

An analogy activity for incorporating students' conceptions of types of solutions

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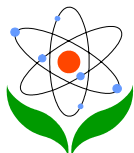
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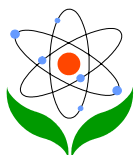
Abstract

There are the only two studies available on the types of solutions -- unsaturated, saturated, supersaturated, dilute and concentrate -- in the related literature with respect to students' understanding. But, no study focuses on remediation of students' alternative conceptions with regard to the aforementioned concepts, based on the assumption that learners actively construct and transform their own meanings, rather than passively acquire and accumulate knowledge transmitted to them. Therefore, this study can fill in a gap in the literature by designing an activity on the types of solutions in regard to four-step constructivist teaching strategy. Also, some suggestions were made for future studies and further investigation.

Keywords: Solution Chemistry, Types of Solution, Guide Material, Constructivism, Alternative Conception

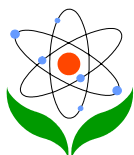
Introduction

There are three dynamic domains in the cognitive system; conception, categories, and frameworks (Gilbert & Watts, 1983), which have a rigid relationship with each other. Firstly, conceptions are developed by means of individual view or hypothesis. Then, based on conceptions categories emerge. Finally, frameworks are generated by taking into consideration categories. This means that the better conceptions are constructed or comprehended, the better the other steps are improved. Since the first step depends on the students' experiences or hypothesis, it is possible that miscellaneous conceptions different from the one accepted by scientific community may arise. These conceptions generally named "misconception", "alternative conception", "children's science" (e.g., Helm, 1980; Hewson & Hewson, 1984; Nakhleh, 1992; Costu, Unal & Ayas, 2004) are also pieces of intellectual thought (Schmidt, 1997). Further, Stavy (1991) pointed out that there is a dynamic competition in the cognitive system in which the strongest concept dominates. This means that if an alternative conception outweighs a scientific one in this dynamic process, it affects the subsequent understanding or structure. At that point, what will we do as science educators? Do we ignore the alternative conceptions or endeavor to overcome them?. Of course, we should struggle to remedy them if we desire to get students to have scientific comprehension at a more sophisticated level.



Since alternative conceptions are important for further learning, one is able to find numerous studies if one enters "misconception" or "alternative conception" as key words in data bases. But, elicitation of alternative conceptions does not mean dealing with all of them. However, diagnosing them is central for remediation. Hence, much research has been conducted into underlying topics such as "particulate nature of matter", "dissolving and solutions", "combustion", "chemical bonding"(Griffiths, 1994). Amongst these underlying topics, solution chemistry, which is a pre-requisite for some topics such as electrochemistry, acids and bases, chemical equilibrium, is one of the most investigated topics because of its importance. Studies on solution chemistry have concentrated on various perspectives as follows: *dissolution, the nature of solutions, solubility, energy in solution processes, effects of temperature and stirring to dissolution of solid in liquid, conservation of mass during dissolution process, types of solutions--unsaturated, saturated and supersaturated and vapor pressure lowering, solubility of a gas in water and the relationship between vapor pressure and boiling point, and strategies to overcome students'conceptions* (Calik, Ayas & Ebenezer, 2005).

Within the aforementioned perspectives, only two studies, Pinarbasi and Canpolat (2003) and Calik and Ayas (2005a) focused on eliciting students' conception on types of solutions. The former stated that many students thought a solution in equilibrium involved an undissolved solute was a supersaturated solution. In other words, most of students under investigation had difficulty in differentiating the distinction between a supersaturated solution and a saturated solution, so that the students may see a saturated solution as supersaturated if dissolved and undissolved solute are in equilibrium. Finally, they asserted that seeing undissolved solute as a component of solution forms the idea that a supersaturated solution includes the undissolved solute. The latter attempted to draw out students' comprehension related to dilute and concentrate solutions. They pointed out that some of the students at lower grades tended to exploit some hypothesis such as if solution in Beaker B is a saturated solution, solution in Beaker A must be an unsaturated solution. Moreover, they emphasized that some of the grade 7, grade 8 and grade 10 students stated that both of the solutions are the same because, both of them include sugar. However, no teaching strategy has been offered with regard to types of solutions to challenge students' alternative conceptions or replace them with scientific one. However, some alternative strategies in other different perspectives of solution chemistry such as a hypermedia environment to animate the dissolution process (Ebenezer, 2001), a unit on solution

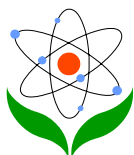


chemistry working collaboratively with a chemistry teacher (Ebenezer & Gaskell, 1995), a group exploration to inquire about the solubility of salt, sugar, potato flour, baking soda (Kaartinen & Kumpulainen, 2002), a teaching-learning sequence on the particle model of solubility (Kabapinar, Leach & Scott, 2004), a worksheet to incorporate students' conceptions of conservation of mass in the dissolution process (Johnson & Scott, 1991), and an analogy about conservation of matter during dissolution process (Taylor & Coll, 1997) were devised and implemented.

Since students' pre-existing ideas influence their learning, teachers need to explore them during lesson sequences. However, teachers do not know how to exploit students' conceptions in the teaching-learning process (e.g., Çalık & Ayas, 2005b; Driver & Oldman, 1985; Fensham, Gunstone & White, 1994; Matthews, 2002). On the other hand, given that the science curriculum is replete with many topics, they may not have enough time to design new activities even if they know how to design them. We, as science educators, ought to assist teachers with activities in addressing and incorporating students' conceptions into lesson sequences. Hence, the present article intends to unlikely design an activity on the types of solutions -- *unsaturated, saturated, supersaturated, dilute and concentrate* -- based on the assumption that learners actively construct and transform their own meanings, rather than passively acquire and accumulate knowledge transmitted to them (e.g., Ayas, 1994; Rezai & Katz, 2002; Taber, 2000; Vosniadou & Brewer, 1987).

The Use of Analogy in Designing The Activity

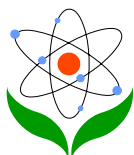
Analogies are one of the conceptual change activities to enhance and to facilitate students' understanding by challenging the students' pre-existing ideas (e.g., Iding, 1997; Stavy, 1991; Taylor & Coll, 1997; Tsai, 1999). Analogical reasoning can be thought of as a process of schema transfer from a familiar domain into an unfamiliar situation so that analogies can enable students to capture insight of the given events, especially at sub-microscopic level (Wong, 1993). In this process, the greater the match of knowledge between target and analog occurs, the better the analogy works. Therefore, the new knowledge domain becomes more meaningful because students can now visualize the given phenomena with their familiar one. But, while doing this, teachers should stress that this is only analogical reasoning. If not, the analogies may lead students to develop various alternative conceptions (i.e., Coll & Treagust, 2001;



Calik & Ayas, 2005b; Newton, 2003; Yerrick, Doster, Nugent, Parke & Crawley, 2003). It must be stated that in spite of the prevalent use of analogy in chemistry teaching, there have been few studies about the use of analogy during instruction because there has been a shortage of research as to how analogies can be exploited in the classroom (Duit, 1991; Ganguly, 1995). In this paper, we attempt to present how the developed analogy can be used during instruction. Also, analogy mapping that links with the given phenomena is provided within a model for incorporating students' conceptions.

Table 1. Analogy mapping of the illustrated phenomena;

Analog Feature	Comparison	Target Feature (types of solution)
The numbers of men and women	Compared to	Amount of solute and solvent
Sitting down in bus seats homogenously	Compared to	The dissolution process
The numbers of passengers in bus as presented step 2 and/or step 3 and/or step 4 (percentages of women per man)	Compared to	The dilute and concentrated solutions
The full capacity of bus as stated step 4	Compared to	Saturated solution
Picking up women under hot weather or intensive sunshine and sitting down the seats homogenously amongst men. Then, they get off the subsequent bus stop.	Compared to	Supersaturated solution
Step 2 and 3 before reaching full capacity	Compared to	Unsaturated solution
Percentage of women per man in case of full capacity	Compared to	Solubility
Each of men and women	Does not compared to	Particles of solute and solvent because each of them includes much more particles at sub-microscopic level
Sitting down the seats of bus	Does not	The dissolution process because it



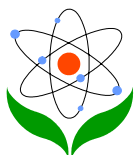
homogenously	compared to	involved in more intricate interaction between solute and solvent
Picking up women under hot weather or intensive sunshine and sitting down the seats homogenously amongst men. Then, they get off the subsequent bus stop.	Does not compared to	Supersaturated solution because preparation of it require to be heated if enough solute is available
Percentage of women per man in case of full capacity	Does not compared to	Solubility means dissolved solute at 100 ml solvent

Analogy

Please read the following case carefully and then fill into the given schema

1. Think of a bus, whose full capacity is 40, with 25 men who sit down homogenously (bus stop 1)
2. Four women (bus stop 2), five women (bus stop 3) and six women (bus stop 4) get on the bus at each of the subsequent bus stops respectively and sit down homogenously amongst men
3. After reaching full capacity, the driver notices five women who are hitchhiking but there is no seat. She/he is not keen on leaving them under intensive sunshine and picks them up. Finally, the women get on the bus (bus stop 5) and sit down seats homogenously amongst men as in case of the other bus stops.
4. Then, the women who get on the bus stop 5, get off at the subsequent one.
5. Taking into account the given story, please fill in the subsequent schema by counting the percentages of women per man.

The numbers of passengers	Bus Stop 1	%	Bus Stop 2	%	Bus Stop 3	%	Bus Stop 4	%	Bus Stop 5	%	Bus Stop 6	%
Men												
Women												



A Model for Incorporating Students' Conceptions in a Lesson

The teaching model intended by us comprises of four phases:

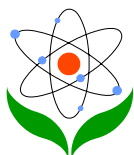
- eliciting students' pre-existing ideas,
- focusing on the target concept,
- challenging students' ideas, and
- applying newly constructed ideas to similar situations (Ayas, 1995).

We introduce the analogy to illustrate types of solutions by means of this teaching model.

Eliciting students' pre-existing ideas

In this phase teachers clearly draw out students' pre-existing ideas: *"Is there any difference or relationship between the terms "unsaturated, saturated and supersaturated solutions" and "dilute and concentrate solutions"? Explain your reason", "Does a saturated solution equivalent to concentrate solution? Explain your reason?", "Does a unsaturated solution equivalent to dilute solution? Explain your reason?"* Students' conceptions are as follows:

1. Many students thought a solution involving undissolved solute as a supersaturated solution (Pinarbasi & Canpolat, 2003).
2. Seeing undissolved solute as a component of solution forms the idea that a supersaturated solution includes the undissolved solute (Pinarbasi & Canpolat, 2003).
3. Some of the students at lower grades tended to exploit some hypothesis such as if solution in Beaker B is a saturated solution, solution in Beaker A must be an unsaturated solution (Calik & Ayas, 2005a).
4. Some of the grade 7, grade 8 and grade 10 students stated that both of the solutions are the same because, both of them include sugar (Calik & Ayas, 2005a).



Focusing on the target concept

In this phase, students debate the bus analogy in small groups to evaluate their pre-existing ideas. We first represent students' conceptions and then describe how the analogy includes students' conceptions.

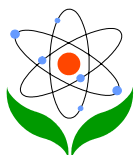
1. Many students thought a solution in equilibrium with undissolved solute was a supersaturated solution (Pinarbasi & Canpolat, 2003). Since students are able to visualize the bus analogy, they may acquire the idea that if enough solute is available, a supersaturated solution is prepared by heating and then by cooling the solution. Therefore, they may grasp that to form a solution the solute must disperse into solvent rather than staying at the bottom as undissolved solute.

2. Seeing undissolved solute as a component of solution forms the idea that a supersaturated solution includes the undissolved solute (Pinarbasi & Canpolat, 2003). Since women and men sit down the seats of bus homogenously, they may improve the idea that preparing a supersaturated solution not only need to be heated if enough solute is available, but also be cooled. Also, they may comprehend that to produce a solution must incorporate in dissolved solute rather than undissolved one.

3. Some of the students at lower grades tended to exploit some hypothesis such as if solution in Beaker B is a saturated solution, solution in Beaker A must be an unsaturated solution (Calik & Ayas, 2005a). The analogy not only indicates criteria of saturated solution as 100 ml solvent but also shows that dilute or concentrate solutions does not include a constant criteria. In case of the dilute and concentrate solutions, the principal difference is the amount of solute at the same solvent.

4. Some of the grade 7, grade 8 and grade 10 students stated that both of the solutions are the same because, both of them include sugar (Calik & Ayas, 2005a). Analogy points out that there are differences amongst types of solutions, i.e., changing the numbers of women in each of the bus stops at the constant number of men is similar to that of solute at the constant amount of solvent.

Teacher clarifies incomprehensible points of the analogy, but refrains from providing any clues so that she/he allows students to implement interpretive discussion while carrying out it. During the discussion, students are asked to answer to the following

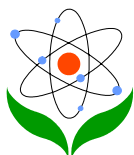


questions: *"each of four beakers includes 100 ml water at the same temperature. Three of them incorporate table salt, but the other one does not. 15 g table salt is dropped into water in Beaker B whereas 36 g table salt is added into each of Beaker C and D. Then, a bit of table salt is put into Beaker D, and then, it is heated until the new added solute dissolves. Thereon, Beaker D is cooled to its onset temperature (at the room temperature solubility of table salt is 36 g/100 ml). Which of the foregoing situations is similar to context of this case? Explain your reason?", "if you think men as solute and women as solvent, which of the foregoing situations reflect the terms "supersaturated solution, saturated solution and unsaturated solution" Explain your reason", "each of two beakers contains 50 ml water at room temperature. Latter, 5 g table salt is added into one of the beakers, whilst 10 g table salt is also dropped into the remaining one. Which of the foregoing situations is similar to context of this case? Explain your reason", "Could you match the terms "dilute and concentrate solutions" with the given analogy? Explain your reason", "Is a saturated solution equivalent to a concentrate solution? Explain your reason?" "Is an unsaturated solution equivalent to a dilute solution? Explain your reason?" "While you are matching the terms "dilute and concentrate solution", why solubility of table salt at 100 ml water is not given? Explain your reason?"*

After answering the questions about the analogy, in order to determine whether or not students have understood the types of solutions, they are asked to respond the subsequent question: *"Based on your answers to the questions, explain the distinctions between the terms "dilute-concentrate solutions" and "unsaturated-saturated-supersaturated solution" and what each of the terms means."*

Challenging Students' Ideas

In this phase, a teacher ought to verify the knowledge students have constructed. But some students may not have comprehended even after gaining experience with the analogy, so that they need to be informed whether their conception is correct or incorrect. Prior to addressing the target concept, the teacher evaluates students' understanding to elicit whether or not students have constructed the correct chemical idea. If some students have not yet understood the concepts, the teacher uses a Socratic dialogue to teach the similarities and differences between analog and target concept. In doing this, the teacher clearly teaches the chemical knowledge or target



concept so that she/he confirms or disconfirms the knowledge/concept students perceived.

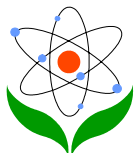
Applying newly constructed ideas to similar situations

In this phase, it is expected that students are able to apply their newly learning experience to other similar situations to enhance its plausibility. Students are asked to answer in the following questions: *"50 g Na₂S₂O₄ is added into beaker including 100 ml water at room temperature. Then, it is heated to 100°C and 181 g Na₂S₂O₄ is dropped into the beaker (its solubility at 100°C is 231 g/100 ml water). Finally, the solution is cooled until room temperature. Could you tell me what type of the formed solution is? Explain your reason?"*, *"solubility of ZnCl₂ is 200 g/100 ml at room temperature. 25 g ZnCl₂ is added into 50 ml water. If you had to prepare dilute and concentrate solutions by using this solution, what would you do? Explain your reason?"* *"What is the main difference between 'saturated solution' and 'dilute and concentrate solutions'? Explain your reason"*. Furthermore, to portray students' real understanding, students are asked to write a narrative as to what they learned so that they may readily assess and monitor their own learning.

Implications for Learning and Research

To teach the types of solutions, a learning experience with a simple, time-efficient analogy is illustrated here. Since the learning experience is designed based on students' pre-existing ideas, teachers may exploit this model to incorporate in their conceptions on other topics. If they notice that the learning experience presented here is fruitful, then teachers could develop the suggestions, taking into consideration their own experience. Besides, teachers may try to devise new learning experiences by means of their experience.

Although analogies allow teachers to make abstract concepts/theories concrete for learners, they may lead to students developing various meanings if they are developed improperly. Therefore, teachers should become conscious of their students' developing conceptions of analogies (Harrison & Treagust, 2000). On the other hand, some students may not comprehend the connection between the analog and target concept. In such a situation, teachers should regularly check students' visualization of



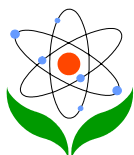
the analogy. Finally, this study is only an attempt to present alternative teaching method in order to exploit the model based on students' pre-existing ideas. But, the current study has limitation because its applicability has not been investigated. Therefore, further investigation is needed to determine its applicability in the classroom.

Acknowledgement

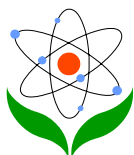
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