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University Students' Attitudes towards Chemistry Laboratory: Effects of Argumentative Discourse Accompanied by Concept Mapping

Üniversite Öğrencilerinin Kimya Laboratuvarına Karşı Tutumları: Kavram Haritasına Dayalı Tartışmacı Söylevin Etkisi

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ABSTRACT

The purpose of this study is to investigate the effects of argumentation based on student-constructed 'pre' and 'post' laboratory concept maps on students' attitudes towards chemistry laboratory in a university general chemistry course. Concept mapping has been used as a tool to carry out the argumentations about chemical concepts involved in general chemistry laboratory experiments between instructors and students, and among students. In the experimental group, students (N=41) performed their general chemistry laboratory experiments using individual, small and large group discussions based on students' pre- and post- laboratory concept maps, whereas the control group students (N=43) performed their laboratory investigations using traditional approaches. A questionnaire to test the attitudes of students towards chemistry laboratory (QATCL) has been administrated to both groups as pre- and post-tests. The statistical analysis (ANCOVA) of results of QATCL post-test showed that there has been a significant difference favoring the experimental group with respect to students' attitudes towards chemistry laboratory. Hence, it is found out that argumentative discourse founded on pre- and post-laboratory concept maps are more effective in *improving students' attitudes towards chemistry laboratory than traditional teaching methods.*

Key words: Argumentation, concept maps, attitudes towards chemistry laboratory

ÖZET

Bu çalışmanın amacı, öğrencilerin üniversite genel kimya laboratuvarlarında hazırladıkları laboratuvar öncesi ve sonrası kavram haritalarına dayalı gerçekleştirilen tartışmaların derse karşı tutumları üzerine etkinliğini araştırmaktır. Kavram haritaları, öğrencilerin genel kimya laboratuvarı deneyleri kapsamındaki kavramlarla ilgili kendi aralarında ve araştırmacılarla tartışmalar yapmaları için bir araç olarak kullanılmıştır. Deney grubu öğrencileri (N=41) deneylerini laboratuvar öncesi ve sonrası hazırladıkları kavram haritalarına dayalı yaptıkları bireysel, küçük ve büyük grup tartışmalarıyla yürütürken, kontrol grubu öğrencileri (N=43) laboratuvar deneylerini geleneksel yaklaşımlara dayalı gerçekleştirmişlerdir. Kimya laboratuvarına karşı tutum anketi her iki grubun öğrencilerine hem ön ve hem de son test olarak uygulanmıştır. Ankete ait sonuçların istatistiksel analizleri (ANCOVA), öğrencilerin kimya laboratuvarına karşı tutumları açısından deney grubu lehine anlamlı bir farklılık olduğunu göstermiştir. Bu nedenle, laboratuvar öncesi ve sonrası hazırlanan kavram haritalarına dayalı yapılan tartışmaların, öğrencilerin kimya laboratuvarına karşı pozitif tutum geliştirmede geleneksel laboratuvar öğretiminden daha fazla etkin olduğu sonucuna varılmıştır.

Anahtar kelimeler: Tartışma, kavram haritası, kimya laboratuvarına karşı tutum

1. Introduction

Science education without laboratory investigations is unthinkable (Hegarty-Hazel, 1990:55). Domin (1999a) states in his study named "a review of laboratory instruction style" that research is needed that addresses which style of laboratory instruction best promotes the following specific learning outcomes: (1) conceptual understanding, (2) retention of content knowledge, (3) scientific reasoning skills, (4) higher-order cognition, (5) laboratory manipulative skills, (6) better attitude towards science, and (7) a better understanding of the nature of science. Unfortunately, the gap between the goals of laboratory work and the actualized outcomes is vast. The reason of this gap is generally considered as the type of laboratory experience a student receives depends upon the pedagogy and instructional methodology. Four distinct styles of laboratory instruction have been prevalent throughout the history of chemistry education, as follows: expository, inquiry, discovery, and problem-based (Domin, 1999a). In this connection, instruction in the science laboratories at Universities in Turkey is generally carried out through expository approaches that are the most common laboratory style in other many countries. Expository or verification approaches in laboratory are described as students following directions to arrive at a predetermined outcome, illustrating an important reaction, and verifying a principle or theory. The predominant feature of the expository lesson is its "cookbook" nature, which emphasizes following specific procedures to collect data (Domin, 1999 a, b; Tobin, Tippins and Gallard, 1994). Unfortunately, our students in the science laboratories strive to collect records of their experiments, to transform these records into graphs, or diagrams and drawing conclusions-often without knowing why as stated by Novak and Gowin (1984) as follows:

> "Often students enter into a laboratory wondering what they are supposed to do or see and their confusion is so great that they may not get as far as asking what regularities in events or objects they are to observe, or what relationships between concepts are significant. As a result of, they proceed blindly to make records, manipulate apparatus, or make constructions with little purpose and little consequent enrichment of their understanding of the relationships they are observing or manipulating" (Novak and Gowin, 1984: 48).

On the other hand, science laboratories should help students in constructing and/or reconstructing their conceptual framework and constructing new knowledge from the experiences in the laboratory that they consciously integrated to their prior knowledge (Roth & Rochoudhury, 1993). In line with this perspective, this study aims to being carried out *scientific argumentations* with students based on their own concept maps in a university general chemistry laboratory.

Studies related to concept mapping on some variables (e.g., achievement) generally showed positive results except for a few studies (e.g., Lehman, Carter & Kahle, 1985). There are important differences between this study and other concept map studies. First, instead of examining the effects of concept mapping on generally students' achievement in many earlier studies (e.g., Esiobu & Soyibo, 1995; Markow & Lonning, 1998; Okebukola, 1990), this study focused on students' attitudes towards chemistry laboratory. According to Chiappetta, Waxman, and Sethna (1990), it is difficult to change students' attitudes and perceptions towards science, due to the complex nature of human learning. Also, it is easier to improve students' achievement than their attitudes and perceptions towards science.

The following primary research question formed the basis of this study: Do the argumentative discourse based on student-constructed pre- and post-laboratory concept maps significantly improve university students' attitudes towards chemistry laboratory compared to traditional laboratory teaching?

2. Methods

Participants

A total of 84 students, ages 18 and 19, were randomly selected from ten universities general chemistry laboratory classes taught in the second semester of the 2002-2003 academic year in the Faculty of Education, Gazi University, Ankara, Turkey. Forty-one students were in the experimental group and 43 students were in the control group.

Instrument

A questionnaire of attitudes towards chemistry laboratory (QATCL) developed by the first author consisted of a 40 positive and negative item-Likert Scale, with 'strongly agree', 'agree', 'undecided', 'disagree' and 'strongly disagree'. Scores of 5, 4, 3, 2 and 1 respectively were assigned for positive items, and reverse scoring for negative items. QATCL consisted of six factors: Special interest to chemistry laboratory (10 items), chemistry laboratory as a difficult subject (5 items), chemistry laboratory in school science (6 items), anxiety towards chemistry laboratory (7 items), career planning related to chemistry laboratory (5 items), and perception of chemistry laboratory as an important subject (7 items). Alpha-reliability coefficient of QATCL was found to be 0,83 for this study. Some examples of QATCL are shown in Appendix A.

Procedures

This study involved pre-test post-test control group design (Campbell & Stanley, 1963). After the pre-tests were administrated to both groups, the laboratory course in the experimental group began with three training sessions (5 hours long) on concept mapping, which involved teaching students how to construct and score concept maps using several chemical topics. After the training period, three weeks were allotted for students to individually construct three sets of pre- and post- laboratory concept maps on three chemical topics: 1) the types of chemical reactions, 2) Boyle's Law, and 3) the determination of equivalent mass. The students were grouped into small groups to facilitate collaborative learning, which would allow students to make decisions by consensus and to seek assistance primarily from their peers. During the next five laboratory sessions, *scientific argumentations*, including individual, small and large group discussions, based on students' pre- and post-lab concept maps about chemical concepts involved in general chemistry laboratory experiments were carried out with students. Chemistry laboratory topics were to: (1) the heat of reaction, (2) the effect of temperature on the rate of chemical reactions, (3) the effect of concentration on the rate of chemical reactions, (4) chemical equilibrium, and (5) the pKa of a weak acid–acid and base indicators.

Scientific Argumentations in Chemistry Laboratory

The conceptualization of science learning as argument has been recently proposed by Driver, Newton, and Osborne (2000, 2004), Kuhn (1993), Jimenez-Aleixandre, Bugallo-Rodriguez, Duschl (2000) and Erduran (2204). According to Driver, Newton and Osborne (2000), scientific discussions or arguments are seen to be at the heart of science and central to the discourse of scientists and if science education is to help students engage with the claims produced by science-in-the-making, science education must give access to these forms of arguments through promoting appropriate classroom activities (p. 288). During this research study, we used students' pre- and post-lab concept maps as a tool to carry out the scientific argumentations, including individual, small and large group discussions, about chemical concepts involved in general chemistry laboratory experiments between us and students, and among students.

Laboratory Design

First, the instructor and his two research assistants spent 5–10 minutes with each student discussing his or her pre-lab concept map. The purpose of the individual discussion was to understand students' reasons for their conceptions and help students become aware of their own preconceptions. During the individual discussions, we focused more on students' partial understanding, alternative conceptions, and also critical propositions. We asked students to answer our questions based on their pre-laboratory concept maps (see Figure 1) and to put forward their reasons for their responses. After the individual discussions in each small group, we carried out a small group discussion (10 minutes) with all members of each small group. Each student of small groups was asked to listen carefully his or her peers during individual discussions. So, students were asked to evaluate each other's arguments during the small group discussions. When they agreed, they were encouraged to say their reasons, or when they disagreed, they were encouraged to challenge with counterarguments. Instructor did not intervene to students' responses and did not provide any feedback during individual and small group discussions. It should be noted that we always avoided explicit evaluation of students' answers such as "right" or "wrong".

Afterwards, students were engaged in a *large group discussion* to negotiate scientific meanings based on our findings in pre-lab concept maps and the individual and small group discussions. For example, students' pre-lab concept maps, individual and small group discussions revealed that the chemical equilibrium is not a dynamic process. Hence, the instructor built a large group discussion focusing on the differences between static and dynamic equilibrium using two every day examples: (a) static equilibrium: children on a see-saw at the balance point (i.e., the equilibrium position) no movement of the children or the see-saw occurs; (b) dynamic equilibrium: a boy ascending the escalator at the same rate as the escalator descends. At the balance point (i.e., the equilibrium position) the boy and escalator are moving at the same rate in opposite directions.

Students collected records of their lab investigations, transformed these data into graphs, tables, figures, and schemas, interpreted their records and transformations, and made knowledge claims. Students were asked to examine their own preconceptions in pre-lab concept maps with the findings of their lab investigations. Subsequently, a large group post-lab interpretive discussion was carried out. Students' scientific comments concerning the lab investigations were recorded on the board and interpreted to determine whether or not students answered their initial questions. The instructor also carried out post-lab discussions to provide sub-microscopic explanations to their macroscopic observations in the chemical equilibrium reactions. For example, although our students had experienced the application of Le Chatelier's principle--the effects of concentration and temperature changes on the chemical equilibrium—in their lab investigations, they could not explain the changes in the rates of forward and reverse reactions during the restoration of chemical equilibrium. Hence, the instructor directed the students to think about the sub-microscopic properties of the chemical equilibrium reactions**.** Similarly, interpretive discussions with respect to the non-observable properties were carried out in all other lab investigations.

After post-lab discussions, students individually prepared post-lab concept maps by using their own concept labels. The purpose of the post-lab concept maps was especially to help students become aware of the conceptual changes. The changes in their conceptual knowledge based on their post lab concept maps (see Figure 2), including their new alternative conceptions and partial understandings were discussed.

For example, students understood that when equilibrium is re-established after temperature or concentration changes, the rates of forward and reverse reactions are equal to those at the initial equilibrium, and an increase in concentrations of products is directly proportional to the value of Keq, which led to the discussion of dynamic structure of chemical equilibrium on mathematical equation ($K= [C]^c [D]^d / [A]^a [B]^b$).

Data Analysis

A one-way between groups analysis of covariance (ANCOVA) was used to analyze whether or not there are significant differences between the control and the experimental groups on the posttest scores of QATCL. In the beginning of the study, students' pre-test scores of QATCL were used as the covariates for controlling pre-existing differences between the experimental and control groups.

3. Results

Table 1 shows that the mean of students' pre-test scores on the QATCL in the control group is higher than those in the experimental group.

Table 1. *Means and standard deviations (below) of the experimental and control groups for pre-tests of the QATCL as used the covariates.*

Test	Control Group (N = 43)	Experimental Group (N = 41)
QATCL	142,50 (16,30)	136,31 (15,26)

Table 2 summarizes the results of ANCOVA on the post-test scores of QATCL. The tabulated data indicate that there are significant differences, [F = (1, 81) = 27,20, p < 0,001], between the experimental and control groups.

Table 2. *The results of ANCOVA for post-test scores of QATCL*

Source of Variation	Sum of Squares	df	Mean Square	F	p
Covariate					
QATCL (pre-test)	23160,56	1	23160,56	440,36	0,000
Treatment	1430,74	1	1430,74	27,20	0,000
Residual (Error)	4628,31	81	52,59		
Total	27859,67	83			

The adjusted mean scores of the QATCL post-test in table 3 indicate that the control group had an adjusted mean of 155,27 on the QATCL post-test, while experimental group had an adjusted mean of 163,35 on the QATCL post-test. These results show that students taught with argumentations based on student-constructed pre- and post-laboratory concept maps on students' attitudes towards chemistry laboratory were significantly affected more positively than those in the control group, who learned chemistry laboratory with the traditional way.

Table 3. *Unadjusted mean scores, standard deviations, and adjusted mean scores of the QATCL post-test for two groups*

Groups	N	Unadjusted mean	SD	Adjusted mean
Control Group	41	158,39	16,21	155,27
Experimental Group	43	160,16	19,05	163,35

Discussion

The purpose of this study was to investigate the effects of argumentative discourse founded on student-constructed pre- and post-laboratory concept maps on in a university general chemistry. The quantitative results of data in this study confirm a significant improvement favoring the experimental group with respect to students' attitudes towards chemistry laboratory. Besides the results of QATCL, our classroom observations indicated that students' awareness of their own learning through argumentations based on their concept maps made them think about relevant concepts, and the changes between their pre- and post-lab concept maps helped them to learn how to learn conceptual knowledge that guide lab investigations, and how this knowledge is generated during the chemistry laboratory investigations. In our study, through unstructured interviews and classroom observations, we also found that students who learn by using argumentations founded on their concept maps felt more competent and confident as well as enjoyed the challenge of constructing new ideas with each other or us during scientific discussions. Also, students who understood their weaknesses during individual and small group discussions struggled to promote their conceptual understanding in the relevant concepts, and students often talked about the development of their argumentative abilities involving chemical topics. Moreover, our unstructured interviews with students about argumentations based on their concept maps showed that their argumentations made the knowledge they gained in chemistry laboratory course more permanent. This kind of laboratory style with scientific argumentations gave opportunities for students to engage in their own learning in chemistry laboratory and so, gave them a sense of ownership over their laboratory investigations. Another important reason for improved attitudes towards chemistry laboratory was because students were provided greater autonomy to take control of their own learning through argumentations. So, we attribute their positive feelings towards chemistry laboratory to the scientific argumentations based on their concept maps.

References

Chiappetta, E. L., Waxman, H. C., & Sethna, G. H. (1990). Students' attitudes and perceptions. *Science Teacher*, 4, 52-55.

Domin, D.S. (1999a). A review of laboratory instruction styles. *Journal of Chemical Education*, 76, 543-547.

Domin, D. S. (1999b). A content analysis of general chemistry laboratory manuals for evidence of higher-order cognitive tasks. *Journal of Chemical Education*, 76, 109-112.

Driver, R., Newton, P. ve Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education*, 84, 287-312.

Erduran, S., Simon, S., and Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's argument pattern for studying science discourse. . *Science Education*, 88, 915-933.

Esiobu, G.O., & Soyibo, K (1995). Effects of concept and Vee mappings under three learning modes on students' cognitive achievement in ecology and genetics. *Journal of Research in Science Teaching*, 32, 971-995.

Jimenez-Aleixandre, M. P., Bugallo-Rodriguez, A., & Duschl, R. A. (2000). "Doing the lesson" or "Doing science": Argument in high school genetics. *Science Education*, 84, 757-792.

Kuhn, D. (1993). Science argument. Implications for teaching and learning scientific thinking. *Science Education*, 77, 319-337.

Markow, P.G., & Lonning, R.A. (1998). Usefulness of concept maps in college chemistry laboratories: Students' perceptions and effects on achievement. *Journal of Research in Science Teaching*, 35, 1015-1029.

Novak. J.D. & Gowin, D. B. (1984). *Learning How to Learn*. Cambridge Press.

Lehman, J. D., Carter, C., and Kahle, J. B (1985). Concept mapping, vee mapping, and achievement: Results of a field study with black high school students. *Journal of Research in Science Teaching*, 22 (7), 663-673.

Okebukola, P. A. (1990). Attaining meaningful learning of concepts in genetics and ecology: an examination of the potency of the concept-mapping technique. *Journal of Research in Science Teaching*, 27, 5, 493-504.

Osborne, J., Erduran, S., and Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching*, 41, 10, 994-1020.

Roth, W.M., and Roychoudhury, A. (1993). Using vee and concept maps in collaborative settings: Elementary education majors construct meaning in physical science courses. *School Science and Mathematics*, 93, 237-244.

Tobin, K.; Tippins, D. J.; Gallard, A. J. *In Handbook of Research on Science Teaching and Learning*, Gabel, D., Ed.; Macmillan: New York, 1994; pp 45-93.

Appendix A

Working in chemistry laboratory is interesting and exciting. (Special interest to chemistry laboratory); The experiments that I performed in chemistry laboratory are too complex and difficult. (Chemistry lab as a difficult subject); Chemistry laboratory course is one of the most boring courses in school. (Chemistry laboratory in school science); Working in chemistry laboratory makes me nervous and upset. (Anxiety towards chemistry laboratory); I would not enjoy being a scientist carrying out the investigations in a chemistry laboratory in future. (Career planning related to chemistry laboratory) I think that chemistry laboratory is a waste of time. (Perception of chemistry laboratory as an important subject).

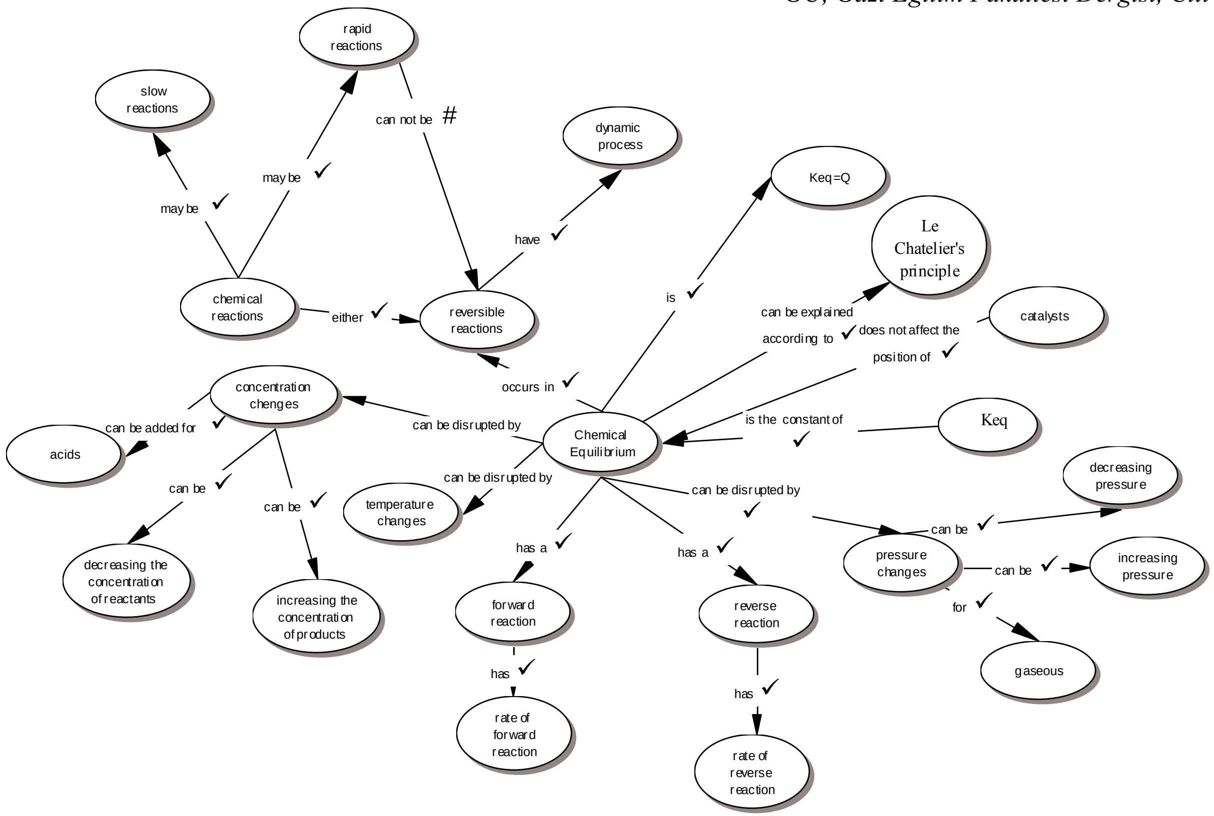

Figure 1. A student's pre-lab concept map for the chemical equilibrium

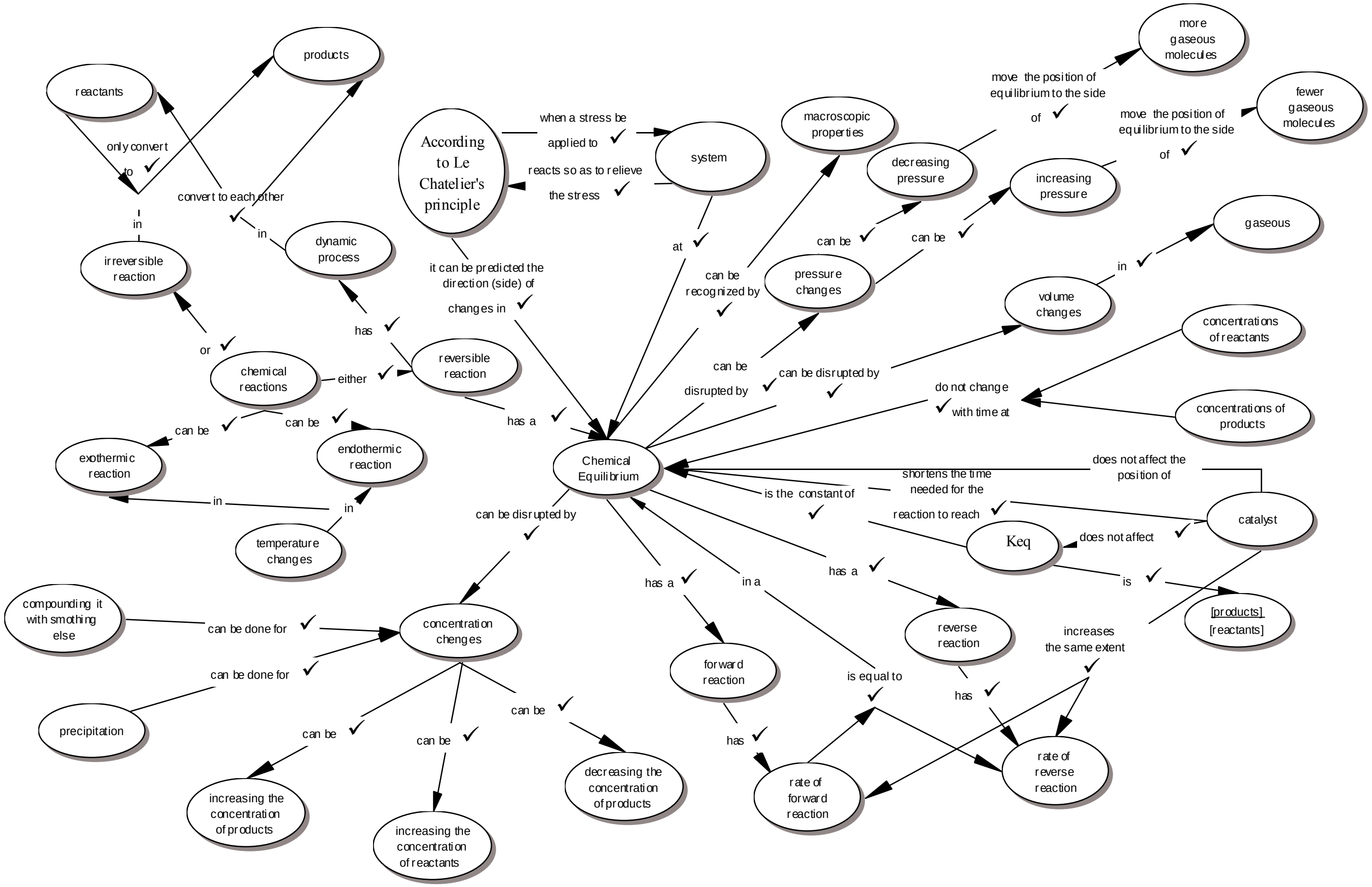

Figure 2. The same student's post-lab concept map for the chemical equilibrium