Thinking Skills and Creativity 10 (2013) 68–78

Contents lists available at ScienceDirect

Thinking Skills and Creativity

journal homepage: http://www.elsevier.com/locate/tsc

Analysis of the Scientific Imagination Process

Hsiao-Chi Ho, Chia-Chi Wang, Ying-Yao Cheng*

Institute of Education, National Sun Yat-Sen University, Taiwan

ARTICLE INFO

Article history:
Received 29 July 2012
Received in revised form 7 April 2013
Accepted 18 April 2013
Available online 14 May 2013

Keywords:
Creativity
Invention
Scientific imagination
Scientific Imagination Process

ABSTRACT

Scientific inventions arise from the exercise of a rich imagination. This study aimed to explore the mechanisms and factors influencing the Scientific Imagination Process of elementary school students. Five award-winning science teachers and nine students recruited from a southern city of Taiwan participated in this study. The five teachers had an average seniority of 24.6 years and had won numerous major awards in the International Exhibition for Young Inventors (IEYI). The nine students had been instructed by these teachers with regard to their entries to the IEYI. Data were collected via teacher interviews, student interviews, and classroom observations. Data were analysed using qualitative methods and coded using ATLAS.ti software. This study provided multiple forms of evidence to ensure research validity. The results identified three stages in the Scientific Imagination Process: Initiation Stage, Dynamic Adjustment Stage, and Virtual Implementation Stage. Each stage was found to have its own key components. Additionally, individuals were influenced by both internal (e.g., motivation and personal dispositions) and external (e.g., family environment, teacher guidance, peer interactions, and multiple life experiences) factors during the process of scientific imagination. Several implications and suggestions for further research were also discussed.

> Imagination is more important than knowledge
>
> ~ Albert Einstein

1. Introduction

1.1. Scientific invention and imagination

Scientific inventions arise from the exercise of a rich imagination. Indeed, imagination is the driving force behind human thought, and human civilisation is created by the operation and exercise of imagination. Current developments in scientific technologies are the best examples of the process leading from the concretisation of imagination to the demonstration of creativity (Vygotsky, 1930/2004). From Cai Lun's invention of paper during the Eastern Han dynasty in AD 105 and the Chinese invention of printing technology in AD 550 to the invention of computers in AD 1946 and the development of the Internet in recent years, all great inventions originated from human imagination. Human beings use imagination to construct scientific theories and create new inventions to improve life through the process of constant thinking and trial and error. For example, Albert Einstein famously imagined himself flying at light speed and visualised the objects that he might see; from that flight of fancy and following further thought and verification, he ultimately developed the theory of general relativity. Thomas Edison invented light bulbs by imagining the use of many different materials for filaments and

* Corresponding author at: Institute of Education, National Sun Yat-sen University, 70 Lienhai Road, Kaohsiung 80424, Taiwan. Tel.: +886 7525 2000x5856; fax: +886 7525 5892.
E-mail address: chengyy@mail.nsysu.edu.tw (Y.-Y. Cheng).

1871-1871/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.tsc.2013.04.003

through many repetitive tests. The imaginative tale of the Monkey King, Sun Wu-kong, who created clones of himself from his own hair in the classic novel set in the Ming dynasty, *Journey to the West*, which inspired cloning of Dolly the sheep during the 20th century (Campbell, Mcwhir, Ritchie, & Wilmut, 1996). The cloak of invisibility in the Harry Potter series may become a reality with the metamaterials currently being investigated by American and British scientists (Pendry, Schurig, & Smith, 2006). Therefore, when human beings encounter the unknown, the exercise of imagination can generate many advances. Exploration, testing, and problem solving can yield many unexpected achievements that change the world (Mey, 2006; Osborn, 1953; Zabriskie, 2004; Zhao, Hoeffler, & Dahl, 2009).

Imagination is an innate ability of human beings, the basis for all creative activities, and the result of cognitive and emotional processes. Imagination operates based on daily life experiences that inspire creative activities (Lindqvist, 2003; Vygotsky, 1930/2004). Economic and cultural changes must be mediated by imagination and creativity, whereas scientific education is a good way to cultivate talented individuals with rich imaginations and creativity (McCormack, 2010). In other words, imagination constantly affects our thinking, language, and experiences (Adams, 2004; Grant, 2004; Mountain, 2007). The integration of imagination into scientific education and the use of different topics, such as the process of invention, is the key element to facilitate students to create products with their imagination. It can also provide opportunities for them to explore and stimulate their learning in order to find the best solutions to problems. These promote their ability to live well in the future (Church, 2006).

However, the definition of imagination is broad and vague. Gerard (1946) considered imagination to be an activity that produces novel concepts or mental insights. Lothane (2007) claimed that imagination is a basic ability to form mental images and link aspects of reality through visual images. Osborn (1953) has divided imagination into two categories, meaningful and non-meaningful. Meaningful imagination includes visual imagery such as speculative imagery, reproductive imagination, and structural visualisation, in addition to vicarious imagination such as empathy and role play. Non-meaningful imagination includes hallucinations, illusions, and dreams. Pelaprat and Cole (2011) characterised imagination as a process of image making that eliminates "gaps" arising from biological and cultural–historical constraints and that enables ongoing coordination of thoughts and actions. Innovation and creativity originate from rich imagination, whereas imagination is the precursor of the imagination process. Therefore, in the domain of scientific innovation, imagination is the mental activity that links daily life experiences and generates novel ideas. This mental activity is not limited by rules, nor is it hindered by current modes of thinking. It is an ability to construct images in the brain that are further concretised and visualised to generate ideas or prototypes that can solve current problems in life.

1.2. Factors affecting imagination

Osborn (1953) believed that people with more active imaginations and broader knowledge bases also have stronger associative abilities. Associative ability has an important status among the accidental factors contributing to creativity. As proposed by Lothane (2007), imagination is a basic ability that forms mental imagery or links events with ideas through the visualisation of images; thus, associative ability is a key element in imagination. Furthermore, imaginative people also need to have a capacity for sharp observation. Both of observation and imagination are abilities essential for conducting scientific research (De Cruz & De Smedt, 2010). Only by having the ability to constantly observe surrounding events or objects can one perceive an invariant truth or unique phenomenon. Imagination needs to be based on observation to enable us to deduce new ideas from what has been learned (Chen, 2000; Zeng, 2009).

Additionally, factors in the external environmental, such as multi-sensory stimulation, an atmosphere of openness, abundant resources, and teacher incentive awards, are major influences on imagination (Gallas, 2001; Osborn, 1953; Wood & Endres, 2004; Zabriskie, 2004; Zarnowski, 2009). Long, Winograd, and Bridge (1989) described seven perceptual forms of imagination: visual, auditory, gustatory, olfactory, tactile, kinaesthetic, and organisation sense. Douville (2004) also believed that the Sensory Activation Model (SAM), which relies on multi-sensory stimulation, is helpful for stimulating students' imaginations. Studies have shown that students in multi-sensory imagination groups have greater imagination ability than do those in other groups (Wood & Endres, 2004). This shows that imagination is closely linked to the concrete perceptual experiences available in an individual's current environment (Reijnders, 2010). Through multi-sensory stimulation, students can be facilitated to develop their imaginations and form more ideas through free association. At the teaching site, an open learning atmosphere that encourages and emphasises innovation facilitates the development of imagination and the ability to engage in creative expression. Teachers play a key role in establishing the atmosphere of the teaching site. Establishment of an open and free creative space by teachers will provide an environment that will not threaten the students but will encourage their imaginations. This type of atmosphere will help students generate notions that are not limited by current thinking modes (Dilek, 2009) and promote a continuous flow of creative ideas.

1.3. Purposes of the study

Through the operational process of imagination, students develop new and creative ideas that can lead to the generation of products or concrete objects (Eckhoff & Urbach, 2008). This process provides students with opportunities to explore the world, identify their interests, find solutions to problems, and further develop abilities that are necessary for the future