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Öğrencilerin Kimyasal Denge Konusundaki Kavram Yanılgıları

Students' Understanding of Higher Order Concepts in Chemistry: Focusing on Chemical Equilibrium

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Abstract

Most research shows that students have some misunderstandings and their ideas are difficult to change. We educators should know what children have in their minds in order to find suitable teaching strategies which might be used to help to develop students' understandings. Understanding their ideas is also necessary for the development and improvement of practice in science education. In this paper, the issue of changing children's ideas will be discussed briefly; and, then a review of the literature on the misconceptions held by students on the topic of chemical equilibrium, which is one of the most difficult areas for students to understand will be made. The article concludes with some implications.

Key Words : Chemical equilibrium, concepts in chemistry.

Öz

Çoğu araştırma öğrencilerin kavram yanılgılarının olduğunu ve bu yanlış algılamaların değişmesinin zor olduğunu göstermiştir. Biz eğitimciler öğrencilerin anlamalarına yardımcı olacak uygun öğretme stratejilerini saptayabilmek için onların kafalarında neler olduğunu bilmemiz gerekir.Bu fen eğitimi için de gereklidir. Bu makalede, öğrencilerin sahip oldukları fikirlerin değişmesi konusu tartışılacak ve anlaşılması çok zor konulardan biri olan kimyasal denge konusunda öğrencilerin sahip oldukları kavram yanılgıları hakkında bir derleme sunulacaktır. Makale konuya ilişkin, uygulamaya yönelik bazı önerilerde de bulunmuştur.

Anahtar Sözcükler : Kimyasal denge, kavram yanılgıları.

Introduction

There is a large body of research available in the literature about students' understandings or misunderstandings in science. This kind of research is essential for the improvement of science teaching. So why is it essential and important? Why do we need to do research in this area? It can be understood from the research that students' preconceptions are not in accordance with the science concepts we wish to teach. In other words, they do not understand what we expect from them. This might seem self-evident, but we must ask if our teaching always recognises this fundamental point. Knowing what the pupils are already thinking when they come to lessons is important for science teachers in terms of helping them choose the teaching methods.

The child has ideas about things; and, these ideas play a role in learning experiences (Driver, Guesne, and Tiberghien, 1985a, 4) but what is the source of these ideas? The information students use to construct their concepts comes from public knowledge, informal prior knowledge from everyday experiences, parents, peers, and commercials (Nakhleh, 1992). For example, they have experiences of what happens when they drop, push, pull or throw objects and in this way they build up ideas (Driver et. al., 1994). In other words they learn automatically and naturally from everyday life. That is the way children generate their own understanding and their ideas about things. The influence of their existing knowledge on children's understanding is known as the constructivist view of knowledge. This means that we

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use what we already know to try to make something out of new information. Constructivism tells that knowledge exists only in our heads where it is constructed by each of us in our own way (Dewey, stated in Herron, 1996). So a child uses his or her existing knowledge structures to make sense of any given event/ situation (Johnson & Gott, 1997).

Gilbert, Osborne, and Fensham (1982) mentioned three different assumptions on which science teaching has been based. The first one is that learners have no knowledge before teaching and their mind can be filled with teachers' science. According to the second assumption learners have some ideas but after teaching them they can easily change their ideas and accept the teachers' view of science. On the other hand, the third assumption believes that children's science views are so strong that they will persist and interact with science teaching. These are the assumptions that we could take into account while teaching science but it seems that the third one is the most important because most research shows that children's ideas are powerful and difficult to change. It would seem that most teaching is based on the first two assumptions and has had very little success in terms of developing students' understanding of scientific ideas. As Gilbert et. al .(1982) emphasise, if the science curricula and teaching are to be based on the third assumption we need to learn much more about children's ideas. This is one of the reasons why we need to conduct research about students' ideas. As an example Johnson's (1998a, 1998b) longitudinal study may be given. In this paper he reports findings in relation to children's understanding of boiling water and ideas about particles. His research tested their understanding of the nature of the gaseous state with the example of boiling water, evaporation and condensation. About boiling water, pupils were asked to say what the bubbles are in boiling water. Most of them said, "air" (Johnson, 1998b); they did not perceive that bubbles were the gaseous state of water. The idea of 'gas as a substance' was what students did not understand. And, he concluded 'if pupils do not appreciate that a substance, such as water, can exist as its own body of gas one has to ask what they are supposed to understand when they are told of 'gases' such as oxygen or carbon dioxide' (Johnson, 1998a). Of course this affects the understanding of the other areas of chemistry.

The author then found that informing a pupil that the bubbles in boiling water were water in *the gas state was not enough and he added that the pupils need a means of seeing why such a happening is a possibility.* In order to develop students' understandings in this area, and Johnson (1998a) suggested improving their knowledge of particles; and, the findings showed that this approach was necessary for most pupils of his study and it worked for the understanding of the gaseous state, although it took time. The point of the research is that students' ideas have to be replaced by the scientific view somehow. With research we can improve our teaching while using children's ideas rather than ignoring them while teaching.

The findings of this kind of research let educators know what children have in their minds. We need to take students' prior conceptions, of which research informs us, into consideration so that we can think up some possible teaching strategies which might be used in helping to develop students' understanding; i.e., designing the curriculum. In this sense such studies provide valuable insight. Now let us discuss the issue of changing children's ideas.

Changing Children's Ideas

Hackling & Garnett (1985) suggest that, because of the students' prior knowledge, learning in science should be seen as a restructuring of existing ideas, rather than just adding information to existing knowledge. This is supported by Bergquist & Heikkinen (1990, p.1000) when they say, "education should be thought of as producing change in a students conceptions rather than simply accumulating new information within the students' memory. Moreover, according to Posner et al. (1982, cited in Hameed, Hackling, & Garnett, 1993) to facilitate conceptual change learners must first be dissatisfied with their existing ideas in relation to their experiences, and then the new conception must be intelligible to the students and appear plausible and fruitful in terms of providing new insights. Of course the key question is how to make the new conception intelligible. To do this we have got to build on what they are already thinking which is the constructivist argument. That is why we should know about students' existing ideas. Here the role of the teacher has the greatest importance.

Teachers are crucial components in educational institutions and play an important role in students' understanding of concepts. First, they have to be aware of the students' ideas, and they bear these ideas in mind while teaching, which is not that easy. Driver et al. (1985b) say that if the existing knowledge is known by the teacher, he/she can suggest activities which may challenge or extend the range of application of these ideas. However Driver et. al. (1985a, p.3) found that "even after being taught, students have not modified their ideas in spite of attempts by a teacher to challenge them by offering counter evidence". Challenging does not appear to be enough. Johnson & Gott (1997) have suggested this might be because teaching has not been focussing on the key ideas that children need to develop in order to understand the scientific view.

Johnson states (1997, 22-23) "in chemistry education the teaching gets on with delivering a great deal of information without ever focusing on the ideas that pupils need to develop in order to make any sense of this information". When teachers do not take this into account the students' anxiety will be about just passing exams rather than understanding. However, understanding what a child is thinking is not a simple matter even though it is necessary to the development and improvement of practice in science education (Johnson & Gott, 1996).

However, it is still difficult to change students' opinions even if the teacher knows what the misunderstandings are, because he/she might have to design an experiment or prepare a lesson which has to suit all the students' needs as they all have different understandings of the phenomena. However, we should not forget that these ideas may not be the only reason for not learning what we want them to learn because there are so many factors when they are learning, such as teachers, textbooks, and children's environment. Existing ideas are one of a number of factors but we can say that they are undoubtedly of fundamental importance.

Many students are not constructing an appropriate understanding of fundamental concepts of chemistry from the very beginning (Nakhleh, 1992). Given that, they cannot fully understand the more advanced concepts, which build on the fundamentals.

A Review of Misconceptions About Chemical Equilibrium

One of the science subjects in which students have a very poor understanding is chemical equilibrium. Research suggests that it is one of the most difficult areas for students to understand in chemistry. When students assimilate any misunderstandings of chemical equilibrium into their mind this will propagate additional misunderstandings about other chemistry topics. This is because equilibrium is fundamental to students' understanding of other chemistry topics such as acid and base, rate of reactions or solubility. Students also show a high rate of misconceptions about acid-base and ionic equilibrium. For example, Banerjee (1991) found that students and also teachers felt that there were no hydrogen ions in an aqueous solution of NaOH or indistilled water. In this paper the research findings on misunderstandings in the topic of chemical equilibrium, what children are saying, and what the textbooks are saying about it will be reviewed. The analysis will investigate whether or not this research gives insight into key ideas that are not being targeted by the teaching.

Before describing the misunderstandings, it would be useful to give a brief analysis of what school science says about "chemical equilibrium". As written in the school textbooks there are two kinds of chemical reactions, those that are called reversible and those that are called irreversible reactions. For chemical equilibrium the reaction should be a reversible one and be a closed system. At equilibrium the forward and backward reactions are proceeding at the same rate. We can give the following reaction as an example of a reversible reaction in a closed system: first, $NH+_4$ and OH- are going to be formed from NH_3 and H_2O and then NH+4 and OH- will form NH_3 + H_2O. So the system consists of both the reactants and the products.

$$NH_3(aq) + H_2O(l) \rightleftarrows NH+4_{(aq)} + OH^-_{(aq)}$$

Two types of chemical equilibrium are defined: homogeneous and heterogeneous equilibrium. In homogenous equilibrium each of the reactants and products are in the same phase. In heterogeneous equilibrium there will be more than one phase involved.

$H_2(g) + Cl_2(g) \rightleftarrows 2HCl(g)$ Homogeneous equation.

$CaCO_3(s) \rightleftarrows CaO(s) + CO_2(g)$ Heterogeneous equation.

At equilibrium, the concentration of the reactants and products obey the equilibrium law. For the reaction

"$aA + bB \rightleftarrows cC + dD$"

$K=[C]^c . [D]^d /[A]^a . [B]^b$ = equilibrium constant, ([C] means concentration of substance 'C')

The equilibrium constant is a constant value for a particular reaction at a particular temperature. The equilibrium constant tells us the position of equilibrium: a high K means a high concentration of the 'products' at equilibrium.

The effect of conditions on the position of equilibrium can be summarised by Le Chatelier's Principle (LCP): if a constraint, i.e., a change in temperature, pressure or concentration is applied to a system in an equilibrium, the equilibrium moves in the direction which tends to reduce the effect of the constraint.

Except from the temperature, changing other variables (like pressure) does not change the equilibrium constant but changing temperature results in a new value of the equilibrium constant. The effect differs for the exothermic and endothermic reaction. However, reversible reactions that are exothermic in one direction are endothermic in the other direction. For example, the formation of ammonia is exothermic. ($N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)}$). If the temperature is raised, the system can absorb heat by the dissociation of ammonia into nitrogen and hydrogen. As a result of this the equilibrium constant for the formation of ammonia is decreased and the equilibrium moves to the left. Conversely, if the temperature is decreased, the equilibrium constant is increased and the equilibrium moves to the right.

While teaching and learning chemical equilibrium, the important thing to learn is the explanation of what equilibrium is. The way of approaching this point should give an effective understanding to the students. How about the books? How do they explain arriving at a position of equilibrium? In these books we can find these descriptions about the state equilibrium:

"A state of dynamic equilibrium is reached when the forward and reverse reactions occur at the same rate" or,

"Equilibrium is a dynamic process and it occurs when the rates of two opposing processes are the same" or,

"Chemical equilibrium always takes place in a closed system and it is a dynamic process". Two examples for possible explanations of dynamic equilibrium can be given from two books. In the Lister's and Renshaw's (1991) book, in order to explain the dynamic nature of the equilibrium, they give the water example in a closed system. They say 'the properties of the system will now remain constant but the evaporation and condensation are still going on at the same rate. This situation is called a dynamic equilibrium'. There is another example in the book of Liptrot et. al. (1971). 'An athlete training on a moving conveyor belt is in a state of dynamic equilibrium if his speed is exactly matched by the speed of the conveyor belt in the opposite direction'.

And about position of equilibrium, what is stated is

"If the conversion of reactants into products is small, the position of equilibrium lies to the left and if the equilibrium mixture is largely composed of products, the position of equilibrium lies to the right".

These explanations might be plausible for scientists (especially for chemists); however, it should be questioned whether students, when they read these kind of descriptions, would perceive equilibrium as what we expect them to learn about it. Are the books good enough for students and are they or we giving students the full picture of equilibrium? Table 1 below summarises the contents of the books. As is seen, the contents of the books are more or less the same. In the first book, for example, the author preferred to explain LCP after explaining the factors affecting the position of equilibrium whereas the other four books explained LCP with the effects of factors, which 'might' be more understandable.

These are the key points about equilibrium as they are presented in the students' books although there can be differences in approach. The five books consulted for Table 1 are "The Elements of Physical Chemistry, Goddard & James, 1969" (1, English); "Modern Physical Chemistry, Liptrot, Thompson and Walker, 1971" (2, English); "A Level Chemistry, Ramsden, 1985" (3, English); "Understanding Chemistry for Advanced Level, Lister and Renshaw, 1991" (4, English); "Liseler icin Kimya 2 (Chemistry for High Schools), Sina, 1993" (5, Turkish).

Table 1
The Content of the Books

Area of content	B1	B2	B3	B4	B5
Preparation questions					X
Irreversible and reversible reactions and dynamic equilibrium: some reactions are given as examples of reversible reactions and shown in a graph explaining activation energy	X	X	X	X	X
Examples of reversible reactions: esterification; the reaction between hydrogen and iodine; the Haber process; the reaction between iron and steam; thermal dissociation and questions			X		
The equilibrium law is explained	X		X	X	X
Verification and application of the equilibrium expression: there are examples of finding equilibrium. Constant	X	X	X	X	X
Factors affecting the position of homogeneous equilibrium: definitions of homogenous equilibrium: definitions of homogenous equ and effect of pressure, concentration, temperature and catalysts. Examples of homogenous equ.	X	X			X
Heterogeneous equ: definitions and the examples are given	X	X		X	X
Factors which affect the position of equ., the equ. constant and the rate at which equ. is achieved. Le Chatelier's Principle is explained in details and the summary is given in a table	X	X	X	X	X
The relation between energy changes and equilibria: the equ constant in terms of a partial pressure expressed. Equations of Kc, Kp and calculation of them	X		X	X	X
Experiments to determine equ constant		X			
Questions	X	X	X	X	X

Students' understandings concerning the topic of chemical equilibrium have been the subject of considerable research in recent years (Nakhleh, 1992; Garnett et. al, 1995; Hameed, Hackling & Garnett, 1993; Banerjee, 1991; Niaz, 1995; Hackling & Garnett, 1985; Bergquist & Heikkinen, 1990; Maskill & Cachapuz, 1989; Banerjee & Power, 1991; Wheeler & Kass, 1978; Gorodetsky & Hoz, 1985). Table 2 gives a summary of the characteristics of the research. These studies have clearly identified a considerable number of misconceptions. Generally the researchers used interviews and open ended or multiple choice tests about the position of chemical equilibrium, changing equilibrium conditions, and characteristics of chemical equilibrium. There are not enough details given about the tasks so it is assumed that they are suitable.

Misconceptions that the research claims to identify are as follows:

- One of the common misunderstandings about chemical equilibrium is that students are not able to distinguish between the concepts of mass and concentration (Wheeler & Kass, 1978; Gage, 1986, cited in Bergquist & Heikkinen, 1990). For example, when they are dealing with problems about the equilibrium constant they use mass instead of concentration. The students' ideas are not clear about the fundamental connection between mass and concentration, and unfortunately this misunderstanding might cause difficulties for other topics and not just for equilibrium.
- From their study, Hackling and Garnett (1985) found that most students were able to explain that once equilibrium was achieved the concentrations of each species remained constant. However, a widely identified misconception held by students regarding chemical equilibrium is that they think

Table 2
Characteristics of the Research

Authors	No of Sample	Age	Type of Res.	Year
Wheeler & Kass	99	17	MIT, CHAT, PT1, SK6	1978
Gorodetsky & Hoz	70	17	FS	1985
Hackling & Garnett	30	17	IS	1985
Maskill & Cachapuz	30	14	WAT	1989
Bergquist & Heikkinen	5 research projects		R	1990
Banerjee & Power	46	17-18	PP	1991
Banerjee	162	17	DT	1991
Nakhleh	3 research projects	17	R	1992
Hameed et. al.	30	16-18	PPD	1993
Niaz	78	19	T	1995
Garnett et. al.	9 research projects	17	R	1995

MIT: The misconception identification test, CHAT: Chemistry achievement test, PT1: The combinatorial task, SK6: Skempt test, FS: Free-sort task, IS: interviewing students, WAT: The word association test, R: Review, PP: Pre-test - post-test without a control group, DT: Diagnostic test, PPD: Pre-test – post-test – delayed post-test, T: Test given to the students.

there is a simple relationship between the concentrations of reactants and products (Garnett et al., 1995; Hackling and Garnett, 1985; Hameed et al., 1993). For example, students think that at equilibrium the concentrations of reactants equal the concentrations of products or the concentrations of substances with equal coefficients in the chemical equations are equal. Sometimes yes, they are but not all the time. The probable reason for this misunderstanding stems from the misconceptions of chemical equations and reaction stochiometry. For example Yarroch (1985, stated in Garnett et. al. 1995) found that many students showed a lack of understanding of coefficients in chemical equations. They believed that equation coefficients are numbers just for balancing equations but have no real meaning in terms of the interacting substances.

- Hackling and Garnett (1985) indicated that the rate approach to equilibrium might create many conceptual difficulties. For example Wheeler and Kass, (1978) reported that students are not able to distinguish between how fast a reaction proceeds and how far the reaction goes (i.e. position of equilibrium). Banerjee and Power (1991) found that students thought that increasing the temperature of an exothermic reaction would decrease the rate of the forward reaction instead of the rate of both opposing reactions increasing. The probable reason for this could be that students try to interpret the rate using LCP. Because in the definitions of LCP, for the temperature for example, the equation moves in the direction which reduces the effect of the temperature. Students, who have this difficulty, must think that 'in exothermic reaction if the heat comes out when I heat the system, there will be more heat. There is already heat in the system so that the forward reaction rate must decrease".
- Another confusing aspect between the rate and extent of a reaction held by students reported by Hackling and Garnett (1985) was that when the concentration of a reactant is increased for a reaction at equilibrium the rate of the reverse reaction decreases. However, if the concentration of a reactant is increased, the position of equilibrium shifts in the direction of right to left. That does not mean that the rate of the reverse reaction decreases but rather the relative rate of the forward reaction

increases, to produce an overall change in concentration until a new equilibrium is established.

- They also found that some students believed that the rate of the forward reaction increases as the reaction gets going whereas, when reaching the equilibrium forward and reverse reactions are equal and remain constant. Again it shows that they do not understand how the position of equilibrium is arrived at.
- Another misconception held by students is that when equilibrium is re-established following an increase in the concentration of a reactant, the rates of forward and reverse reactions will be equal to those at the initial equilibrium. However, when the concentration of a reactant increase it affects the other concentrations and the rates will be different from the initial ones (see p.6).
- Students are uncertain that the equilibrium constant is in fact a constant (Banerjee, 1991; Hackling and Garnett, 1985; Wheeler and Kass, 1978). They believe that "K" changes when the concentration of one of the components in an equilibrium system is altered or changes in the volume of a gaseous system, which leads to a change in the equilibrium constant. For example Hackling and Garnett (1985) found that the addition of a reactant to an equilibrium system often led to the conclusion that the equilibrium constant would be greater than under the initial conditions.
- Gorodetsky and Gussarky (1986, stated in Garnett et al., 1995) reported that some students failed to perceive an equilibrium mixture as a single entity and considered the two sides of a chemical equation as if they were independent. For example, they think that if we change the concentration of a product, there will not be any change at the other side of the equilibrium. They are thinking of the reaction as a one-way process. As was mentioned earlier, the reason may be that students think that as the reaction has to reach equilibrium its forward rate must increase but, for example, that there is no reverse rate.
- Students showed very poor understanding of the dynamic nature of chemical equilibrium (Nakhleh, 1992). They assumed that when the equilibrium existed no further reaction was occurring. The reason the author gave for this was that students confused everyday meanings of equilibrium with chemical equilibrium perceiving chemical equilibrium to be the same as physical balance like riding a bicycle.
- Many students showed confusion over the use of LCP itself (Bergquist and Heikkinen, 1990 and Hackling and Garnett, 1985). For example they thought that a change to an equilibrium system could result in a change in the concentration of a particular reactant or product without necessarily affecting the concentrations of other reactants and products involved in the reaction. They also expressed uncertainty about how a temperature, volume, or pressure change will alter the equilibrium concentrations.
- Hackling & Garnett (1985) found that students had misconceptions about the effect of a catalyst on the equilibrium system. Students believed that a catalyst could affect the rates of the forward and reverse reactions differently. As a result of this misconception they understand that this led to a different equilibrium yield. They then sometimes predicted that it was possible to increase the yield of the product in a chemical reaction by selecting a catalyst which favoured the forward reaction (Garnett et al., 1995) whereas there is no catalyst effect to equilibrium, a catalyst just helps the equilibrium to be establish in a shorter time.

Why these misconceptions?

Perhaps this is because of the teaching methods used by a teacher or the methods used in textbooks and a lack of awareness of existing conceptual ideas that are responsible for creating some of the difficulties. Bergquist and Heikkinen (1990) claimed that it seemed necessary to look critically at the instructional methods and materials of general chemistry in search of possible sources of difficulty for students in understanding equilibrium. It would be more useful if the textbooks were examined for more than just equilibrium because the misconceptions of equilibrium held by students probably result from previous chemistry concepts not just from the concept of equilibrium.

Another reason for the misunderstanding seems to be what the system or we expect from the students practically. As Bergquist & Heikkinen (1990) explained, many chemistry examinations focus on computational skills and recall of definitions; and, they noted that questions that require students to synthesise information and apply concepts are not very common in such examinations. To demonstrate mastery of chemical equilibrium concepts, for example, students are asked to solve computational problems; correct results are accepted as an indication that students understand equilibrium correctly. This is a really dangerous approach since many equilibrium computations are readily solved by the application of an algorithm. Thus, correct responses do not necessarily reveal whether a student understands chemical equilibrium but it only indicates that the student can compute the equilibrium constant or calculate equilibrium concentrations.

More importantly it seems that the misconceptions are not due to students but to us as educators. We are not familiar with their ideas or thoughts, and we are not looking for good teaching.

In their review, Garnett et al. (1995, 87-90) suggested following reasons for the problems.

Use of everyday language in a scientific context

The use of everyday language in a scientific context causes students' misunderstandings. For example, in the equilibrium content, because of the use of the word balance, students may think that chemical equilibrium is like a physical equilibrium as in riding a bike. The authors concluded that language creates different mental pictures for different people, and consequently educators need to use words and expressions which are unambiguous and which describe the subject accurately. Students are not only confused by everyday language but they also have difficulties with the unfamiliar technical words used in the text and questions (Ochiai, 1993; Bergquist & Heikkinen, 1990). Therefore, some vocabulary can generate different perceptions from student to student.

Use of multiple definitions and models

The use of multiple definitions is another source of difficulty for students. For example, in different subjects such as chemistry and physics sometimes the same words or same the symbols are used for different subjects and sometimes different terminology is used when dealing with the same concept. For example, "V" stands for velocity in physics whereas it stands for volume in chemistry.

Rote applications of concepts and algorithms

It is understood from the research that there is a tendency for students to reduce theoretical understanding to a level that they can understand. Subsequently, they use their own understanding or they solve problems using their own formulas. For example, when students solve a problem relating to Le Chatelier's principles they may easily apply rote learning without understanding what is going on when the equilibrium conditions are changed. Garnett et al. (1995) suggest that materials should be presented in ways that encourage students' understanding of concepts, rather than in ways which promote rote learning and the unthinking application of algorithms. White & Gunstone) 1989, cited in Garnett et al., 1995) have suggested using metacognition strategies for helping students' understanding.

Overlapping similar concepts

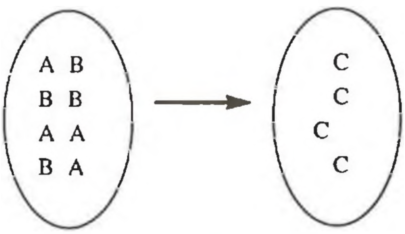
Students' tendencies to confuse related concepts is another point that Garnett et al. (1995) addressed concerning misconceptions. For example, in chemical equilibrium students have some of the attributes of physical equilibrium: the equality of the two sides and a static nature (Gorodetsky & Gussarsky, 1986; cited in Garnett et al., 1995). So educators must be aware when teaching that they should remind children to distinguish between the similar terms which are another problem for students to deal with.

Garnett et al. (1995) mentioned another implication from students' prior experiences. They said that students have their own existing ideas already and they bring these ideas directly to classes, and these ideas can result in students establishing conceptions quite different from those accepted by the scientists. Since the misunderstandings are based on the basic concept, preconceptions from prior world experiences are always with the students. Maybe this is not a problem for the misunderstandings of chemical equilibrium but we can say that prior experiences or prior knowledge from previous chemistry subjects can cause misunderstandings. What is the underlying problem? As Johnson & Gott (1997) asked: is our teaching missing a key idea that we know but students do not but we assume that they know? For example, if students did not understand chemical change itself within a reaction mixture, then this would affect the understanding of the position of equilibrium and reaching the state of equilibrium. For example, books talk about change in rates but not about change in the composition of the reaction mixture.

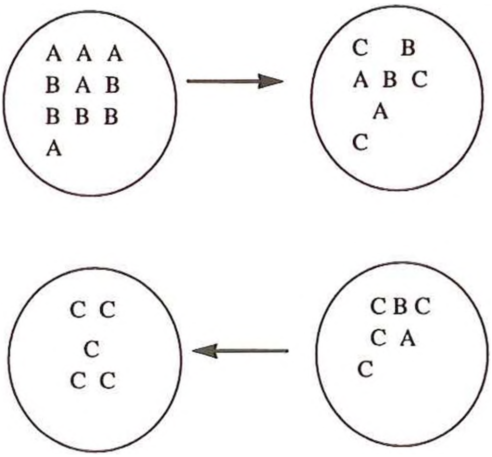
Maybe this model can provide a way of understanding chemical change and chemical equilibrium:

Now let us take the non-equilibrium reaction:

A + B Æ C



This seems to be the image pupils have, there is just a change, reactant to product. At the beginning there are just the reactants, A and B; when the reaction gets going A and B gives the product C at the end of the reaction there is C only. Reactants give the product (or products). (It is assumed that the exact rates of A and B form C). There is no equilibrium here. Now let us apply this model to the reaction of A + B Δ C and see what really happens:



Equilibrium is just when the composition does not change to completion. The equilibrium gives the rates in which A's and B's change to C's. We can start with any ratio of A and B in the mixture. This idea seems to be missing, and would explain difficulties with equilibrium.

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