A TECHNIQUE TO PROBE THE LEARNERS' KNOWLEDGE STRUCTURE IN THE CONTEXT OF SOLUTION CHEMISTRY TEACHING: THE WORD ASSOCIATION TEST

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1. Introduction

The content of science and its connection to ideas contribute to the learning process. Student learning is influenced by learner's representation and organization and learner's epistemology and ability level (Tyson et al., 1997).

As stated by Liu and Ebenezer (2002) a renewed interest in students' conceptions has resulted in a phenomenal increase in research studies on a large variety of science concepts (Driver & Erickson, 1983; Wandersee et al., 1994 cited in Liu & Ebenezer, 2002; p, 112). The popularity in student conceptions research has also engendered an interest among pioneer scholars in the field that overmany studies are purely descriptive, and the theoretical underpinning and practical implications are insufficient. Liu and Ebenezer (2002) also stated that, pioneer scholars feel that there is a need for an integrative theory or theories for describing and predicting students' conceptions (Wandersee et al., 1994). Two research emphases on students' conceptions have risen in the literature. One focuses on the qualitatively different ways of sensation natural phenomena by students, thereby the research endeavor is to develop descriptive categories of students' conceptions. Typical examples for this research emphasis are Ebenezer and Erickson (1996) and Renstrom et al. (1990). The other emphasis is explicitly cognitive psychology orientated and focuses on describing cognitive structures of students' conceptions. The examples are West and Pines (1985), Derman and Eilks (2016) and Derman and Ebenezer (2020).

Cognitive approaches about learning theory underline the importance of the interaction between the learner and the environment, the construction of a set of concepts and schemata through experience (Ausubel, 1978; Anderson, 1980, cited in Wilson, 1990). These netwoks are the cognitive structure of the individual. According to Tsai (2001), student knowledge gained from science courses is stored in the long term memory hierarchically and represented as a *cognitive structure* in their memory.

Though there is no single accepted meaning of it, the term of cognitive structure is well-founded (e.g. West, Fensham & Garrand, 1985; West & Pines, 1985; White, 1985; Bahar & Tongac, 2009). The facts, concepts, propositions, theories, and raw perceptual data are represented as individual's cognitive structure which also includes the individual's personal organisation of their knowledge (White, 1985). However, there is a limited amount of information about how these representations take places based on neural structures (Taber, 2008).

There are different terms like *structural knowledge* (Jonassen *et al*., 1993 cited in Liu and Ebenezer, 2002) or *knowledge structure* (Nakipoglu, 2008) to describe *cognitive structure*. The knowledge about how concepts within a domain are interrelated is structural knowledge, and it is also defined as the content-specific cognitive structure which deals with the essential element of students' conceptual understanding by being different from declarative knowledge. Studies on structural knowledge leans on how the conceptual understanding is structured in terms of inter-relationships between and among concepts instead of describing students' conceptions in categories (Liu & Ebenezer, 2002).

In the last decade, different research techniques such as word association, concept mapping, interviewing etc. have been used as research techniques (Lee, 1986; 1988). Gunstod (1980) highlighted some issues in terms of the method used to investigate cognitive structure of respondents (learners). White (1979) also explored some of these issues like the interactive nature of the purpose, the assumed model and the dimensions of cognitive structure of concern and the methodology used.

For example, there is a possibility of a cognitive structure probe itself affecting the cognitive structure. With methods based on interviews or the detailing of thought processes, the introspection is likely to cause some change in a respondent's cognitive structure.

Rumelhart and Norman (1978 cited in Gunstone, 1980, p. 46) proposed three broad modes of learning of complex topics: (1) accretion (the addition to knowledge/cognitive structures involving the topic), (2) restructuring (the reorganisation of knowledge/cognitive structures involving the topic), and (3) tuning (the smoothing of performance resulting from continued use of knowledge/cognitive structures related to the topic).

In addition to the information above, Taber's following perspective to determine cognitive structure in science education research would be beneficial for the pedagogy:

> *If research in science education is to inform pedagogy it is important to distinguish between ways of thinking that are well-established and tenacious and likely to impede new learning unless challenged; and ideas that may be romanced when a learner is asked an unanticipated question about a topic that she has previously given little thought to, and might well never be generated, let alone committed to, in the absence of being asked what seems an obscure question"* (Taber, 2008, p. 1031).

Çalık et al. (2005) mention about researchers examined solution chemistry and related studies to identify students' conceptions and their difficulties in using different research methods. Likewise, Fensham and Fensham (1987) conducted research on students' conceptions of the nature of solution using three phenomena: solids dissolving in water, reaction between chemicals in solution, and the influence of various factors on the rate of reactions by using clinical interviews.

Ebenezer and Erickson (1996), and Ebenezer and Fraser (2001) investigated grade 11 students' conceptions of solubility and first year chemical engineering students'conceptions of energy in solution process respectively via using a “phenomenographic” tradition of individual interviews. In their study, Pınarbaşı et al.,(2006) used multiple choice concept test as “Solution Concepts Test” to investigate the effect of conceptual change text-oriented instruction over traditional instruction on students’ understanding of solution concepts (e.g., dissolving, solubility, factors affecting solubility, concentrations of solutions, types of solutions, physical properties of solutions) and their attitudes towards chemistry.

In another study, Adadan (2014) examined probe the proggression of particular solution chemistry concepts (e.g., saturated and supersaturated solutions) with the help of interviews. By using a different method which is free writing tecnique, Liu and Ebenezer (2002) explored grades 7 and 12 students’ conceptions of solutions descriptivly and structurally.

2. Theoretical Perspective

One of the main goals of chemistry education is to support students develop an understanding of concepts and use them when solving a problem in a new situation. It is a fact that students frequently find solving chemistry problems difficult. According to Uzuntiryaki and Geban (2005), a major obstacle to solve chemistry problems can be the lack of understanding of chemistry concepts.

There are some requirements in chemistry learning like intellectual thought and discernment. Therefore, students must have logical thinking ability to reach comprehension (Blake and Norland, 1978) as the content is full of many abstract concepts such as dissolution (Çalık et al., 2005; Stavridou & Solomonidou, 1989; Abraham et al., 1994; Ebenezer & Gaskel 1995; Çalık, Ayas & Coll, 2007; Adadan & Savaşçı, 2012; Adadan & Savaşçı, 2014), particulate nature of matter (Liu & Lesniak, 2005; Adadan, Trundle & Irving, 2010) and chemical bonding (Othman, Treagust & Chandrasegaran , 2008).

Since a great number of students do not understand some basic conceptes of chemistry, they may fail to understand the more advanced topics including reaction rate, acids and bases, electrochemistry, chemical equilibrium, and solution chemistry (Uzuntiryaki & Geban, 2005; Çalık et al., 2005; Adadan & Savaşçı, 2012).

As these concepts are abstract and theoretical, they seem problematic to students (Ebenezer, 2001). That is why, it is crucial to understand the chemical processes such as melting, evaporating, dissolving, diffusion, electron transfer, ion conduction, and intermolecular bonding (Ebenezer, 2001).

The study of the behavior of solution concepts has been a fundamental part of junior and senior high school science and chemistry courses for many years (Çalık et al., 2005; Çalık, 2005; Adadan & Savaşçı, 2012). Much of the research exploring learners’ ideas about, and understanding of, science topics has been framed in terms of ‘misconceptions’, ‘alternative conceptions’ or ‘alternative frameworks’ (Taber, 2002; Duit, 2007; Taber, 2008).

By taking these into consideration, it can be said that the study of the behavior of solution concepts has been a essential part of junior and senior high school science and chemistry courses for many years (Çalık et al., 2005; Çalık, 2005; Adadan & Savaşçı, 2012). Therefore, studies on learners' understanding of science topics have been outlined in terms of 'misconceptions', 'alternative conceptions' or 'alternative frameworks' (Taber, 2002; Duit, 2007; Taber, 2008).

Nonetheless, these conceptions assume that learners have a steady way of thinking and understanding a subject as the general view suggests that 'conceptions' represent structures kept in memory in some form, and activated as whole (Taber, 2008).

Nakhleh (1992) suggested that after a student integrated misconceptions into his cognitive structure, these misconceptions interfere with subsequent learning. The student is then left to connect new information into a cognitive structure that already holds inappropriate knowledge. Thus, the new information cannot be connected to his/her cognitive structure and misunderstanding of the concept will occur.

According to Nakhleh (1992), misconceptions hinder later learning when a learner integrated misconstructions into his cognitive structure. Then, they are expected to connect new information into a cognitive structure that already holds unfitting knowledge. In such a situation, the new information cannot be associated with his/her cognitive structure and misinterpretation of the concept will arise.

Griffiths et al. (1988) proposed three steps needed to overcome student alternative conceptions. Diagnosis is the first one as a central step. After that, prescriptive and remediation come respectively. Most of the learners have misconstructions about solution process and the diverse aspects of solution chemistry (Teichert, Tien, Anthony, & Rickey, 2008; Haidar & Abraham 1991; Çalık et al., 2005; Çalık , 2005; Mulford & Robinson, 2002; Ebenezer & Gaskel 1995; Stavridou & Solomonidou, 1989; Uzuntiryaki & Geban, 2005; Çalık et al.,2007 ; Adadan & Savaşçı, 2012) .

In a study conducted by Abraham, Williamson and Westbrook (1994), the concept of dissolution with the original five concepts was added with the sample of 9th grade physical science students, 11th and 12th grade high school chemistry students, and college students who were enrolled in their first semester of general chemistry course at a university. In this study, it was observed that only a few students in the college chemistry had some comprehension of chemical change, periodicity, or phase change, while the use of particulate terms (atoms, molecules and ions) increased across the grade levels.

In a different study, Cosgrove and Osborne (1981) interviewed secondary students in New Zealand to determine students' conceptions of the solution process. When the students were shown a tea spoon of sugar dissolving in water, they were asked, "What happens to the sugar?" This study revealed that younger ones generally stated dissolving as melting while the older ones connected the process with the suitable technical term, but had no sound scientific concepts behind these terms.

In a similar study, Longdon, Black and Solomon (1991) compared 11–12 and 13–14 year-old students' understandings of dissolution; they found out that understanding of the particle interpretation enriched in parallel with advancing age. Similarly, Mulford and Robinson (2002) accentuated that learners had the misconception that total mass of the solution is lighter than sum of the mass of solute and solvent.

Other studies also reported that students referred to the interaction between the solute and the solvent in the dissolution process, they thought it to be a chemical change (Prieto et al., 1989; Stavridou & Solomonidou 1989; Haidar & Abraham 1991; Abraham et al., 1994; Ebenezer & Gaskel 1995).

Blanco and Prieto (1997) studied with 12–18-year-old students to investigate how stirring and temperature affect the dissolution of a solid in a liquid, and they reported a poor progress in the development of chemical understandings in terms of the effects of stirring and temperature processes.

In addition to students' having difficulty in how stirring and temperature affect the dissolution process, Blanco and Prieto (1997) stated that upper level students explicated, "Heat yielded currents that dragged at the salt." Their conclusion was by direct observation of the mechanical events students start to think the phenomenon of solution do not occur without mechanical events, so the development of chemical concepts was rather poor. Students explain the process with "melting" or "density" (Haidar & Abraham 1991; Lee et al., 1993; Abraham et al., 1992; Ebenezer & Erickson 1996; Ebenezer, 2001).

Learning chemistry vocabulary can be challenging for many students (Song & Carheden, 2013) because it has both scientific and everyday meanings. Because of the resilience of alternative conceptions (or misconceptions) that are embedded in larger conceptual frameworks, developing a scientific conceptual understanding is rather difficult (Treagust & Duit, 2008).

According to Hewson and Hewson (1983), the knowledge students possess before instruction may play an important role as a significant source of learning difficulty experienced by them. Likewise, everyday language (Prieto et al., 1989; Ebenezer & Erickson 1996), formal reasoning ability (Haidar & Abraham 1991; Abraham et al., 1994; Uzuntiryaki & Geban, 2005), instruction (Haidar & Abraham 1991; Uzuntiryaki & Geban, 2005) and pre-existing knowledge (Haidar & Abraham 1991; ; Uzuntiryaki & Geban, 2005; Abraham et al.,1994) are significant in the development of students' concept learning related to solutions.

3. Word Association Test (WAT)

Word association test, which is commonly used in science teaching research to determine and map the concepts in students' cognitive structure, the relationships between the concepts and their conceptual structures, is a data collection tool and it is used by many researchers (Shavelson, 1972; 1974; Bahar & Hansell, 2000; Bahar & Tongaç, 2009; Nakipoğlu, 2008; Schizas, Katrana & Stamou, 2013).

As for Shavelson (1972), the rank of students' answers shows at least a significant part of the structure within the semantic memory, and between concepts in a WAT. Johnson (1967, 1969 in Gunstone, 1980, p. 46) is known to be the first researcher who used Word Association as a technique for exploring aspects of the content and structure of an individual's knowledge in a specific content area.

Johnson carried out a series of studies with high school students taking physics course and found out a positive correlation between problem solving performance and number of associations related to the problems. Similarly, Shavelson (1972) conducted a study in which high school subject were instructed to think like a physicist by using a one minute response time WAT test.

Bahar, Johnstone and Sutcliffe (1999) administered WAT to identify students' cognitive structures in elementary genetics. WAT has been used for various purposes in science teaching research. These studies showed that using WAT is a strong method since it reveals the types and numbers of the concepts in the learners' cognitive structures and also it reveals the relationship between them.

In another study, Isa and Maskill (1982) designed an investigation to find out whether WATs would identify dissimilarities between main science words being learned in two different (Malaysian and Scottish) cultural settings, and they reported that the tests noticeably differentiated between the two cultures, the Malay students commonly created more associations than the Scottish students.

By using WAT, Bahar and Tongaç (2009) tried to explore the effect of different teaching approaches on students' cognitive structures (N=110) related to circulation system. They applied WAT as as a pre and post tests to all study groups. It was observed that the post-WAT mind maps obviously displayed significant difference about complexity and branching. In the light of this information, it was concluded that the teaching approach might seem to have an effect on the associations between concepts in their minds.

In a similar study, Nakipoğlu (2008) analyzed the knowledge structure of non-major science students about atomic structure through WAT. In this study, WAT was applied as pre-test and post-test before and after teaching. The analysis indicated that teaching had affected the students' knowledge structure since the differences observed in the students' knowledge structures before and after teaching.

Schizas, Katrana and Stamou (2013) conducted a case study and examined how secondary school students' understand the concept of "decomposition". By using Network analysis method, they tried to measure, represent and analyze structures and uses of science jargon and notation. The analysis demonsrated associative relations "in which concepts are represented by nodes and individuals' associations retrieved from memory serve as linkages between nodes".

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