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New Approaches
Нови подходи

TEACHING INTERMOLECULAR FORCES WITH LOVE ANALOGY: A CASE STUDY

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Abstract. This paper provides an example of an innovative science teaching applied in an introductory chemistry course for future elementary teachers at a small university in northeastern Turkey. The aim of the lesson is to help prospective elementary teachers understand the intermolecular forces in a simple way and see an innovative teaching example.
Keywords: intermolecular forces, chemistry education, introductory chemistry, innovative teaching, analogies in chemistry

Introduction

Researchers see teachers' professional development as the most crucial variable in the science education reform movement (Karakas, 2010). Teacher education programs should graduate teachers who can reason soundly about their teaching (Fenstermacher & Soltis, 1986). The National Research Council (NRC) standards state "since the current reform effort requires a substantial change in how science is taught, an equally substantive change is needed in professional development practices."[1)] Better prepared teachers are more effective in developing higher-order thinking skills and meeting the needs of diverse students through different learning approaches (Begle, 1979; Druva & Anderson, 1983; Karakas 2008). Conceptual teaching of problem solving and thinking skills, life relevancy, and life experiences are recommended by science educators (Rutherford & Ahlgren, 1990). Problem solving and thinking skills that revolve around life experience may be better taught through a student-centered classroom that emphasizes process-oriented learning (Cachapuz & Paixao, 2002) . Pre-service teachers must be presented with teaching strategies that challenge their thinking and encourage them to ask questions (Cachapuz & Paixao, 2002). Vigorous modeling of student-centered and process-oriented instruction must take place in classrooms where teachers actually learn science content.[2] Undergraduate pre-service education must change to alter current education.[2]

This paper is the result of an innovative lesson planned, designed and implemented by the researcher in an introductory chemistry course taught to prospective elementary teachers (non-science majors) in Turkey to reach the above mentioned teacher education goals. The main objective was to help prospective elementary teachers understand the intermolecular forces in a simple, but novel way.

One of the primary objectives of teaching is to provide understandable instruction (Rutherford & Ahlgren, 1990). Teachers should try to find innovative ways to attract and sustain students' attention for better understanding. "Teaching for understanding has to be every teacher's purpose in teaching" (Wiggins & McTighe, 1998). Scientific conclusions have to be artfully interpreted and applied to particular educational situations (Dewey, 1963). Based on this philosophical stance, the researcher attempted to meaningfully incorporate the attraction between girls and boys as an analogy to intermolecular forces. It is believed that this analogy may lead to an easy understanding of the concept. Perhaps as well, this analogy could be used by these future teachers as a teaching method more fully and more often in their future classrooms in various other ways. Moreover, this analogy could help prospective teachers to understand what the term "teaching for understanding" means by seeing the example of teaching for understanding implemented by their instructor. Some researchers said that analogies can be seen as a "two-edged sword" because they can help students understand difficult scientific concepts; however, if not used properly, analogies can engender alternative conceptions (Cherif et al. 1997; Harrison & Treagust 1993). The author was aware of this possibility.

Students learn best in a context that illustrates the taught material's practical value (Shaker, 2001). Some researchers proposed that if the curriculum is to support a genuine search for self and social meaning, then it ought to be drawn from concerns young people have about themselves and their world (Brodhagen et al., 1998). In line with this statement, the instructor modified the instructional material of an introductory chemistry course on intermolecular forces to connect students' learning to the world around them. The aim was to teach the concept of intermolecular forces in a way that is driven from their environment, and is connected to their daily life.

The lecture

To begin with, the instructor changed the title of the lesson *'Intermolecular Forces'* to *'Attraction between Girls and Boys.'* The reason of title change was to attract students' attention. When the title was presented to the class, there was complete silence and rapt attention as the students were curious to know why the instructor was talking about attraction between girls and boys in an introductory chemistry course. All the 60 students in the class were freshmen students in the second semester of their study of elementary teaching in a small university in Northeast Turkey.

Because they take very few science courses in high school, students in the introductory chemistry course were unfamiliar with the concept of intermolecular forces. In Turkey, students in high school have to choose their track of study in their first year, choosing from three tracks: mathematics, science, or social science studies they are initially placed in upon entrance to high school. Students who chose Social Science studies have very few science classes throughout their high school years, and this deficiency needs to be rectified in their later time in teacher preparatory courses. There is a nation wide university entrance exam in Turkey, and students who graduated from social science studies can only choose certain majors in the university, one of which is the elementary teaching program.

When asked whether they had heard the term 'intermolecular forces,' students said that they had not heard it before this class. The instructor suggested to the class that they in some way have experienced intermolecular forces in their everyday life, but they just didn't realize it. This would be a lecture where students would see that they had already prior knowledge of such intermolecular forces. The instructor started the lesson by asking students whether they had ever been in love, or had friends who are in love. There was some giggling in the class, as some students said that they had been in love, some are still in love, and some had friends who had been in love, or are in love currently. Then he said that they would create a love drama in the classroom and asked a male and a female student who were a couple to come forward. The students hesitated at first, but one couple came to the front of the classroom. The instructor said what happens in a relationship between a male and a female if there is a love. Students gave various answers with laughter. The instructor said in a patriarchal society such as Turkey, the male is supposed to take care of the female. Then the instructor said that basically, the male has to revolve around the female like an electron revolving around a nucleus. After mentioning this, and to avoid possible sources of misconceptions, the instructor projected the simple Rutherford–Bohr atom picture on to the wall as an oversimplification and explained that nucleus is made up of more than one particle, atoms have mostly more than one electron revolving around a nucleus. The teacher then asked the couple to perform the drama via a female student standing still like a nucleus, while the male student orbiting around her in a circle. This led to intense laughing in the classroom. The instructor asked another female student to come forward in front of the classroom, and asked what would happen to the 'relationship' between the couple if another attractive female is presented in their environment, will the male show some interest in her? Students again gave some funny answers (of course the instructor was aware of the fact that this has no counterpart in the microscopic world; all electrons are identical, and for that matter all nuclei are identical from the electrons point of view; isotopes exist, of course, but the effect of the corresponding nuclei is negligible, however the aim in this lecture was to make simple analogy and this was explained to the students). The instructor said, “Well at least the male will take a look at her I suppose, and to do so his revolving around his girlfriend will slow and concentrate on one place, which is obviously the other attractive female presented in the environment.” The instructor explained that this is what happens in the London dispersion force where instantaneous polarization is caused by instantaneous changes in the dipole of atoms, caused by the location of the electrons in the atoms’ orbitals. Like the male student taking a look at the other attractive female presented in the environment, his revolving around his girlfriend slows on the side where the other attractive female is presented. The instructor further explained that when an electron is on one side of the nucleus, this side becomes slightly negative (indicated by δ-); this in turn repels electrons in neighboring atoms, making these regions slightly positive (δ+). This would exemplify another male orbiting around the other attractive female; the instructor asked another male student to come forward to simulate this chemical nature. Many male students were willing to come forward and the instructor randomly selected one of them to come in front of the class. The male student revolved around the other ‘attractive’ female student, giving the appearance of an electron revolving around a nucleus. Now there were two couples in the love drama; females standing still and males orbiting around each of them. The male of the first couple, while revolving around his girlfriend, slowed when he came near the second female. He pushed the other male, who was revolving around the second female, to the other side of the second female. He did this to have eye connection with the second female, thus, ‘complicating’ the relationship. Students were laughing while the four students were performing the above explained act. The instructor then explained that the induced dipole (like the first male slowing and showing some interest in the second female) causes a brief electrostatic attraction between the two atoms (like the brief attraction between the first male and the second female and their making eye contact with each other). The electron immediately moves to another point and the electrostatic attraction is broken, like the second male becoming a little jealous and coming between the first male and the second female, thereby stops their eye contact. The instructor further explained that London dispersion forces are typically very weak because the attractions are so quickly broken (there is always a jealous boyfriend), and the charges involved are so weak (there is a very weak attraction between the male and female of the two ‘atoms’ and there is no ‘cheating,’ as which could portray a bond being broken). Electron density in a molecule may be redistributed by proximity to another multipole. This would be played out in the dance as orbiting males concentrate around one female on one side if there is a presence of other attractive female on that side. Electrons will gather on the side of a molecule that faces a positive charge, and will retreat from a negative charge. This drama would be 'played' out as males gathering on the side of a molecule that faces another attractive female, only to then retreat from the jealous boyfriend of hers. Hence, a transient multipole can be produced by a nearby polar molecule (e.g., a transient unstable relationship can be produced by a nearby unstable relationship), or even by a transient multipole in another nonpolar molecule (e.g., a transient unstable relationship can be produced by a nearby stable relationship). The instructor said that London dispersion force work like the relationship between females and males, sometimes males get bored and start looking to other females; but as well, there is always some jealous boyfriend that comes to his senses and turns back to his girlfriend. So, London dispersion force is as complicated as human relationships. He further clarified that this is a simple analogy and London dispersion is usually caused by a number of electrons within the electron distribution. The instructor asked students whether they now know how London dispersion force works, and almost all of the class held their hands up. However, how many students understood the London dispersion force concept needs to be further investigated.

The instructor then moved to dipole-dipole interactions and explained that they are caused by permanent dipoles in molecules, which is like having a permanent problem in the relationship. He said that when one atom (the first couple in front of the class) is covalently bonded to another (are friends with the other couple in front of the class) with a significantly different electronegativity (with a significantly different and more attractive female to the male of the first couple), the electronegative atom draws the electrons in the bond nearer to itself (the attractive female of the second couple draws the male of the first couple nearer to herself) and becoming slightly negative (complicating the relationships with the second female, whom now has two males around her). Conversely, the other atom becomes slightly positive (the first female having a male who is less interested in her, leaving her more alone at home).

Electrostatic forces are generated between the opposing charges (between the opposite sexes), and the molecules align themselves to increase the attraction (and the couples align themselves to increase the attraction, thus creating a complicated relationship). The instructor continued by saying that hydrogen bonds are form of dipole-dipole interactions, caused by highly electronegative atoms (caused by couples with highly attractive females). They occur between hydrogen (the first couple in front of the class) and oxygen (couple where the nucleus is Maria Sharapova), fluorine (couple where the nucleus is Kim Kardashian) or nitrogen (couple where the nucleus is Beyonce), and are the strongest intermolecular force (force which creates the highest chance of cheating). The high electronegativities of *F*, *O* and *N* (the high desirability of Maria Sharapova, Kim Kardashian, and Beyonce) create highly polar bonds with hydrogen (create highly unstable relationship within the first couple), which leads to strong bonding between hydrogen atoms on one molecule, and the lone pairs of *F*, *O* or *N* atoms on adjacent molecules (leads to strong bonding between male of the first couple and the lone attractive females of other couples).

Later, the instructor familiarized prospective teachers with London dispersion force, dipole-dipole interactions, and hydrogen bonds as it was written in the textbook. Thus, there was a gradual shift from known (human relationship) to unknown (intermolecular forces) as recommended by some science educators (Lawson, 1999). The instuctor used an alternative explanation in order to facilitate learning of chemistry with simple terms and by utilizing the 'language' known to this specific population, young prospective teachers. Most of the students showed enhanced understanding of the intermolecular forces on their final exam where they were asked to explain London dispersion force in simple terms. Forty five students out of sixty received full grades on the questions. Five students received six out of possible ten points on the question, where four students received credit for five out of a possible ten. Lastly, six students did not get any points on the questions at all. This shows a very good understanding of the London dispersion force. And in one on one conversation with some students during the breaks they said that they had enjoyed the lesson and understood the intermolecular forces via this drama depiction. However, how much understanding was generated by these students needs to be further investigated later in their actual teaching environment.

Conclusion

The instructor described the mechanisms underlined in intermolecular forces by arousing the curiosity of the students (by giving an attractive title), by sustaining their interest throughout the topic (by relating to real life), and by using simple language (appropriate to their level of understanding) (Karakas, 2008; 2010). The way of explaining the intermolecular forces used in this article could also be used in science teacher education classes, in high school science classes, and perhaps in junior high school science classes; however it is definitely appropriate for introductory chemistry courses, because it is really related to undergraduate students' life experiences at this moment, this being their presence as young adults in college, engaging in relationships with other males and females. Connecting abstract science concepts to real life experiences is recommended by a number of science educators. In this article, the researcher tried to implement an innovative science lesson in the classroom, by connecting the intermolecular forces to real life experiences (to complicated girlfriend-boyfriend relationships).The ways of teaching described in this article supports the National Research Council's call for "substantial change in how science is taught" and also contribute in the professional development practices of teachers.[1)] The ways of teaching described here could help science educators to educate future teachers to reason soundly about their teaching, as well as to perform skillfully (Fenstermacher & Soltis, 1986). It also supports Rutherford & Ahlgren's (1990) call of conceptual teaching for life relevancy, and life experiences and Cachapuz & Paixao's (2002) call for student-centered classrooms that emphasizes process-oriented learning, thinking skills that revolve around life experience, and presents prospective teachers with teaching strategies that challenge their thinking, and encourages them to ask questions. Teaching in ways described here gives an example of the Holmes Group's (1986)[2)] call for vigorous modeling of student-centered and process-oriented instruction where teachers actually learn science contents.

БЕЛЕЖКИ

1. http://www.kids4research.org/frog_dvd/NSE_Standards.pdf
2. http://www.holmespartnership.org/Tomorrows_Teachers.pdf

REFERENCES

Begle, E.G. (1979). *Critical variables in mathematics education: findings from a survey of the empirical literature.* Washington: Mathematical Association of America.

Brodhagen, B., Weilbacher, G. & Beane, J.A. (1998). What we've learned from "Living in the future" (pp. 117-133). In.: Beyer, L. & Apple, M. (Eds.). *The curriculum: problems, politics, and possibilities.* Albany: State University of New York Press.

Cachapuz, A. & Paixao, F. (2002). Placing the history and the philosophy of science on teacher education (pp. 10-19). In: Bizzo, N., Kawasaky, C.S., Ferracioli, L. & Rosa, V.L. (Eds.). *Rethinking science and technology education to meet the demands for future generations in a changing world. Vol. 1.* Parana: IOSTE.

Cherif, A.A., Adams, G.E. & Cannon, C.E. (1997). Nonconventional methods in teaching matter, atoms, molecules, and the periodic table for nonmajor students. *American Biology Teacher, 59*(7), 1-11.

Dewey, J. (1963). *Experience in education*. New York: Macmillan.

Druva, C.A. & Anderson, R.D. (1983). Science teacher characteristics by teacher behavior and by student outcome: a meta-analysis of research. *J. Res. Sci. Teaching, 20,* 467-479.

Fenstermacher, G.D. & Soltis, J.F. (1986). *Approaches to teaching.* New York: Teachers College Press.

Harrison, A.G. & Treagust, D.F. (1993). Teaching with analogies: a case study in grade 10 optics. *J. Res. Sci. Teaching, 30,* 1291-1307.

Karakas, M. (2008). Graduating reflective science teachers through problem based learning instruction. *Bulgarian J. Science & Education Policy, 2*, 59-71.

Karakas, M. (2010). Disco dancing and kinetic theory. *J. Chem. Educ., 87,* 928-930.

Lawson, A.E. (1999). What should students learn about the nature of science and how should we teach it? *J. College Science Teaching, 28,* 401-411.
Rutherford, F.J. & Ahlgren, A. (1990). *Science for all Americans.* New York: Oxford University Press.
Shaker, P. (2001). Literacies for life. *J. Educ. Leadership, 59*(2), 26-29.
Wiggins, G.P. &. McTighe, J. (1998). *Understanding by design.* Alexandria: Association for Supervision and Curriculum Development.

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