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# Promoting conceptual change of learning sorting algorithm through the diagnosis of mental models: The effects of gender and learning styles

Wilfred W.F. Lau *, Allan H.K. Yuen

*Faculty of Education, The University of Hong Kong, Hong Kong*

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ABSTRACT

It has been advocated that pedagogical content knowledge as well as subject matter knowledge are important for improving classroom instructions. To develop pedagogical content knowledge, it is argued that understanding of students' mental representations of concepts is deemed necessary. Yet assessing and comparing mental model of each individual is very tedious and time consuming. This study attempted to use gender and learning styles to associate mental models in learning sorting algorithm. The Gregorc Style Delineator (GSD) was used to measure learning styles of the participants. Mental models were assessed using the Pathfinder Scaling Algorithm (PSA). Results indicated that females showed greater similarity in mental models than males and concrete learners also exhibited closer resemblance to the expert mental model than abstract learners. These suggest that gender and learning styles can be meaningfully used to associate mental models in order to provide a group-based instead of individual-based diagnosis and thus promote conceptual change in learning.



## 1. Introduction

Over the years, research has provided evidence in support of the notion that pedagogical content knowledge as well as subject matter knowledge are important for improving classroom instructions. McCaughtry (2005) refers to pedagogical content knowledge as "knowing subject matter, pedagogy, curriculum and students" (p. 379) and argues that "teachers must know students' prior knowledge and modes of understanding" (p. 380). This view is shared by Diana (1993) who asserts that:

> Teachers need to know more than just their subject. They need to know the ways it can come to be understood, the ways it can be misunderstood, what counts as understanding: they need to know how individuals experience the subject (p. 3).

Yet traditional assessment procedures provide few cues as to how students understand or misunderstand in the course of their learning since emphasis is usually placed on the outcomes rather than the process. To remedy this problem, Reeves (2000) suggests the use of alternative techniques of assessment. One of these assessment techniques suggested is cognitive assessment which aims to measure students' higher-order thinking skills and this is accomplished commonly by externalizing "the relationships they have made among concepts and processes within a domain and to reveal the structure of their knowledge" (p. 107). This notion of the structure of knowledge can be referred to as mental model according to Staggers and Norcio (1993). However, assessing and comparing mental model of each individual is very tedious and time consuming. Also, mental model studies conducted in the past have been criticized for an over-dependence on the performance data of the users which could be problematic (Sasse, 1991). The present study aimed to use gender and learning styles to associate mental models in learning sorting algorithm so as to provide a group-based diagnosis of mental models in order to promote conceptual change. To measure mental models, this study adopted the Pathfinder Scaling Algorithm (PSA) (Schvaneveldt, 1990) which is preferable to other conventional methods in which mental models are elicited per se without any reliance on performance tests.

## 2. Learning styles

It is commonly held that individuals learn in significantly different ways. These individual differences have been studied extensively under the heading of learning styles. Unfortunately, however, reaching a definitive definition of the notion of learning styles is not obvious

* Corresponding author. Address: Faculty of Education, The University of Hong Kong, Pokfulam Road, Hong Kong. Tel.: +852 28592540; fax: +852 25406360.
*E-mail addresses:* wilfredlau@graduate.hku.hk, wflau.geo@yahoo.com (W.W.F. Lau).

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since different researchers tend to work in isolation and address different aspects of the subject of styles. In other words, it is difficult to define learning styles unequivocally. Perhaps the definition by Riding and Rayner (1998) is the most comprehensive. They describe learning style as "an individual set of differences that include not only a stated personal preference for instruction or an association with a particular form of learning activity but also individual differences found in intellectual or personal psychology" (p. 51).

The notion of learning styles is further confused by the occasional use of terms such as "cognitive styles" and "learning strategies" interchangeably with "learning styles" in the literature. Yet there is no consensus as to whether they are really referring to the same concept. Messick (1994) defines cognitive styles as "characteristic modes of perceiving, remembering, thinking, problem-solving, and decision making, reflective of information-processing regularities that develop in congenial ways around underlying personality trends. They are inferred from consistent individual differences in ways of organizing and processing information and experience" (p. 122). Riding and Cheema (1991) point out that learning style is more concerned with the use of cognitive style in a practical learning situation while cognitive style is reserved more for academic purposes. They add that, as compared with the bipolar nature of cognitive style, learning style encompasses more elements, which are not mutually exclusive. This seems to suggest that cognitive style is in fact a component of learning style. However, there is empirical evidence showing that learning style and cognitive style may be two independent constructs (Sadler-Smith, 2001). Another problematic term associated with learning styles is "learning strategies". A learning strategy is understood as "a set of one or more procedures that an individual acquires to facilitate the performance on a learning task. Strategies will vary depending on the nature of the task" (Riding & Rayner, 1998, p. 80). On the other hand, learning style of an individual is more inherent to himself or herself and relatively stable over time (Loo, 1997).

One intriguing aspect of learning styles concerns its nature. As Riding and Cheema (1991) argue, cognitive/learning styles have been traditionally viewed as either a structure or a process or both and these different views have different implications for education settings. Cassidy (2004) discusses the "state-or-trait" debate on learning styles and provides a more workable explanation: "a style may well exist in some form, that is it may have a structure, but that structure is, to some degree, responsive to experiences and the demands of the situation (process) to allow change and to enable adaptive behaviour" (p. 421). Nonetheless, in this study, learning style is understood as innate individual differences in terms of perceiving and processing information.

## 3. Mental models

The theory of mental models describes how individuals interact with the world cognitively. Yet defining the term "mental models" has been a subject of controversy in the literature. Doyle and Ford (1998) remarked that "available definitions are typically brief, overly general, and vague, and different authors offer definitions that markedly disagree on centrally important features of mental models" (p. 21). Despite this, the definitions by Gentner and Stevens (1983) and Johnson-Laird (1983) are widely quoted as references. Norman (in Gentner & Stevens, 1983, p. 7) described mental models as follows: "In interacting with the environment, with others, and with the artefacts of technology, people form internal, mental models of themselves and of the things with which they are interacting. These models provide predictive and explanatory power for understanding the interaction." He further notes that mental models are incomplete, inconsistent, unstable, inaccurate, and parsimonious. Johnson-Laird (1989) defines a mental model as follows:

> A mental model can be defined as a representation of a body of knowledge – either long-term or short-term – that meets the following conditions: (1) Its structure corresponds to the structure of the situation that it represents. (2) It can consist of elements corresponding only to perceptible entities, in which case it may be realized as an image, perceptual or imaginary. Alternatively it can contain elements corresponding to abstract notions; their significance depends crucially on the procedures for manipulating models. (3) Unlike other proposed forms of representation, it does not contain variables... In place of a variable... a model employs tokens representing a set of individuals (p. 488).

There are in fact underlying differences in these two definitions. As pointed out by Greca and Moreira (2000), the definition by Gentner and Stevens (1983) represents an instructional approach which aims to provide "knowledge about the physical phenomena and, particularly, about mechanical and technological devices people develop" (p. 2) while that by Johnson-Laird (1983) represents a theoretical approach which attempts to "offer a unified and explanatory theory of distinctive cognitive phenomena, such as deductive reasoning and discourse comprehension" (p. 2).

In the literature, mental models have been described in different ways as "internal representation that the learner forms of the target system" (Papastergiou, 2005, p. 343), "mental representations to reason about, explain, and predict the behavior of external systems" (Ramalingam, LaBelle, & Wiedenbeck, 2004, p. 172), "complex schemas comprised of components and the relationships among them" (Brandt, 2001, p. 82), knowledge about a system, its component parts, and how they influence one another (Fein, Olson, & Olson, 1993), "organized structures consisting of objects and their relationships" (Staggers & Norcio, 1993, p. 591), and "a person's understanding of the environment" (Shih & Alessi, 1993, p. 157). Another related term is "conceptual models". It should be noted that a conceptual model is an appropriate representation of the target system created by researchers, teachers, designers, scientists, and engineers with the intention of facilitating understanding and teaching (Gentner & Stevens, 1983; Greca & Moreira, 2000). On the other hand, a mental model is constructed individually and recursively through interaction with the external world.

Notwithstanding the discrepancies in the definitions described above, in general, a mental model can be understood as a cognitive structure that forms an internal representation of objects of the external reality. It is a working model that enables individuals to understand and explain the phenomena, to make predictions and inferences, and to make decisions.

## 4. The Gregorc Style Delineator

The Gregorc Style Delineator (GSD) (1982) was used to measure the participants' learning styles in this study. This instrument and the reasons for using it are described below. According to Gregorc, the GSD was developed from data gathered through observations, taped interviews, and written protocols employing the phenomenological methodology which allows the collection and analysis of data of the "cognitive subjective perspective of the individual who was behaving, and the individual's feelings prior to, during, and subsequent to