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Enhancing prospective chemistry teachers' cognitive structures in the topics of bonding and hybridization by internet-assisted chemistry applications

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Abstract

The purpose of this study is to determine the effects of internet-assisted chemistry applications on prospective chemistry teachers' cognitive structures in the topics of bonding and hybridization. The sample of the study consisted of 36 prospective chemistry teachers attending Hacettepe University, Faculty of Education, the Department of Chemistry Education in 2010-2011 academic year and taking Basic Chemistry I lesson. In the study, students were separated into experimental and control groups according to their pre-cognitive structures. Students were requested to answer two open ended questions. Answers by each student were gathered and evaluated by flow map method. "Bonding and hybridization" topics were taught to control group with traditional teaching method and to experimental group besides traditional method internet-assisted applications were conducted. The same open-ended questions were given to both groups and their cognitive structures were examined once more. The differences between control and experimental groups' cognitive structures were examined. A significant difference was identified in favour of experimental group (p<0, 05). The mean score of the Experimental group was X=19.94, and the mean score of the Control group was X=13.88. In addition, subsequent to internet assisted chemistry applications differences in terms of concepts and descriptions in prospective chemistry teachers' in experimental and control group cognitive structure have been determined. When post flow maps of prospective chemistry teachers in experimental group, on whom internet assisted chemistry applications were made, are formed, it has been determined that there are more statements about hybridization, hybridization types, molecule geometry and bond angles compared to control group.

Keywords: Cognitive structure, Internet-assisted chemistry applications, flow map, bonding and hybridization, prospective chemistry teachers

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1. INTRODUCTION

How students think, organize knowledge and how they learn are among the greatest area of interest of education researchers. Each person uses different methods and techniques in organizing knowledge. Cognitive structure is a presumptive structure indicating the organization of concepts in students' long-term memories and the relationships between them (Shavelson, 1974; Selvi and Yakışan, 2005). A great majority of students try to memorize a lot of knowledge and their cognitive structures consist of isolated knowledge sets. Students with weak cognitive structure have the ability to process weak knowledge and adapt knowledge to new conditions and daily events (Tsai and Huang, 2002). Determining cognitive structure help teachers know the knowledge structures, pre-knowledge and misconceptions in their students' minds. As a result of this, teachers can arrange learning strategies in an appropriate way and realize conceptual change. Analyzing cognitive structures of students provides them with seeing how their learning takes place and thinking about alternative concepts and contributing their conceptual development (Tsai and Huang, 2002).

The internet is a computer network that connects databases and computers in all over the world. According to Maule (1997), internet is used to support the traditional learning and for the development of new forms of learning. Facilities of media increase with sound quality of internet, animated videos and three dimensional virtual realities. Pedagogical internet sites can be defined as a compilation of web pages prepared with the aim of education or training that provides the required pedagogical sources or can directly participate in education (Buissoon, Chaynes, Delestre, Dumoulin and Le Bescond, 2004). In many studies it was determined that, use of internet with the aim of education increased students' interests, changed teacher-student relationship, contributed to shaping and analyzing thoughts (Hubert, Petit, Demily, Detroz and Denis, 2001; Pichault, 2001; Küçükcankurtaran, 2008).

The animations and simulations presented by the internet provide understanding microscopic and dynamic processes and natural cycles and expensive experiments and activities that are difficult to be realized in the class environment. Information technologies such as internet supported education and computer supported education developed cognitive skills in students by providing educational tools that can be used in lessons. The feature of animating and visualization abstract scientific events in the class makes these topics easier to understand (Para and Ayvaz Reis, 2009).

There are a lot of studies in which computer and internet technology has been used in literature. Barak and Dori (2005) have stated that computer based models are beneficial to chemistry learning in four levels: macroscopic, microscopic, symbolic and chemical process and computer based visual models are effective for students to understand chemical topics, theories and molecule structures. Frailich, Kesner and Hofstein (2009) conducted their studies with 10th- grade high school students. They applied success test for quantitative side of the study and made observation and teacher-student interviews for the qualitative side of the study. At the end of the research, it has been found out that students who have learned the topic of chemical bonding with web based learning applications consisting of active and cooperative learning strategies understand better. Frailich, Kesner and Hofstein (2007) researched the effect of web based chemistry learning on students' perceptions, attitudes and success in their studies. At the end of the study, it has been found out that experimental group is more meaningfully successful than the control group. This has shown that web based learning has a significant effect on students' perceptions, attitudes and success. Own (2006) has worked with 146 people attending Chemistry course at Providence University and applied "Group Embedded Figures Test" and "success test" as instrument of data collection. It has been concluded that success result of experiment group is higher than that of control group and the group applying web based learning learns better and is more successful. Uzunboylu (2002) examined the effect of English grammar learning on student success when it is applied on web assisted. At the end of the research, it has been found out that English grammar success of the students in experiment group making English grammar exercises with web assisted method is higher than the success of the students in control group making the exercises with traditional methods. Ying-Shao and Rex (2002) examined the effect of web assisted educational simulations in science learning in their study conducted with 140 students from Iowa State University. Success test has been applied and interview has been made in the study. A significant difference between groups has not been found. However, interviews have shown that simulations and multiple representation support science learning.

For representing students' cognitive structures, a flow-map method is used. Anderson and Demetrius (1993) developed the method of flow maps different form concept maps and semantic network diagram in order to determine cognitive structure. The basic sense underlying flow map process is to expose the thoughts observed by the answerer from his expressions or defining the phenomenon he created in his memory. In this process, the expressions of the answerer recorded in the interviews are analyzed and the rank and place of the thoughts and the relationships between them are mapped in a diagram. According to the process of creating flow map developed by Anderson and Demetrius (1993), written expressions are transformed into flow maps in the following way:

1. Exposing the knowledge of the student
2. Transforming the expressions of the student into flow map
3. Indicating the flow of thought as connective expression lines via arrow marks
4. Indicating the related expressions with recurrent arrow marks
5. Numbering each expression and recording the time passing during the process of memorizing knowledge (Selvi and Yakışan, 2005).

Tsai and Huang (2001) analysed the knowledge of 28 5th- grade students regarding reproduction in the curriculum using flow map in their study. Teaching programme regarding reproduction was carried out for three weeks and interviews were made to determine cognitive structure of the students every week and after two months following the teaching programme. Interviews were analysed by forming flow map and cognitive structure of the students were revealed. It was found out that development of cognitive structure is composed of three stages: "knowledge development", "knowledge extension" and "knowledge refinement".

Also Bischoff (2002) used flow maps to determine prospective teachers' cognitive structure about magnetism and electricity. In another study Selvi and Yakışan (2005) aimed to examine students' cognitive structure about the topic carbon cycle. 30 prospective biology teachers who are post graduate students (without thesis) have attended the study. The prospective teachers were asked to write main steps about the carbon circle and the relationship of those steps with each other. Their written explanations were evaluated by forming flow maps. At the end of the study it was observed that students had lack of knowledge while recall and constructing relationship between concepts. And also they observed that students could not write the basic steps of the carbon cycle.

For science teachers and educators, determination of students' cognitive structures is vital for the study of their knowledge, conceptual understandings and misconceptions. Cognitive structure represents the organization and relationships of concepts in a students' long term memory (Tsai, 2001).

Within this study flow maps were used in order to determine the effects of internet assisted applications on students' cognitive structure about the topics bonding and hybridization. In some studies students stated bonding and hybridization as an abstract and difficult topic (Gabel, 1996; Levy Nahum, Hofstein, Mamlok-Naaman and Bar-Dov, 2004). For this reason bonding and hybridization is chosen as research topic.

The prospective teachers will transfer their knowledge to students in the future. Therefore, it is important to determine the knowledge and cognitive structures of prospective teachers and to develop their cognitive structures.

1.1. Aim of the study

The aim of this study is to determine the effects of internet-assisted chemistry applications on prospective chemistry teachers' cognitive structures in the topics of bonding - hybridization and differences in terms of concepts and descriptions in prospective chemistry teachers' in experimental and control group cognitive structure subsequent to internet assisted chemistry applications by using flow maps.

Research questions of this study have included:

1. What are the cognitive structures of prospective chemistry teachers about bonding and hybridization before the applications?
2. What are the cognitive structures of prospective chemistry teachers about bonding and hybridization after the applications?
3. Is there a statistically significant difference between cognitive structures of the students in experimental and control groups about bonding and hybridization after the applications?

4. Are there any differences in terms of concepts or descriptions of prospective chemistry teachers in experimental and control groups after the applications?

2. METHOD

Pre- and Post-test Control Group Design was used in the study. 36 prospective chemistry teachers from Hacettepe University participated in this study. The flow map method was used as data collection tool. Descriptive statistics were used to determine the cognitive structures of the prospective chemistry teachers in experimental and control groups about the topics of bonding and hybridization before and after the applications. Also independent samples t-test was used to determine whether there is a statistically significant difference between cognitive structures of the prospective chemistry teachers in experimental and control groups about the topics after the applications. Analysis results were assessed at the level of 0, 05. The qualitative analysis method was used to examine whether there is a difference in the cognitive structure of prospective chemistry teachers in experimental and control groups in terms of concepts or descriptions after applications.

2.1. Sample

The sample of the study consisted of 36 prospective chemistry teachers attending Hacettepe University, Faculty of Education, the Department of Chemistry Education in 2010-2011 academic year and taking Basic Chemistry I lesson. In the study, students were separated into experimental (8 Boys and 10 girls) and control groups (7 Boys and 11 girls) according to their pre-cognitive structures.

2.2. Data collection tools

2.2.1. Flow maps

In the study, flow maps were used in order to determine the cognitive structures of prospective chemistry teachers about the topics of bonding and hybridization. Two open-ended questions were asked the prospective chemistry teachers in relation to the topic and pre-flow maps were prepared by the researchers depending on the written answers given to these questions according the procedure of Anderson and Demetrius (1993). The numbers of linear and recurrent connections in the flow maps were calculated and students' flow map scores were determined. These scores were accepted as the indicator of conceptual achievement. After the applications, the same two open-ended questions were asked the prospective chemistry teachers and post-flow maps were prepared in same way according to the written answers. Then post conceptual achievements were determined. In addition, a flow map about the topic was prepared by the researchers. According to this, the maximum score that can be obtained from the flow map was determined as 36.

2.2.2. Reliability of flow map method

The reliability of the flow-map method was determined by a second independent researcher who is an expert in chemistry education to code conceptions from the students' narratives according to Anderson and Demetrius' procedure (Anderson and Demetrius, 1993). The Pearson correlation coefficient (r) for each student for linear linkages ranged from 0.71 to 0.96.

2.3. The implementation steps of the study

Two open-ended questions were asked prospective chemistry teacher in relation to the topics of "bonding and hybridization" in order to determine their cognitive structures and conceptual understandings. These questions are:

What is hybridization? How does it occur? What are the hybridization types? Please explain it.

What is chemical bond? What are the chemical bond types? How does a chemical bond occur? Please explain it.

The written answers given by prospective chemistry teacher to the open-ended questions were collected and flow maps were prepared for each prospective teacher. The numbers of linear and recurrent linkages in the flow maps were determined and prospective chemistry teachers' post flow map scores were determined. In the light of data obtained from flow maps, the students having low, medium and high cognitive structures and conceptual understanding were determined. Students having cognitive structures from all levels were distributed to the groups equally and experimental and control groups were constituted. The topic was explained to the students in control group via traditional method. However, the topic was explained to the prospective chemistry teachers in experimental group via three-dimensional presentations, figures and animations by using data in

http://www.mhhe.com/physsci/chemistry/essentialchemistry/flash/hybrv18.swf

http://people.southwestern.edu/~footezm/GenChemTutorials/vseprquiz/vsepr_quiz2.html

http://www.mp-docker.demon.co.uk/as_a2/topics/shapes_of_molecules/index.html

web pages in the internet environment along with traditional method. In addition, prospective chemistry teachers applied various exercises and quizzes on the internet. Each group realized these applications during two weeks in 10 class hours time.

After the applications, the same two open-ended questions were asked to the prospective chemistry teachers in both groups once again and written answers were collected. Post flow maps were prepared for each prospective chemistry teachers by the researchers, the numbers of linear and recurrent linkages were calculated and post flow map scores were determined. Whether there was a statistically significant difference between the post flow map scores of the prospective chemistry teachers in experimental and control groups, and thus between their conceptual understandings or not was determined.

3. FINDINGS

The resulting findings were examined in line with the research questions of the study. With regard to the first research question of the study, the prospective teachers' cognitive structures related with "bonding and hybridization" before the applications were examined with flow maps. To this aim, the flow-maps prepared by the researchers for control and experimental groups were individually analyzed. Table 1 shows the average linear linkage number calculated by means of flow-maps.

Table 1. The mean number of the linear linkage estimated through flow-maps before the applications of control and experimental groups

Groups	N	Minimum	Maximum	Mean	Std. Deviation
Control Group	18	1	16	8.50	4.09
Experimental Group	18	2	17	7.55	3.64

The research revealed that the prospective teachers in both groups established only linear linkage on "bonding and hybridization". Therefore, only linear linkage average was used during the analysis. As Table 1 shows, the mean linear linkage number in the flow-maps for control group is =8.50, it is =7.55 for Experimental Group. It has been determined that the linear linkage number developed by the prospective teachers is approximately minimum 1 and maximum 17. Therefore, it has been seen that the prospective teachers has confined knowledge and conceptual understanding on "bonding and hybridization", poor cognitive structures and they put the relevant statements in a linear order.

In regard to the second research question, the prospective teachers' cognitive structures related with "bonding and hybridization" after the applications were examined with flow maps. To this aim, the flow-maps prepared by the researchers for control and experimental groups were individually analyzed. Table 2 shows the average linear linkage number calculated by means of flow-maps.

Table 2. The mean number of the linear linkage estimated through flow-maps after the applications of control and experimental groups

Groups	N	Minimum	Maximum	Mean	Std. Deviation
Control Group	18	3	21	13.88	5.37
Experimental Group	18	9	28	19.94	5.68

As Table 2 shows, the mean linear linkage number in the flow-maps for control group is =13.88 it is =19.94, for Experimental Group. It has been determined that the linear linkage number developed by the prospective teachers in control group is approximately minimum 3 and maximum 21 and for experimental group minimum 9 and maximum 28. (An example of the Flow-maps developed by one of the prospective chemistry teachers in experimental group before and after the applications are attached in Appendix 1)

To mention the third research question of the study; independent samples t-test analysis was carried out in order to investigate the relation between the prospective teachers' success level and whether there is a statistically significant difference between cognitive structures of the prospective chemistry teachers in experimental and control groups about bonding and hybridization after the applications. Table 3 shows independent t-test results.

Table 3. Independent t-test results of the students in experimental and control groups about bonding and hybridization after the applications.

Study Group	**N**	**Mean**	**sd**	**t**	**p**
Experimental Group	18	19.94	5.68	3.28	.002
Control Group	18	13.88	5.37		

The mean score of the Experimental group was X=19.94, and the mean score of the Control group was X=13. 88. A significant difference was identified in favour of experimental group was observed (p<0, 05).

Related to the fourth research question in which we have researched whether there is a difference in terms of concepts or descriptions of prospective chemistry teachers in experimental and control groups after internet assisted chemistry applications, flow maps that have been formed with answers of prospective chemistry teachers have been examined. It has been seen that prospective chemistry teachers in experimental group have explained correctly bond types, hybridization types that molecules have, molecule geometry and bond angles with their examples in chemical bonding and hybridization questions. However, prospective chemistry teachers in control group have given limited information about bond types and hybridization types, could not explain molecule geometry and bond angles of molecules correctly.

4. CONCLUSION AND DISCUSSION

Although for determination of students' cognitive structure, studies related with computer assisted education, internet assisted education or studies about hypermedia applications effects have been done; in such kinds of studies for determination of cognitive structure generally concept maps have been used. Liu, Chen and Chang (2010) investigated the effects of computer assisted applications on students' cognitive structures and found that computer assisted concept maps improved students success in English lectures. Similarly, Kim, Yang and Tsai (2005) analyzed the positive effects of online collaborative concept maps and found that internet is a good learning tool for co-constructing knowledge. But there are not so many studies investigating the effects of internet assisted education on students' cognitive structure by using flow maps. With this point of view, within this study the effects of internet-assisted chemistry applications on prospective chemistry teachers' cognitive structures were investigated.

36 flow-maps that were prepared by the researchers through the answers of the prospective teachers to the open ended questions regarding "bonding and hybridization" and that aims to discover the students' relevant cognitive structures have been analyzed. The linear linkages have handled since the prospective teachers had developed only linear linkages. The number of the linear linkage average developed by the prospective teachers before the applications has been found 1 at minimum and 17 at maximum and after the applications has been found 3 at minimum and 28 at maximum . These values have been considered to be extremely low; for, it had been assessed in the flow-maps formulated by the researchers that the linear linkage is 36. Accordingly, it has been concluded that that the prospective teachers has confined knowledge and conceptual understanding on "bonding and hybridization", poor cognitive structures and they put the relevant statements in a linear order. These findings are in consistent with the results of study held by Selvi and Yakışan (2005).

Independent t-test results revealed that a significant difference in students' cognitive structure was identified in favor of Experimental group. Approving Para and Ayvaz Reis (2009) thoughts these results show that supporting the lecture with animations and visualizing bonding, hybridization, and bond formation made the topic easier to understand and improved students' cognitive structure. Also, it supports the statement of Carpi (2001) "web materials have advantages in developing chemistry learning and teaching." That there is more statement in the flow map of prospective chemistry teachers in experimental group than control group and they have higher success overlap with the different studies in literature. (Frailich,Kesner and Hofstein, 2009; Ardac and Akaygun, 2005; Barak and Dori, 2005)

When post flow maps of prospective chemistry teachers in experimental group, on whom internet assisted chemistry applications were made, are formed, it has been determined that there are more statements about hybridization, hybridization types, molecule geometry and bond angles compared to control group. As the studies in literature (Gabel, 1996; Levy Nahum, Hofstein, Mamlok-Naaman and Bar-Dov, 2004) states, chemical bonds are difficult to learn, abstract and complex. Therefore, teachers have difficulties in teaching the topic and students have difficulties in learning it. In addition to traditional methods, teachers sometimes use models to teach chemical bonds. However, use of computers, internet technology, three dimensional simulations and videos in education makes students' comprehension easier and develop it. Findings of our study overlap with the finding of Barak and Dori (2005) which says computer based visual models are effective for students to understand chemical topics, theories and molecule structures. Computer based models provide an effective connection between macroscopic and microscopic levels, which a lot of students have difficulty in. There are lots of studies that state computer and web assisted models, computer simulations, animations and use of visual materials increase students' success and contribute to learning. (Ardac and Akaygun, 2005; Barnea and Dori, 2000; Carpi, 2001; Marbach-Ad, Rotbain, Stavy, 2008). Frailich, Kesner and Hofstein (2009) expressed that web based learning applications including active and cooperative learning strategies makes students to understand the topic of chemical bonds better. Frailich, Kesner and Hofstein (2007) found in their study that web based chemistry teaching have a significant effect on students' attitudes, perceptions and success as well. Own (2006) has observed in his study carried out 146 people from Province University and attending a chemistry course, that the group making web based application learns better and is more successful.

It is important to determine students' cognitive structure in education in terms of both determining the pre knowledge that students have and directing teaching-learning activities prepared in light of pre knowledge acquired. Hence, teachers can determine pre knowledge of students in different topics examining their cognitive structures by flow maps and direct the curriculum. Also, students' possible misconceptions in their cognitive structures can be determined by using flow map method and applications can be realized to prevent these misconceptions. In the following studies, effect of interned assisted applications on retention of knowledge can be determined by the method of flow map. Also, effect of this application on students' motivation, attitude and interest can be examined.

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Appendix 1:

An Example of the Flow-maps developed by a Prospective Chemistry Teacher in Experimental Group before the Applications

Chemical Bonding

⇩

1. Van der Waals bonding

⇩

2. Dipole- dipole bonding

⇩

3. Hydrogen bonding

An Example of the Flow-maps developed by a Prospective Chemistry Teacher in Experimental Group after the Applications

1. Descriptions of chemical bonding
2. Intramolecular bonding
3. Ionic bonding
4. Covalent bonding
5. Nonpolar covalent bonding
6. Polar covalent bonding
7. Coordinate covalent bonding
8. Intermolecular bonding
9. Hydrogen Bonding
10. Van der Waals Bonding
11. Dipole- dipole bonding

1. Descriptions of Hybridization
2. sp hybridization
3. Linear molecular geometry
4. Bond angle of 180^{o}
5. sp^2 hybridization
6. sp^3 hybridization
7. dsp^3 hybridization
8. Trigonal Bipyramidal molecular geometry
9. d^2sp^3 hybridization
10. Octahedral molecular geometry