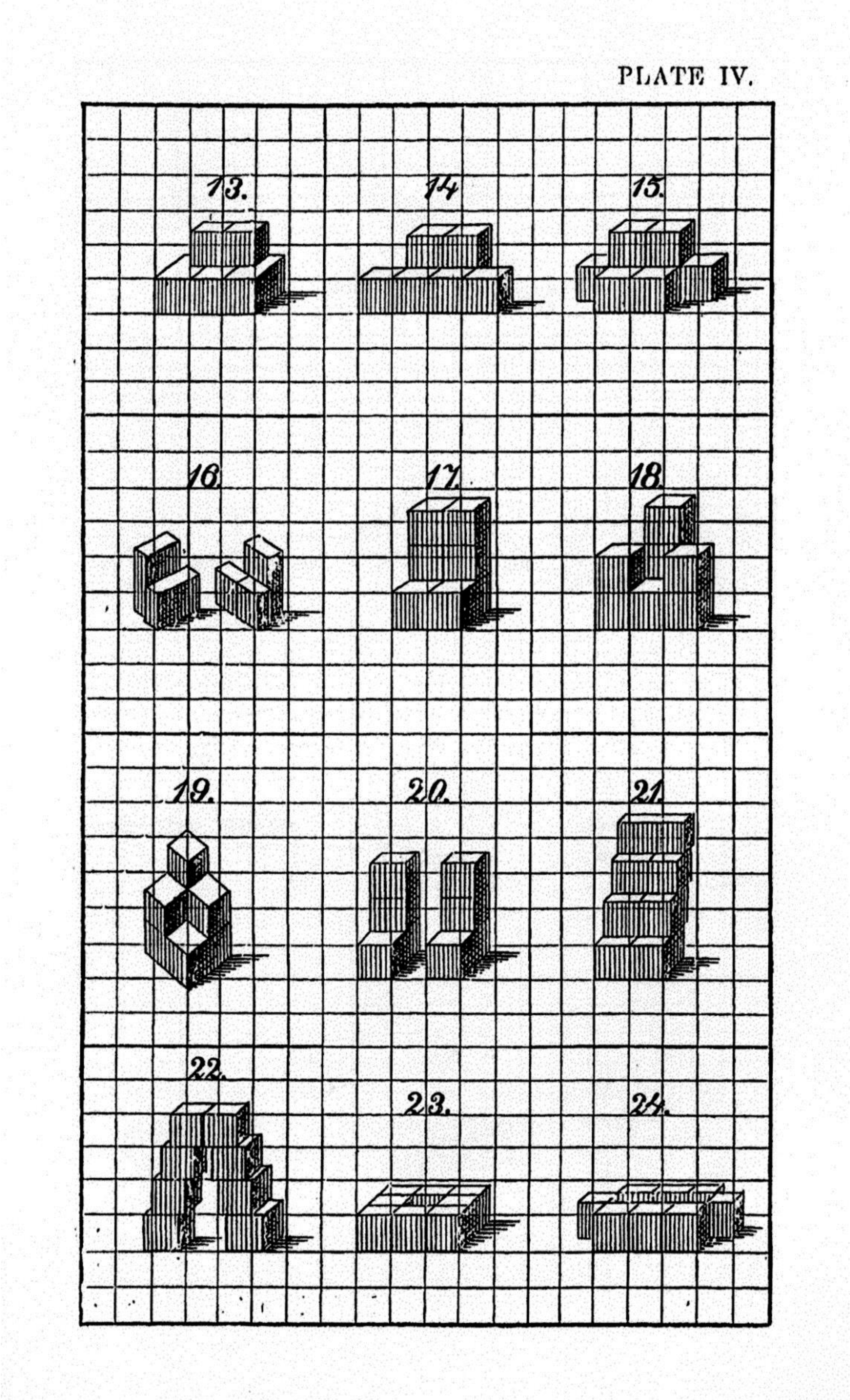


**Figure 1.** Plate IV from Frobel's *Pedagogics*, showing possible arrangements of the cubes in his Gift set

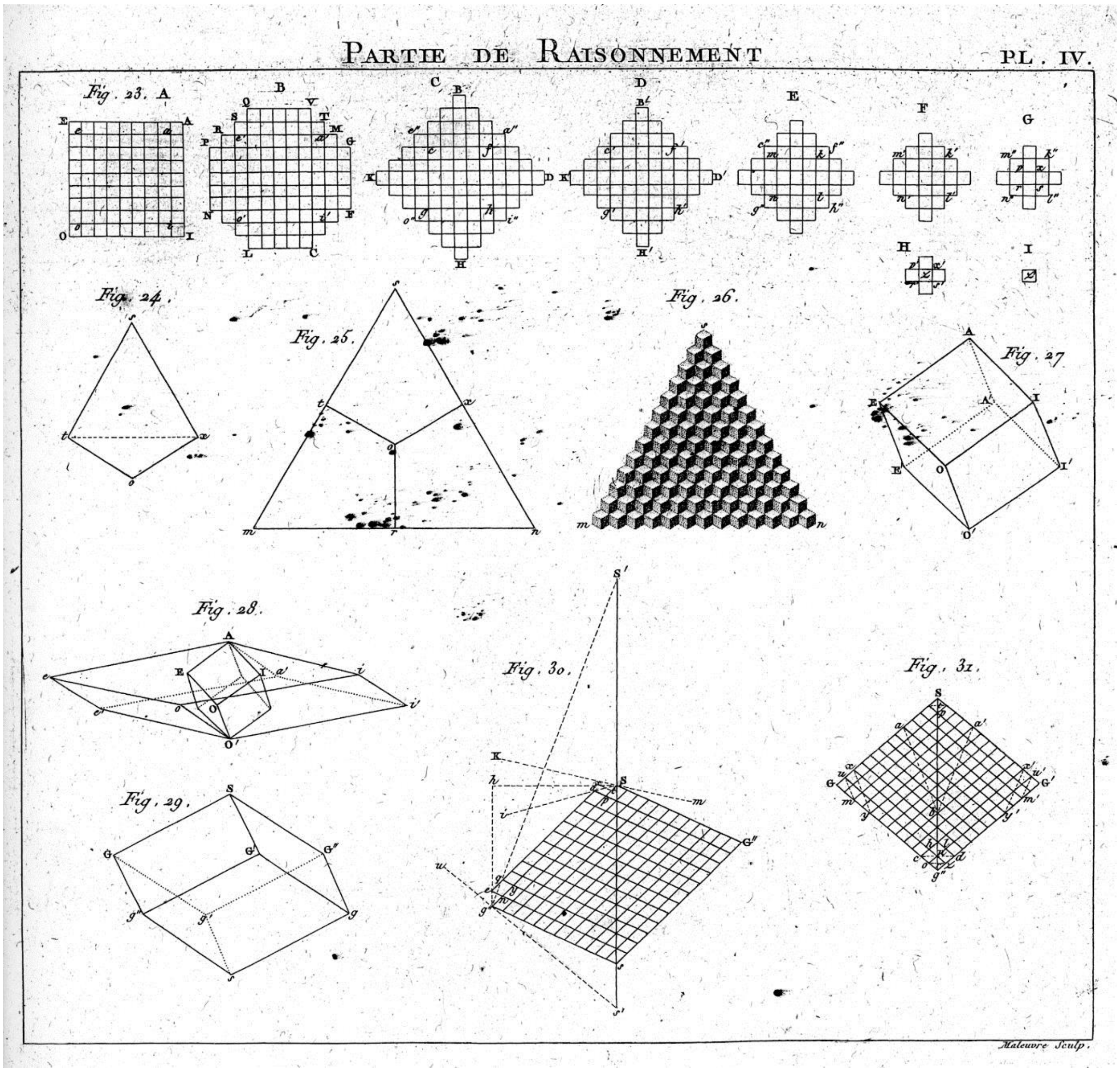


**Figure 2.** Plate IV from Hauy's Traite de Cristallographie, 1822 Vol 5, noting particularly the stepped appearance of Fig 26. This and the other plates mentioned can also be seen in on-line editions scanned by Google; this particular one was copied from the copy in the Science Museum Library, and is reproduced with permission. (Grateful thanks are due to Peter Jackson for assistance with IT issues.)

Another problem is that the toys to which Meinel refers are ball and pin models rather than blocks. Frobel did not personally introduce this sort of toy in his series of Gifts – he died in 1852, but his followers continued to work in the traditions he had tried to establish, and bead/pea and pin models were introduced as "Peas Work", according to Meinel, in the 1850s. Research continues to try to elucidate these points.

## References

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