Analysis of the Scientific Imagination Process

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Background to the research

This article describes how 5 award-winning secondary school teachers of science in Taiwan develop the scientific imagination of their students. They were studied by researchers from the Institute of Education at the National Sun Yat-Sen University, Taiwan, in order to explore the mechanisms and factors which influence the process of scientific imagination in secondary school students.

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The study built on Vygotsky's(1) theory that imagination is fundamental to human thought, and that our history of civilisation is the result of the operation and exercise of imagination. Examples would include the invention of paper during the Eastern Han dynasty (AD105), and numerous prototype ideas which modern-day science has realised e.g. in the classic novel, Journey to the West, set in the Ming Dynasty, the Monkey King reproduces himself using strands of his hair, foreshadowing today's ability to clone and Dolly the sheep (2).

Imagination is an innate ability which results from cognitive and emotional processes. Theoretical models are diverse: Osborne (3) distinguished between meaningful and non-meaningful imagination, whereas Pelaprat and Cole (4) conceptualise it as a process of closing gaps. Here, we approach the notion of imagination as a problem-solving tool. Theorists have also sought to identify the characteristics of imaginative people: keen observation skills and required; openness and free association are conducive, significant factors for organisation of the learning environment. The Taiwan researchers' focus was on how the encouragement of imagination can lead to imaginative ideas that can then result in the production of concrete objects.

Methodology

The researchers recruited 5 award-winning science teachers from different secondary schools in Kaohsiung, a town in southern Taiwan. They included male and female, and had an average 24.6 years' experience of teaching, including prior success in the International Exhibition for Young Inventors (IEYI). Nine 4^{th} to 6^{th} grade students were allotted to a teacher who had previously taught them and who guided them through the process of devising and making an entry for the IEYI over 9 months in 2010.

The researchers observed and recorded lessons for a total of 13 hours, and conducted semi-structured interviews with both teachers and students. These were recorded and validity was sought by triangulating data at each stage of the study. This followed the model proposed by Denzin (5) for optimising validity in qualitative research. The sets of questions used for the initial interviews are shown in table 1.

Table 1: The preliminary teacher and student interview questions

Table 1
Outlines of the first teacher interview and the student interviews.

Outlines	Participants	
	Teacher interview	Student interview
1	Describe your personal characteristics and teaching philosophies.	Describe your personal characteristics and reasons for participating in the IEYI competition.
2	Do you have past experiences relating to inventing? Where did your ideas come from?	Where do the ideas come from? What are your inspirations?
3	When did you start to instruct students for the IEYI? Why did you take on this task?	What kinds of difficulties did you encounter during the process? How did you overcome these difficulties?
4	What methods do you use to prepare students for participation in the IEYI? What are students' responses?	Who did you receive help from during the process? What kind of help? For example, teachers, parents, peers, or the utilisation of other resources.
5	How are ideas for the IEYI presented when you or your students think of them? Do you visualise the final products?	Are there any differences between the final products and the original ideas? Why?

Findings

The researchers identified specific characteristics for each stage of the scientific imagination process. The three stages were defined respectively as Initiation, Dynamic Adjustment and Virtual Implementation. Each stage required different core components in a dynamic, cyclical process. They comprised four elements:

1. brainstorming
2. association
3. transformation and elaboration, and
4. conceptualisation, organisation and formation.

This emerged from their study of 60 different projects during the research period. To illustrate the process, the researchers presented the Illuminated shoes project, which won a golden award in the 2010 competition.

The Illuminated Shoes project

Stage1, Brainstorming

The students began by identifying problems then applying their natural imagination to devise solutions. The issues they proposed were grounded in their everyday lives, e.g. how to make essential tools such as pens easier to carry. The teachers encouraged idea generation by prompting questions and use of visual stimuli. Most of the initial ideas were irrelevant to the problem to be solved. Figure 1 represents these in the first layer of cloud as unshaded shapes. The shaded elements were valid to the identified problem. The researchers found consistency with Csikszentmihalyi (6) in the need for curiosity and adventurousness at this stage of the process: the students wanted to find solutions and had open minds based on both past experience and newly-acquired knowledge (Polycastro and Gardner, 7).

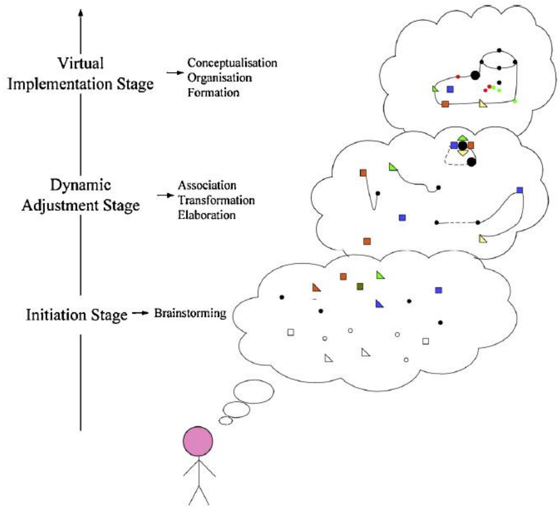

Figure 1: The process of scientific imagination

The Illuminated Shoes project was triggered by students' descriptions of a common problem:

> "I had experiences of going back to my home and shopping in the countryside. There are no streetlamps at night, and I have no hand free to use a flashlight because I carry many things in my hands"
>
> "I went camping with my family, and we went to a big park to see lightning bugs. We had to walk down many stairs to the park, but there was no streetlamp on the road. We didn't have a flashlight and really were afraid of falling down"

From this personal experience, they worked on solutions. Figure 1 again shows which of these were valid and those rejected in this, the initiation stage.

Stage 2, Dynamic adjustment

The second layer of the cloud illustrates how ideas were then linked together: the dotted line represents weaker links than the hard line. Teachers guided the students to identify those which were, for instance, novel, prompting them to deeper reflection. Financial and knowledge resources were also dependent on parental input, forcing the students to consider what they could realistically produce. Hence the process moved from abstract and impractical thinking to repeated modification of their ideas as they analysed contradictions and synergies between their ideas. The researchers termed this 'transformation and elaboration'. It was at this stage that the group decided to create a pair of illuminated shoes.

Stage 3, Virtual implementation

At the top layer of the cloud (figure 1) the focus is on formalising the idea by making prototypes. For the Illuminated Shoe project, this meant deciding on the appearance and material of the product, and how each component would be linked. Figure 2 shows the final design following this process of refining ideas and honing problem-solving skills in order to achieve a high quality product.

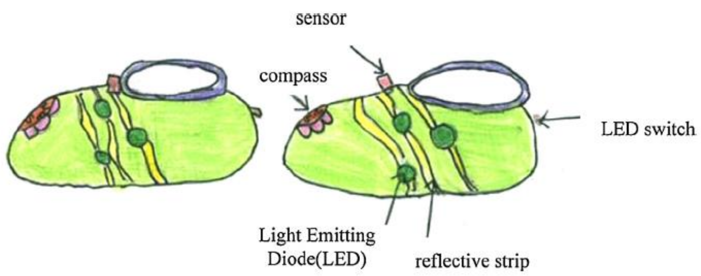

Fig. 2. Prototype of the Illuminated Shoes. The project was created by student group G1, guided by teacher C, and awarded a gold medal at the seventh IEYI in 2010.

Figure 2: Prototype of the shoes

Conclusion

The researchers concluded that origin of scientific imagination lies in the desire to deal with 'inconveniences' found in daily life, and that problem solving requires the operation of imagination. This progresses in small steps rather than revolutionary leaps. They classified these into the 3 stages

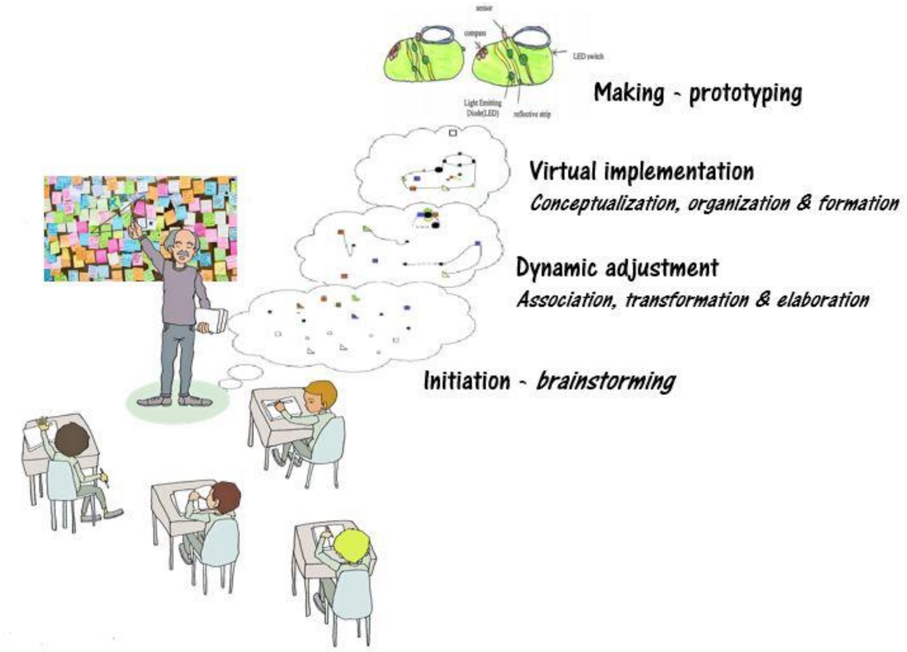

Figure 3: Envisaging the creative process

discussed above. Individuals are affected by both internal and external factors, and their imaginations vary. This is consistent with the findings of previous researchers, where significant factors are the ability to form new associations, observe keenly, be curious, have a desire to learn, be open-minded, adventurous, have wide-ranging prior experiences and interests. They end:

> To sum up, the results of this study showed that the major contributors to scientific imagination are the family environment, teacher guidance, peer interactions and multiple life experiences (e.g. reading novels and science fiction, going to the movies…)

They conclude that further research is called for in order to explore these factors in greater detail.

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I am grateful to Norman Jackson for use of his image of the creative process, figure 3.

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