Thinking Skills and Creativity 13 (2014) 106–119

Contents lists available at ScienceDirect

Thinking Skills and Creativity

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

Development of the scientific imagination model: A concept-mapping perspective

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A R T I C L E   I N F O

Article history:
Received 29 August 2013
Received in revised form 30 January 2014
Accepted 9 April 2014
Available online 24 April 2014

Keywords:
Scientific imagination
Scientific imagination model
Concept mapping

A B S T R A C T

This study aimed to follow up on the research conducted by Ho, Wang, and Cheng (2013) and to develop a model of the scientific imagination using group concept mapping. Participants included five outstanding elementary school teachers and four researchers from southern Taiwan. The framework developed by Trochim (1989) was used as the basis for the construction of concept mappings of the scientific imagination through five panel discussions among the experts. A review of the literature, qualitative interviews, classroom observation, and document analyses were performed on group concept mapping, and independent relevant documents were used for data validation. A qualitative method was employed for data analysis. Finally, we developed the personality, developmental process, picture-in-mind, and surroundings (3PS) model of scientific imagination. Research results indicated that the scientific imagination model not only enhanced understanding of scientific imagination but also applied to daily experiences. The results of the present study are relevant to future projects and research in this domain, including the development of academic-based checklists to foster scientific imagination, the establishment of appropriate assessment tools, and the formulation of a specific curriculum for teaching the concept of scientific imagination.

1. Introduction

Creation and invention originate from a rich imagination. Many inventions originated primarily from ideational processes within what is commonly referred to as the human imagination. Through the operational processes, manipulations, and interactions involving imagination, a human being recognises internally generated creative ideas that lead to the invention and design of concrete objects that are eventually manufactured into products (Eckhoff & Urbach, 2008). Processes stemming from the human imagination potentially provide people with opportunities to explore the world, follow their interests, find answers to problems, and further develop capabilities that are necessary for future survival (Church, 2006). In other words, imagination has a substantial influence on human thinking, language, and life experience (Adams, 2004; Grant, 2004; Mountain, 2007).

Previous studies (Dílek, 2009; Eckhoff & Urbach, 2008; LeBoutillier & Marks, 2003; Lothane, 2007; Vygotsky, 1930/2004) have shown that the definition of imagination and the factors that contribute to its operation have not been examined comprehensively enough to allow for an adequate construction of a complete model of imagination and its stages. Based on

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http://dx.doi.org/10.1016/j.tsc.2014.04.001

this reasoning, Ho, Wang, and Cheng (2013) proposed that the scientific imagination emphasises purposeful processes and defined the scientific imagination as the mental activity involved in creating new ideas that are consistent with scientific principles and are linked to daily life experiences. This mental activity is not limited by rules or hindered by current modes of thought. It is the ability to construct images in the brain, generate ideas, and concretise these mental processes in the invention or creation of objects and products. Additionally, imagination may help people to push the boundaries of current knowledge, to exceed the limitations of generally accepted definitions of reality, and to enter an expanded scientific world and develop more elaborated scientific theories, thereby leading to technological advancements (e.g., new products) that surpass the inventions of the current generation.

Furthermore, Ho et al. (2013) explored the scientific imagination by studying award-winning teachers and students in the International Exhibition for Young Inventors (IEYI) competition using qualitative research methods including interviews, videotapes, and observations. They systematically collected, recorded, and analysed the results to determine how these successful teachers instructed their students. As a result, they proposed three stages in the process of scientific imagination, namely, initiation, dynamic adjustment, and virtual implementation; they also specified four components underlying the scientific imagination, namely brainstorming, association, transformation/elaboration, and conceptualisation/organisation/formation. Their findings constituted preliminary data that clarified the definition, operational processes, and factors contributing to scientific imagination.

In this study, we attempted to use a different approach, concept mapping, to confirm the process underlying scientific imagination. The use of concept mapping can help us think about and differentiate relationships among different concepts. It organises these concepts and integrates them in a systematic, hierarchical, and structured way through symbolic representation (Chiou, 2008; Ruiz-Primo & Shavelson, 1996). Additionally, further construction of a complete scientific imagination model can be achieved by understanding the processes underlying scientific imagination and the factors that contribute to such processes. This theoretical basis should be helpful as a reference and framework for modelling the skilled teaching of a curriculum on scientific imagination. Therefore, the current study aimed to comprehensively understand the three stages and four components involved in scientific imagination (Ho et al., 2013) by constructing concept maps and to develop a model of the scientific imagination.

1.1. *The scientific imagination process*

The process underlying scientific imagination was constructed from a teacher's perspective based on the professional knowledge and rich experiences of award-winning teachers, using data from student interviews and classroom observations as supplementary material (Ho et al., 2013). That study divided this process into three stages: initiation, dynamic adjustment, and virtual implementation. Four different key components operate during each of the three stages: brainstorming (*man-hsiang*, 漫想), association (*lien-hsiang*, 聯想), transformation/elaboration (*chi-hsiang*, 奇想), and conceptualisation/organisation/formation (*miao-hsiang*, 妙想). These three stages and four different components are described below.

1.1.1. *Initiation stage*

The initiation stage is the first stage in the scientific imagination process. The main focus at this stage is on the number of ideas that students can generate to solve a problem. During this stage, the key component is the use of imagination to generate ideas to solve problems encountered by the students themselves or by others in daily life. This stage is known as brainstorming in English (Ho et al., 2013) and as *man-hsiang* (漫想) in Chinese; it refers to thinking in such a way as to generate numerous ideas without regard for usual boundaries or structures. During this stage, teachers usually try to motivate, provide models for, and encourage students to observe experiences in daily life. Operating under the overarching principle of "good ideas come from many ideas", the teacher provides students with stimulation and modelling based on life experiences, and this encourages them to use their extant knowledge base (Cruz & Smedt, 2010; Ward, 1994). Students subsequently generate new ideas by combining existing knowledge under the guidance of teachers. Overlapping ideas and repetition are common during the initiation process.

1.1.2. *Dynamic adjustment stage*

Dynamic adjustment is the second stage in the scientific imagination process. In this stage, students choose one novel idea from the many possible ideas generated and use it to solve a problem. The operation of the imagination during this stage includes two components. The first component is known as *lien-hsiang* (聯想) in Chinese and association in English (Ho et al., 2013). It involves finding ways to envision relationships among ideas; that is, students connect related ideas, extend the concepts behind ideas, and identify contradictions between ideas and reorganise them accordingly (Cheng, Wang, Liu, & Chen, 2010; Koestler, 1964; Osborn, 1953; Pelaprat & Cole, 2011; Vygotsky, 1930/2004). Students are supposed to find as many relationships among ideas as possible.

The second component involves transforming an emergent idea into a novel idea by exploring its associative network. This component is known as *chi-hsiang* (奇想) in Chinese and as transformation and elaboration in English (Ho et al., 2013). It entails interpreting the emergent idea in a new way, thus attaching new meaning to form novel ideas. In this stage, teachers commonly guide their students by raising questions to help them reflect on and modify their ideas. Examples of such questions include "Can this idea solve problems?"; "Has this idea been proposed before?"; and "Will it be better if certain functions or parts are added?" (Ho et al., 2013). This teaching approach is intended to encourage students not to