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Context-Based Chemistry Teaching within the 4Ex2 Model: Its Impacts on Metacognition, Multiple Intelligence, and Achievement

Canan KOÇAK ALTUNDAĞ[1]

[1] Assoc. Prof. Dr., Hacettepe University, Ankara-TURKEY

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ABSTRACT

The purpose of this study is to investigate the impact of context-based chemistry education on the metacognition and multiple-intelligences of preservice chemistry teachers, and their achievement in chemistry lessons in the laboratory environment that includes the 4Ex2 model. Within the framework of the general chemistry laboratory lesson, the treatment group was taught with a context-based chemistry teaching method in the chemistry laboratory using the 4Ex2 model, while the traditional methods were applied in the control group's lessons. It is determined that after the application, abilities to control the metacognitive thoughts of the preservice teachers, who were taught with a context-based chemistry teaching method in the chemistry laboratory within the 4Ex2 model, positively changed compared to those included in the control group. Additionally, the results showed that the preservice teachers in the treatment group, who received context-based chemistry teaching within the 4Ex2 model, were more successful; therefore, this model is an effective teaching method.

Keywords: Context-based chemistry teaching, metacognition, multiple intelligence, preservice teachers, 4Ex2 model.

INTRODUCTION

When students meet the wonderful world of productive chemistry in a laboratory, effective chemistry teaching is realized. Within this scope, the quality of chemistry teaching should not be sought in the test tubes, but in the art of the experiment and in the teachers who design the experiment (Pfeifer, 1995). Additionally, in order to solve the problems emerging during the teaching of chemistry, it is required to have teachers with qualifications that allow them to associate chemistry with daily life in a more meaningful way. Training such chemistry teachers will be possible by closely monitoring various characteristics of the prospective chemistry teachers enrolled in educational institutions and forming these characteristics in the environments that are closely linked with daily life (Freienberg, Kriiger, Lange, & Flint, 2001). Indeed, daily life stands for a one-day period of the mental and physical world (Lindemann & Brinkmann, 1994, Yaman, 2009). According to Fensham

Corresponding author e-mail: canan.kck@gmail.com

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(2009), daily life covers various contexts and scientific aspects. In teaching the notions that are scientifically examined or in understanding the nature of scientific evidence, comparing these notions with questions and enriching them with examples from daily life create realistic learning environments. According to Wu (2003), when connections are established between daily life and chemistry topics, it would be possible to associate multiple contents experienced outside school and the information gained in the classroom. Separating students' daily lives and school subjects causes students to develop useless information systems (Osborne & Freyberg, 1985).

The importance of context-based learning is highly emphasized by constructivist and sociocultural learning theorists. It is suggested that context-based learning is quite effective in students constructing, transferring, and implementing knowledge through their own experiences (Andrée, 2003; Gilbert, 2006). Therefore, presenting course contents involving context-based chemistry activities according to the methods, models and techniques in line with the constructive approach in learning resulted in positive effects favoring the achievement of context-based chemistry teaching (Choi & Johnson, 2005; Coştu, 2009; Kerber & Akhtar, 1996; Kutu & Sözbilir, 2011; Toroslu, 2011; Ulusoy & Önen, 2014; Ültay & Ültay, 2013). However, it is quite easy to find a daily life connection with a chemical reaction or a chemical problem that is the subject of chemistry courses. Learning and inference occur following a series of cognitive processes. Therefore, the adequacy of the cognitive processes of prospective chemistry teachers is of great importance in order for the learning and inference process to be efficient. This is closely related to the nature of cognition. As Brown, Collins, & Duguid (1989) stated, when the nature of cognition is ignored, the provision of information, which is the main objective of education, cannot take place completely. Therefore, Cognitive Theory became one of the theories that have a significant impact on the field of education. This theory focuses on the skill that allows individuals to associate mental states such as beliefs, intentions, desires, and information with themselves or others and to comprehend that others may have different beliefs, intentions and desires (Premack & Woodruff, 1978).

Metacognition is one of the cornerstones of Cognitive Theory. Defined as knowledge and beliefs about mental processes, meta-cognition is a key concept in Cognitive Theory, which helps the maximization of learning (Benjamin & Bird, 2006). Using the concept of metacognition for the first time, Flavell (1976) defined metacognition as the knowledge of individuals about cognitive processes that are necessary for them to comprehend and learn. However, metacognition stands not only for individuals' knowledge of the strategies that are employed while learning, but also for their knowledge about when and where to use these strategies. A healthy individual who is aware of her/his metacognitive abilities knows how to learn, what she/he knows and what she/he should do to gain new information (Wilson & Bai, 2010). On the other hand, some metacognitive functions lead to certain dysfunctional thoughts and coping styles in psychological disorders. In other words, some people may have positive or negative beliefs (meta-cognition) about their thoughts, which affect their evaluation of events (dysfunctional cognition). These kinds of metacognition lead individuals to develop incompatible response styles (Cartwright-Hatton & Wells, 1997, Gwilliam et al., 2004). In further cases, this situation may cause the negative evaluations of individuals about their metacognitions to become permanent, while also decreasing in their reliance on their memories (Mather & Cartwright-Hatton, 2004, cited in Tosun & Irak, 2008).

Questions that explicitly help students think about questions such as "How do I study best?" or "What kinds of tools help me learn?" all engage metacognitive knowledge. This can range from information that helps students assess their own abilities and intelligence to reflections on specific learning processes students tend to use in different situations. Metacognitive regulation involves the ability to think strategically and to solve problems, set goals, organize ideas, and evaluate what is known and not known. It also involves the ability to teach others and make thinking processes visible (Jaleel & Premachandran, 2016). In this context, it is very important that prospective chemistry teachers have positive and healthy metacognitive skills. Today, many concepts, theories, approaches and methods can be associated and configured with metacognition. In this way, it has been possible to justify the relationship between intelligence and multiple intelligence theory thanks to meta-cognition (Kuhn, 2000). Another theory that had a substantial effect on the field of education is the Theory of Multiple Intelligences (Shearer, 2004). This theory, which directs more different and much more varied studies, has been proposed by Gardner (1993). In Gardner's theory, the characteristics of people's different intelligence types are described. Gardner indicates that either one of these intelligence areas is superior to the others; however, other areas do not emerge as the dominant ability. Everybody has these intelligence types; however, each person has them in different combinations or blends (Gardner, 1993). Moreover, the importance of how, when and in which environments learning takes place for an individual is also addressed in this theory (Gardner, 2006). Gardner indicates that when students' multiple intelligence types are associated with the information they learn at school in training and education, acquisition of more information could be achieved (Gabala, 1991). Wilson (2011) also stated that activities that are carried out according to the multiple intelligence types offer students the ability to establish cognitive connections, metacognitive understanding, and various studying techniques. However, Goodnough (2001) confirms that the theory of multiple intelligences opens the door to a variety of teaching strategies that can be implemented within the classroom and suggests that there is no one set of teaching strategies that suits all students at all times, because they have different intelligences; therefore, a particular strategy may succeed with a group of students and not succeed with another. Hence, it is important for prospective teachers to associate the theory of multiple intelligences with the concept of metacognition and to use contexts based on daily life in teaching environments. The realization of the aforementioned aspects would be possible by training teachers who are self-aware, aware of different metacognitive features and various intelligence types, and who know that the acquisitions related to chemistry would be enriched through the availability of teaching environments that are associated with daily life. However, more open and dynamic models need to be suggested in order to realize the individual's potential of using the intelligence types (Marshall, Horton, & Smart, 2008). One of the models proposed based on this opinion is the "4Ex2 Model" proposed by Marshal et al. (2008). The 4Ex2 Instructional Model is based on the 5E instructional model (Marshall et al., 2008).

The researchers argue that the 4Ex2 instructional model provides an education and training environment with an advanced perspective, from which both the students and the teacher would benefit, thanks to its Engaging, Exploring, Explaining and Extending stages. This model allows students to make in-depth inquiries and helps them in comprehending information. In the 4Ex2 model, learning experiences are associated with conceptual understanding, and students are assisted in the learning process (Allal & Ducrey, 2000). This model also assigns importance to combining the metacognitive thinking of students and interrogative teaching models with formative assessment structures (Marshall et al., 2008).

Aim

The purpose of this study is to investigate the impact of context-based chemistry education on the metacognition and multiple-intelligences of preservice chemistry teachers, and their achievement in chemistry lessons in the laboratory environment, which includes the 4Ex2 model.

METHODS

The study is conducted with a purpose that reflects the theoretical framework it is based on and with a method that will serve this purpose (Keeves, 1998). Findings are interpreted within the scope of this purpose. This research is a quasi-experimental study that tests the effectiveness of context-based chemistry teaching within the 4Ex2 model in the chemistry laboratory on the metacognitive abilities, multiple intelligence types, and achievement levels of preservice chemistry teachers, using pre-tests and posttests for control and treatment groups (Campbell & Stanley, 1996; Cohen, Manion, & Morrison, 2001).

The sampling of the study consisted of student teachers randomly chosen from students of Hacettepe University, Faculty of Education, with choosing 43 individuals in total. This study was conducted using the pre-posttest design involving a control group and a treatment group. The experiment group included 22 and the control group included 21 preservice teachers. Metacognitive Scale, Multiple Intelligence Scale, Achievement Test and Structured Grids were applied in the form of the pre- and posttests in both the treatment and control groups. Within the framework of the general chemistry laboratory lesson, the treatment group was taught by applying a context-based chemistry teaching method in the chemistry laboratory by using the 4Ex2 model, while the traditional methods were applied in the control group.

The researcher taught a Chemical Changes module to the treatment group using the 4Ex2 model, supported by context-based learning activities. In the context of the research, five chemistry experiments were designed. These experiments were appropriate for the aims of the research; they could be carried out with simple and cheap materials, and they were interesting for the students. Experimental activities were done with daily substances and materials, without having the necessity for materials related to chemistry and chemical substances. Chemistry experiments appropriate for the Chemical Changes module that can be done with daily materials were designed according to the 4Ex2 model and presented to students as working sheets. The 4Ex2 model consists of four phases. It allows for the integration of laboratory practice to the course (Marshall et al., 2008); therefore, context-based experiments were conducted with the students. The stages of study according to the 4Ex2 model are the following: 1. Engaging Stage: A sample incident selected from daily life related to the subject is shown to students to get their attention. 2. Exploring Stage: In this stage, materials used in the experiment and the ways of doing the experiment are explained so that the experiment is conducted by students without any problems. 3. Explaining Stage: In the stage of explanation, students are asked to explain the results and observations obtained from the experiment. This is achieved through classroom discussions. 4. Extending Stage: In the challenge phase of the 4Ex2 model, students complete the activities on the worksheet.

Analysis of the data obtained in this study was performed by using the SPSS 21 software package. The data obtained following the applications were subject to parametric tests. The ANCOVA test was performed for determining whether the answers given by the preservice teachers differed according to the group they were included in (Treatment-Control). The calculated values were evaluated at the p=0.05 level of significance.

a) Data Collection Tools

The “Multiple Intelligence Scale” developed by McClellan & Conti (2008) and adapted into Turkish by Babacan (2012) was used in the study. The scale was administered in order to determine in which field of intelligence the students were dominant. The Cronbach’s Alpha Internal Consistency coefficient of the scale was identified as 0.85 (Babacan, 2012).

Another one of the data collection tools used in this study was the MetaCognition Scale developed for examining negative metacognitive beliefs, judgments, and processes of an individual. Developed by Cartwright-Hatton and Wells (1997) and adapted to Turkish by Tosun and Irak (2008), the scale is a data collection tool that is suitable for assessing positive and negative metacognitions. Increase in the scores obtained from the scale indicates the increase in negative metacognitive beliefs. In the study conducted by Tosun and Irak (2008), the Cronbach Alpha reliability of the scale was found to be .86. Also in this study, the researcher (Koçak, 2013) structured and developed an achievement test by making use of the questions in the Scientific Achievement Test developed by Ekmekcioglu (2007), in order to determine the preservice teachers' level of knowledge. The average difficulty and Point-Biserial Correlation Coefficient of the achievement test were found to be 0.71 and 0.56, respectively. Alternative assessment and evaluation techniques were also employed for offering equal opportunities to each participating student with different thinking and learning styles (Marshall et al., 2008). In addition to the achievement test, the abilities of the preservice teachers to associate their basic information with daily life were determined using the Structured Grids (Kocak, 2013) developed by the researcher.

b) Data Analysis

Before analyzing the data obtained in the study, the Kolmogorov-Smirnov Test was used to determine whether there was a normal statistical distribution. For the variance analysis planned to be done within the framework of the statistical analysis, the homogeneity of the distribution was first observed with Levene's Homogeneity of the Variances Test. Parametric tests are stronger and more flexible than non-parametric tests. While making statistical analysis on the data, the data are at least required to comply with the normal distribution (Kalayci, 2006). As shown in Table 1, the data obtained from the data collection tool have normal distribution and their variance is homogeneous. According to this finding, no statistical inconvenience was found with regard to the use of parametric tests for analyzing the data.

Table 1. *Results of the Kolmogorov-Smirnov and homogeneity tests (df1 1 df2: 41)*

		Mean	Ss	K Smirnov Z	p	Levene Statistic	pp
Multiple Intelligence Scale	Pretest	4.348	2.428	1.041	.228	.612	.439
	Posttest	4.418	2.565	.952	.325	.000	.984
Meta Cognition Scale	Pretest	3.071	.413	.542	.930	1.412	.242
	Posttest	3.194	.483	1.069	.203	1.977	.167
Achievement Test	Pretest	39.72	14.78	1.16	.135	.082	.775
	Posttest	49.19	16.65	.80	.541	.005	.944
Structured Grids	Pretest	39.61	16.378	.521	.949	.186	.668
	Posttest	44.25	24.167	.546	.927	5.131	.057

FINDINGS

ANCOVA analysis was performed for understanding whether there were significant differences in the dominant intelligence types of the preservice teachers in the treatment and control groups. The results of the ANCOVA analysis given in Table 2 show that when the distribution of the preservice teachers in the treatment and control groups according to their multiple intelligence areas before the application are considered, there are no statistically significant differences in the post-application distributions.

Table 2. *Results of the covariance analysis on the data obtained from the multiple intelligence scale*

Source	Type III Sum of Squares	Mean Square	F	p
Pretest	56.239	18.746	3.817	.75
Group	68.987	68.987	14.04	.30
Error	209.143	5.363		
Total	1116.000			

While the Meta-Cognition Scale pre-test average scores of the preservice teachers in the treatment and control groups were checked, the ANCOVA test was applied in order to determine whether there were significant differences among the posttest average scores of the same scale. Table 3 shows that the overall average of the control group after the test is much higher than that of the treatment group. The results of the ANCOVA analysis indicate that there are significant differences between the overall Metacognition Scale pretest scores and overall adjusted posttest scores of the preservice teachers. In other words, it is determined that after the application, abilities to control the metacognitive thoughts of the preservice teachers who were taught by the context-based chemistry teaching method in the chemistry laboratory within the 4Ex2 model, positively changed compared to those included in the control group. After obtaining the scores of the achievement test on the prior knowledge of preservice teachers and the average pretest scores of the structured grid, the ANCOVA test was administered to determine whether there were significant differences among the posttest average scores of the same data collection tools.

Table 3. *Results of the covariance analysis on the data obtained from the metacognition scale*

Group	Mean	Source	Type III Sum of Squares	Mean Square	F	p
Treatment	3.14	Pretest	1.777	.59	2.87	040
		Group	2.176	2.17		
Control	3.25	Error	8.028	.20	10.52	.002
		Total	448.632			

As shown in Table 4, it is determined that the achievement scores of the treatment group were statistically significantly higher than those of the control group. In other words, the scores of the achievement test and structured grid in the treatment and control groups after the application of the 4Ex2 model were compared using the ANCOVA test; and it was determined that there were statistically significant differences favoring the treatment group.

Table 4. *Results of the covariance analysis on the data obtained from the achievement test and structured grids*

	Group	Mean	Source	Type III Sum of Squares	Mean Square	F	p
Achievement Test	Treatment	84.4	Pretest	6442	2147	8.97	.00
			Group	1335	1335	5.58	.02
	Control	67.5	Error	367	239		
			Total	198			
Structured Grids	Treatment	50.6	Pretest	6855	2285	4.63	.00
			Group	5083	5083	10.33	.00
	Control	37.4	Error	2764	492		
			Total	15100			

DISCUSSION and CONCLUSION

In today's chemistry teaching programs, more advanced and more functional models that interpret the ideas of students in a more comprehensive way are required (Stains & Talanquer, 2007). In this study, context-based chemistry education was carried out by employing the 4Ex2 model in the laboratory, with the aim to contribute to alternative research studies. The main reason for choosing the laboratory as the application environment was that the laboratory activities could be efficient in improving mental development, scientific inquiry and problem-solving skills (Lunetta, 1998). Scientific process skills, which facilitate learning, attain research methods, ensure individuals' active participation and responsibility taking in learning as well as increasing permanence of learning, could be developed through laboratory studies in science (Alkan, 2016). Whether the context-based teaching of chemistry within the 4Ex2 model had any impact on the metacognitive abilities of preservice teachers was specifically examined. In this study, the metacognitive structures of preservice teachers were approached in terms of educational psychology, and the results concerning the level of learning, self-regulated learning and learning improvement were examined (Karakelle & Saraç, 2010). Indeed, with the help of the findings obtained after the application, it was determined that the competencies to control the metacognitive thoughts of the preservice teachers included in the treatment group, who were taught by using a context-based chemistry teaching method in the laboratory within the 4Ex2 model, significantly changed in a positive way, when compared to those included in the control group. According to Flavell (1979), metacognition involves the metacognitive information and metacognitive experiences of an individual. The 4Ex2 model is defined as a model that combines learning experiences with the powerful conceptual structure of the taught content in order to learn better. The 4Ex2 model ensures that students improve their learning abilities by offering them opportunities for using learning experiences (Marshall et.al., 2008). Therefore, a decrease in negative metacognitive beliefs was observed in the group in which the 4Ex2 model was applied.

As a result of their study, Wells and Papageorgiou (1998) determined that different types of metacognition were in a positive relationship with signs of anxiety. Therefore, high metacognitive scores of preservice teachers in the control group could be associated with their levels of anxiety and concerns while studying in the laboratory. In this research, how the context-based chemistry education contributed to the academic achievements of the preservice teachers in the laboratory environment within the 4Ex2 model, was determined with the help of the achievement test and structured grids. It is recommended that the evaluation of daily life-based chemistry teaching be assessed through alternative assessment and evaluation methods, instead of through traditional exams and tests (Bennett, 2003; Gilbert, 2006; Pilot & Bulte, 2006; Yıldırım & Maşeroğlu, 2016; Yıldırım & Konur, 2014). According to the findings obtained as a result of the traditional and alternative assessments and evaluation tools, the achievements of the treatment group, which was taught according to the 4Ex2 model was, were found to be higher than those of the control group, in which traditional method was applied. In other words, the results showed that the preservice teachers in the treatment group, who received context-based chemistry teaching within the 4Ex2 model, were more successful; therefore, this model is an effective teaching method.

In a study conducted by Kerber and Akhtar (1996), a chemistry course was taught through associations with daily life and it was supported by laboratory activities. It was found that students gained more information as a result of the application, compared to traditional laboratory lessons. Similar findings were found in a study conducted by Wu (2003) and it was determined that the achievement level increased when a connection between the daily-life experiences of students and the scientific information they learned was established. In addition, it was understood that students could establish the connections on their own after the applications and they converted their daily life experiences into scientific information. In another study carried out by Zucht, Rossow, Lange and Flint (2004), it was suggested that connections may be established between the chemistry lessons and daily life through the activities and students could have the opportunity to practice their knowledge in such learning environments. It is thought that the reason why the preservice teachers in the treatment group, who were taught context-based chemistry by using the 4Ex2 model, were more successful was that the model provided students with the opportunity to participate in activities affecting their metacognitive strategies more effectively.

Metacognition consists of the conscious controls that individuals apply to their learning process by using their memory effectively (Schneider & Lockl, 2002) and it is about what a cognitive study requires, its impacts and challenges. Since not all tasks are at the same level, different tasks can force individuals to apply different cognitive rules (Victor, 2004). The meta-cognitive strategies employed with effective formative assessments have an important role for individuals in achieving success (Black & Wiliam, 1988). Metacognitive abilities should be developed among school students. Only then can they reflect on their learning methods, their performance in classroom activities, and improve their academic achievements accordingly. Teachers should know the individual differences in the level of metacognitive awareness in a classroom and should teach by taking into consideration students' individual differences so that by effective instructions in the classroom, their metacognitive abilities may enhance well. On the other hand, failure in operating or controlling metacognitive processes is believed to cause poor performance in academic problem-solving tasks of an individual (Brown, Bransford, Ferrara, & Campione, 1983). Methods, techniques, and approaches that ensure that social and physical contexts are employed deliberately help in comprehending cognition and learning in a clearer way (Brown, Collins, & Duguid, 1989). It is known that education informed by considering the fact that individuals have different ways of thinking will be of better quality, and if the different intelligence components are identified the encountered problems can be solved more successfully (Gardner, 1993). From this viewpoint, the multiple intelligence types of preservice teachers were observed after the treatment and control groups had been determined. Metacognitive variances and differences in the achievements of the preservice teachers were caused by intelligence types. In the study conducted by Veenman et al. (2006), the relationship between metacognitive abilities and intelligences, and learning performances of the students enrolled in classes of different levels was examined. According to the findings obtained, significant positive relationships were found between the metacognitive abilities and intelligence levels of students.

Cooper (2008) found that a statistically significant effect of using Multiple Intelligences Theory and metacognition skills is the improvement of academic achievement among students. Furthermore, since metacognition is a long developmental process, research indicates that metacognition increases with age and its different elements have different developmental periods (Flavell, 1979; Hanten, Dennis, Zhang, Barnes, Roberson, Archibald, Hartman, & Sternberg, 1993). For example, in the study carried out by Tosun and Irak (2008), it was determined that there were significant positive relations between age and the ability to use metacognition effectively. In this study, it was determined that there were no significant differences in the intelligence fields of the preservice teachers in the treatment group which was taught according to a context-based chemistry education within the 4Ex2 model, and the preservice teachers in the control group who were taught according to the traditional method. In some studies, it was concluded that the treatment group showed higher performance than the control group, as a result of the applications based on their dominant intelligence fields (Al-Balhan, 2006; Mokhtar, Majid, & Foo, 2008). Through previous results illustrated in general, all intelligence patterns among students came in the following order: self, social, bodily, logical, verbal, visual, musical, and natural intelligence. This arrangement differed among male students: social intelligence came first, followed by self, bodily, logical, verbal, visual, natural, and musical intelligence, whereas self-intelligence came first among female students, followed by bodily, verbal, social, logical, visual, natural, and musical intelligence (Kandeel, 2016). However, it is seen that in some cases there are no significant differences in the intelligence fields of the participants after the applications in general (Uhlir, 2003; Tahriri & Divsar, 2011). The literature review concluded that there were no studies about context-based chemistry teaching in the laboratory within the 4Ex2 model. However, there were certain studies similar to this study on determining different samples and problem situations from daily life, performing tests and preparing worksheets that would draw students' attention in terms of content and type and transferring them to the learning cycle model (Schmidt, Freienberg & Flint, 2002; Yıldırım et al., 2007; Akpınar and Özkan, 2010; Toroslu & Güneş, 2010; Ulusoy & Önen, 2014, Çepni, Ülger & Ormancı, 2017). The findings of these studies are supportive of the findings of this study. Generally, in the studies that were carried out according to the learning cycle models, it was found that students were quite satisfied with the activities and they expressed that similar activities based on daily life should be performed more often (Schmidt, Parchmann, & Rebentisch, 2003; Huntemann, Honkomp, Parchmann, & Jansen, 2001). Recently, greater importance has been given to the relevance of chemistry education in the events that we face in our daily lives. Context-based learning has been supported simultaneously with a model, method, and technique in research projects. It is expected that meeting students' needs and desires to learn a subject using context-based learning activities will make a positive contribution to research in this field.

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