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Pre-Service Physics and Chemistry Teachers' Conceptual Integration of Physics and Chemistry Concepts

Mustafa Tuysuz
Yuzuncu Yıl University, TURKEY
Oktay Bektas
Erciyes University, TURKEY
Omer Geban & Gokhan Ozturk
Middle East Technical University, TURKEY
Bugrahan Yalvac
Texas A&M University, USA

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This study examines the pre-service teachers' opinions about conceptual integration (CI) and their understanding of it. A qualitative phenomenology design was used in the study. Data was collected through in-depth semi-structured interviews comprising ten guiding questions. Three pre-service physics and three pre-service chemistry teachers participated conveniently in the study. While the pre-service chemistry teachers took a course regarding the CI explicitly taught, the pre-service physics teachers were not subjected to any information relating to the CI in their course. Data was analyzed by forming the codes and themes. Generally speaking, while the pre-service chemistry teachers think that physics concepts should be used in the chemistry lessons, the pre-service physics teachers believe that these two subjects' concepts generally are not related to each other. Moreover, the participants had some difficulties in understanding the CI between physics and chemistry concepts. The possible implication for science teacher education and research is discussed.

Keywords: conceptual integration, chemistry education, physics education, pre-service teacher education

INTRODUCTION

In constructivist view, students interpret the new knowledge according to what

Correspondence: Mustafa Tuysuz,
Faculty of Education, Secondary Science and Mathematics Education Department, Middle East Technical University, 06800, Turkey.
E-mail: mustafa0678@gmail.com

they already know. Students' existing cognitive resources shape the nature and the level of the new knowledge integration. If students learn the new knowledge meaningfully rather than rote-memorizing it, they can effectively build their knowledge structures. Constructivist teaching supports meaningful learning and highlights the importance of students' prior knowledge and its role in new learning. When students have adequate prior knowledge and learn the concepts meaningfully, they can achieve conceptual integration (CI) among different subject areas in science (diSessa, 1993; Matthews, 1993).

Conceptual integration can be defined as a skill that learners can employ pre-requisite knowledge or concepts in a certain science subject whilst they are learning a concept or topic in another science subject (Taber, 2003b; Toomey & Garafalo, 2003). In other words, conceptual integration is a measure of how much students could use Coulomb law that is physics topic while learning the chemical bonds in the chemistry lesson. Likewise, Taber (2005) defined the CI as the person's organized knowledge structures that are formed for making connections between different areas. As an illustration, when teachers teach certain chemistry topics at an advanced level, they should use more fundamental chemistry topics, ideas, and concepts at a less advanced level and think about some pre-requisite knowledge of physics or biology topics; therefore, learners can learn this topic meaningfully (Taber, 2008b).

State of the literature

- Although many science educators examined students' conceptions and thinking regarding particular subject areas, the CI in students was not well covered.
- The CI studies in the literature are mainly in understanding chemistry concepts at college and university levels, and these studies are often on a specific chemistry concept. Interviews and other data collection instruments were used to collect data.
- Also, even there are studies about the CI in which physics pre-requisite knowledge is used for teaching chemistry concepts, there are no much more studies about the CI in which chemistry pre-requisite knowledge is used for teaching physics concepts.

Contribution of this paper to the literature

- Studies in assessment and evaluation, teaching methods, and curriculum related with conceptual integration were not found in the literature.
- In addition to these, opinions of pre-service teachers about the CI are worth to study in that it is difficult to understand chemistry deeply without understanding physical concepts behind it or vice versa. Moreover, they are future teachers and the CI affects directly students learning.
- There are a few studies about conceptual integration and this study will put a brick to the construction.

Chemistry and physics are two closely linked domains on many topics, such as ionization energy, mass, force, energy, atomic models, equilibrium, and chemical bonding. Moreover, some topics may appear in both general chemistry and physics courses. These topics can be measurement, unit conversion, fundamental properties of matter, pressure, molecular collisions, various types of bonding, the behavior of charged particles in electric and magnetic fields, states of matter, types of energy, energy conservation, various thermodynamic concepts, electrochemical cells, atomic and nuclear structure, spectroscopy, orbital motion, properties of waves, vibrational motion, electromagnetic radiation, and radioactivity (Toomey & Garafalo, 2003). Therefore, teachers should utilize these concepts in the physics courses or chemistry courses in order to help their' students to achieve the CI. For instance, when teaching chemical bonding, chemistry teachers should use Coulomb law of application of force concept in their courses in order to increase the CI for their students. Moreover, when teaching surface tension, intermolecular forces should be explained by physics teachers to achieve the CI (Taber, 2003b; Taber, 2008b; Toomey & Garafalo, 2003). However, it should not be forgotten that these concepts are only examples since there are many places in chemistry and physics where knowledge of one area is not necessary to students to understand the CI.

As mentioned above, students should be able to achieve the CI in a science lesson. However, this raises the question of what degree of the CI can be managed within

the class by students. If students do not succeed in the CI, how this failure can affect the students? Therefore, the CI should be investigated for some reasons. Namely, it is important to inquire into the CI in order to eliminate misconceptions (Ganaras, Dumon, & Larcher, 2008), promote meaningful learning (Taber, 2005), achieve scientific literacy through nature of science (Lederman, 2007), and develop scientific thinking (Taber, 2008b). First of all, there is a strong relationship between physics and chemistry as mentioned above. Research revealed that students have to understand related physics knowledge structures in order to learn chemistry concepts deeply (Taber, 2003a; Nakiboglu, 2003). Taber (2003b) stated that students can have misconceptions or alternative conceptions in ionization energy if they do not understand pre-requisite physics knowledge regarding ionization energy and if their knowledge about chemistry contradicts with basic physics principles.

Next, Ausubel's meaningful learning theory states that meaningful learning can occur if students connect their new knowledge with existing ones (Taber, 2008a). diSessa (1993) states that concepts are not to be considered alone in terms of the epistemological position in constructivism and they are linked with other concepts. In order to promote meaningful learning and change concepts in students' mind, there should be ecology of the concept without thinking the concept alone (Duit & Treagust, 2003; Furner & Kumar, 2007; Kim & Aktan, 2014). Similarly, Novak (2011) suggested that the CI is necessary for the meaningful learning. Thus, we cannot think each concept separately; there should be ecology of the concept and neighboring concepts that stay under the same roof. At this point, the importance of the CI arises since the CI emphasizes on talking about the concepts of different subject areas forming the base of the topic that is being taught. Hence, science educators make it possible for the students to connect the concepts with their neighboring concepts.

Moreover, when we look at the CI from the nature of science perspective, we can see that the CI is the method of the scientist to see the complete picture. Students need to understand the nature of science (NOS) in order to be scientific literate. When scientists are dealing with a problem, they should consider the entire scientific paradigm of the era for their results not to be in conflict with other theories and laws (Chalmers, 1999; Lederman, 2007). Researchers do not utilize only one discipline to generate their scientific conclusions. They have to use a broad range of subject areas to come to a persuasive argument. As the CI requires combining different disciplines, it helps students mimic the scientists' practices.

Although many science educators examined students' conceptions and thinking regarding particular subject areas (Haidar & Abraham, 1991; Harrison & Treagust, 1996; Osborne, 1983), the CI in students was not well covered.

Taber (1998) studied with 15A level college students (16-18 years of age) in England to understand whether they integrate their basic physics knowledge with chemical bonding. In-depth interviews, samples of student work, test responses, and a limited number of survey instruments were employed in this study. The researcher used the principles of grounded theory approach to examine students as cases. Participants thought that physics and chemistry are separate and unrelated scientific disciplines and also thought that using physics knowledge during the chemistry lesson that is related to chemical bonding is unnecessary. Moreover, students used full electron shells to conceptualize chemical reactions rather than being considered the result of physical interactions. Besides, a participant who studied A-level physics and chemistry concurrently said, "I can't think about physics in chemistry, I have to think about chemical things in chemistry" (p.1010). Therefore, they did not achieve the CI between physics and chemistry for chemical bonding.

In another study, Taber (2003b) administered a diagnostic test based on ionization energy to 334 A level chemistry students to see whether they integrate their conceptions about ionization energy with the aspects of Coulombic electrostatics. The sample of this study was the convenience sample, but it consisted of a heterogeneous group. Results of this study showed that although students have to use the principles of Coulombic electrostatics ($F \propto q_1 q_2 / r^2$) to understand ionization energy meaningfully, they generally used statements related to chemistry such as the nucleus attracts the electron and there is a force between the nucleus and the electron.

Taber (2008b) also developed an interview questionnaire that could be used to explore the extent of the CI in A level students studying chemistry and physics at a college in England. Questions included the topics regarding mechanics, electricity, chemical reactions, physical changes, and chemical bonding were asked. In order to analyze the individual students as discrete cases, in-depth case study was administered and four volunteered students (two males and two females) took part in this study. Participants' responses were examined under the titles which are forces, force and motion, interactions between charges, energy, and particle models. In conclusion, the researcher observed that the four students had some difficulties in the conceptual integration of these concepts.

The other study examining the CI between physics and chemistry was conducted by Nakiboglu (2003). She conducted a study with 167 pre-service chemistry teachers. She examined the difficulties these pre-service chemistry teachers' had in making sense of the concepts related to the atomic orbitals and hybridization. She used a diagnostic test including four open-ended questions and five multiple choice items. Concept-evaluation scheme was used to analyze the data and four categories, which were sound understanding, partial understanding, misconceptions, and no understanding, were defined. Results stated that less than 10 % of the participants were only considered as a sound understanding of these chemical concepts. Thus, students in the field of chemistry had difficulties in using physics pre-requisite knowledge to understand atomic orbitals.

To sum up, the CI studies in the literature are mainly in understanding chemistry concepts at college and university levels, and these studies are often on a specific chemistry concept. Interviews and other data collection instruments were used to collect data. Also, even there are studies about the CI in which physics pre-requisite knowledge is used for teaching chemistry concepts, there are no much more studies about the CI in which chemistry pre-requisite knowledge is used for teaching physics concepts Moreover, studies about assessment and evaluation, teaching methods, and curriculum related with conceptual integration were not found in the literature. In addition to these, opinions of pre-service teachers about the CI are worth to study in that:

- It is hard to understand chemistry deeply without understanding physical concepts behind it or vice versa.
- They are future teachers and the CI affects directly students learning.
- Conceptual integration is a hidden aspect in education literature.
- There are a few studies about conceptual integration and this study will put a brick on the construction.

This study examines how pre-service physics and chemistry teachers think about the CI. The study looks at a different perspective on the CI studies and does not look for whether participants make the CI in a specific physics and chemistry concepts' understanding. It seeks opinions of pre-service physics and chemistry teachers about the CI directly. Moreover, this study investigates the following research questions:

What are the opinions of pre-service physics and chemistry teachers about conceptual integration in terms of

i. Whether they use the CI between physics and chemistry in the past and future?
ii. Whether they have difficulties in instructing topics the CI can be made?
iii. Whether they use different instructional strategies/methods while instructing topics the CI can be made?
iv. Whether they ask the question related to the CI while instructing topics the CI can be made in the future?
v. Whether they have examined curriculum in terms of the CI?

METHODS

Research design

This design of this research is a phenomenology, which is one of the qualitative research methods. Qualitative research methods can be used in research design when the researcher wants to make an in-depth analysis. These research designs help researcher to see a complex picture of a phenomenon in the natural environment (Frankel & Wallen, 2000; Yıldırım & Simsek, 2008). In this study, as pre-service teachers' opinions about the CI were examined, phenomenology design was decided to be the most proper design for the study. Pre-service teachers' opinions about the CI were analyzed with in-depth interviews.

Sampling

Convenience sampling methodology was used in this study. Purpose of the convenience sampling defined as "…saves time, money, and effort but at the expense of information and credibility" (Marshall & Rossman, 2006, p.71). Our sample was the pre-service physics and chemistry teachers who take a practice teaching course in a university in Turkey. There were two sections of the practice teaching course, one of them was for the pre-service physics teachers and the other was for the pre-service chemistry teachers. There were respectively seven pre-service chemistry teachers and eight pre-service physics teachers in these courses. It was decided that three participants are proper in terms of reaching a valuable data as well as in terms of time and effort. These participants were volunteers to participate this study. Thus, convenience sampling methodology was used to select these six teachers.

The six participants in the present study were three pre-service physics teachers (Emine, Merve, Alper) and three pre-service chemistry teachers (Handan, Deniz, Murat). The participants' real names were not used in the study; instead, we used pseudo names for each participant. There were three female (Emine, Merve, Handan) and three male participants. One of the female participants was a pre-service chemistry teacher and the other two were pre-service physics teachers. Their age ranged from 22 to 27. These pre-service teachers were taking practice teaching course during their final semester. The course was six hours at a week. The participants spent two hours at the university and four hours at the practice teaching school (a high school).

The course adopted by the pre-service chemistry teachers differed from the course taken by the pre-service physics teachers in terms of the way the courses were taught. The CI was discussed in the course that was taken by the pre-service chemistry teachers explicitly.

Data collection and instruments

Data were collected through semi-structured interviews. The interview was composed of ten questions. The questions were prepared by the researchers based

on the related literature. At the beginning, there were seven main questions; these questions were reviewed at several times and the final form of the interview protocol was composed. In the reviewing process, the interview questions were reviewed by an expert who specialized in qualitative studies in the educational sciences in a university and several colleagues for validity. First of all, colleagues analyzed the interview questions and gave their feedback. According to the feedback, a second version of the interview was prepared. Then, the second version was analyzed by the expert. The expert and the colleagues examined the questions not only for their appropriateness to the research topic but also whether the questions were clear, open-ended, neutral. Finally, the third version of the interview was gathered. Before the final draft of the interview schedule, an interview was piloted with one of the pre-service teachers. Then, the interview protocol took its final form and internal validity was fulfilled for the interview form.

As it was stated earlier, the final shape of the interview was composed of ten questions. However, the paper did not state all of them for the page limitation. First, students were asked what comes into their mind about physics and chemistry. Next, whether there should be physics inside chemistry and vice versa were proposed to students. Then, it was requested from the participants to provide an example of physics used in chemistry for pre-service physics teachers and vice versa for the pre-service chemistry teachers. For the pre-service teachers who could not give an example, an example was given to see whether they know the CI within the secondary school curriculum physics and chemistry of the concepts in Turkey. For example, adhesion and cohesion forces were given as an example for pre-service physics teachers to see whether they use intermolecular forces while explaining interactions between molecules and Rutherford experiment was given as an example for pre-service chemistry teachers to understand whether they employ Coulomb law while explaining how the alpha particles pass through the plate. Then, the importance of using the CI while learning and teaching physics or chemistry, how often they will or have used, their curriculum knowledge about the CI, and evaluation and assessment of the CI were asked in order (You can check all the interview questions in the appendix-A).

Interviews were conducted with the participants at the beginning and the end of the semester. Detailed information is obtained and correctness of the participants' answers was checked by asking the same questions for the second time. An interview schedule was prepared and the interview conversations were tape recorded with permission of the interviewees. One interview took approximately 45 minutes and interviewees were informed before interviews about the length. During the interviews, what the interviewees had said summarized back to them and member-checking was done for the credibility. After that, all recorded interviews were transcribed.

Data analysis

Strauss and Corbin (as cited in Yıldırım & Simsek, 2008) classified qualitative analysis into two; namely descriptive analysis and content analysis. As content analysis enables the researcher to bring out new themes and dimensions (Yıldırım & Simsek, 2008), it is the most proper data analysis strategy for this study. Qualitative data analysis steps suggested by Yıldırım and Simsek (2008, p. 228) were followed by the researchers; "(1) coding, (2) developing themes, (3) organizing codes and themes, (4) defining and describing the findings and interpretation."

Based on the steps suggested by Yıldırım and Simsek (2008), transcribed data were read carefully and the meaningful incidents (sentences, words, paragraphs) were underlined and determined as codes. Meaningful codes related to each other

were put on the same themes. Finally, codes, themes, and relations among themes (if there exist) were analyzed and based on these, a conclusion was reached.

In the literature there were no predefined themes for the CI proposed by any study Thus, researchers generated codes and then generated the themes according to the interview questions and answers. Coding was done by the researchers, one of whom was a research assistant at physics education and two of whom were research assistants at chemistry education. Determining the codes and themes included several steps. First, the transcribed data of a pre-service physics teacher and a pre-service chemistry teacher were coded by all researchers. Next, they discussed the codes and themes they generated and a final form of the coding sheet was emerged. After researchers had come to a consensus, the codes and themes were reviewed by an expert. Then, the last form of the themes and codes under these themes were composed. Thus, internal reliability (dependability) for data analysis was performed.

According to the research questions, nine themes were formed. These themes were based on two major titles, concepts about conceptual integration; level, background, frequency, attitude, difficulty and contribution and concepts about teaching based on the CI; teaching method, assessment and evaluation, and curriculum.

Based on the final form of the coding sheet, interview data from two pre-service teachers were coded again for the second time for all researchers. Then, researchers again came together and discussed their coding. Numbers were given to each code and the inter-rater reliability analyzes were done for the codes of researchers for each interviewee. Reliability of coding was analyzed using PASW statistical package for Windows. Kappa values were calculated and found an average value of 0.93 between the two researchers. It showed that our codes were similar to each other at 93 percent and the coding procedure was highly reliable.

Interviews were done with six pre-service teachers. All interviews were coded by each researcher. A consensus code for each question for each interviewee was reached after discussion.

RESULTS

In this part of the study, detailed explanation of the results we obtained from interviews will be examined in depth. The students' views about each part which are "conceptual integration levels", "background usage of the CI", "attitude toward the CI", "difficulty faced with applying the CI", "contribution of the CI on learning", "frequency of the CI usage", "teaching methods used while applying the CI", "assessment and evaluation of the CI", and "curriculum knowledge about the CI" will be explained.

Conceptual integration levels

Before talking about how students apply the CI in their classes, how they plan to assess, and whether they examine curriculum in terms of the CI, we should first identify if they know what the CI is and whether there is integration between physics and chemistry. We asked direct and in-direct questions to the pre-service teachers. We requested definitions of physics and chemistry and then if there is a relation between them what the level of relation is, and how this relation is possible. In the first interview, we wanted them to give the CI examples regarding physics and chemistry, and in the second one, we gave concrete examples (surface tension and Rutherford experiment) and wanted them to simulate how they will teach these topics conceptually. According to the results of the analysis, participants' answers,

examples they gave and how they will explain specific examples varied as seen Table 1.

In the first and second interviews, Murat said "concepts of physics and chemistry are "much related" to each other." He stated that:

> I don't consider these two concepts as being different; to be more honest I don't want to consider both the chemistry and physics separately because I think they have a close relation with each other. While I am explaining the matter of pressure in chemistry, and especially while I am explaining the things like blowing up of a balloon on matters of gases, I mostly use the concepts of physics. I used these two concepts together while I was giving a course last academic year on the movements of molecules and the pressure occurred as a result of their collision.

He also stated that he talked about the quantum physics while he is teaching atom models. However, he did not give detailed information about how these concepts were integrated into the lesson. He gave similar answers in his second interview, but different from his first interview, numbers of examples of concepts in chemistry associated with physics were increased. Moreover, when he was asked to give an example of chemistry within physics, he had difficulty in providing an example. He said that he made the connection between chemical bonding and Coulomb force. Furthermore, when researchers asked him how he can make integration between physics and chemistry while teaching Rutherford atom model, he firstly explained that "Rutherford experiment which is related with gold foil, and then he mentioned the reason of deflections in gold metals by emphasizing Coulomb force."

Deniz had a misconception about the CI and gave analogy examples as integration between physics and chemistry. The connection between radioactive radiations and waves, and the relationship between intermolecular forces among electrons and gravitational forces between earth and sun were the examples he gave in the first interview. During the second interview, Deniz gave the CI example regarding the structure of the atom. He stated that:

> While we are teaching the structure of the atom, students should know the concepts about waves. If they know wavelength, frequency and energy of electrons, they will be successful while learning atomic structure. We can't teach quantum chemistry to students if there isn't any information about these concepts related to physics. So, we have to integrate physics and chemistry concepts.

This pre-service chemistry teacher was asked if he can give an example of chemistry incorporated into physics. However, he did not give sufficient examples about it. He stated "When physics teachers are teaching the expansion, they can use the metals and provide examples about the expansion coefficient of iron, the expansion coefficient of copper, etc.". Two of the pre-service teachers had the idea that these two subjects are in relation to each other. Even Handan stated that physics and chemistry related to each other in both interviews, she did not have precise knowledge of the CI and real thought that they are a bit related to each other in the first interview. For instance, she stated "We associated the solar system with the relationship between electron and atom in chemistry lessons." Although she

Table 1. Views of pre-service teachers about the level of integration between physics and chemistry

Level	1st interview	2nd interview
Much Interrelated	Murat	Murat,
Related	Deniz,	Deniz, Handan
A bit related	Emine, Handan	Emine, Alper
Separate	Alper, Merve	Merve

thought that it was an integration example, her explanation was only an analogy.

During the second interview, Handan gave an example related to electrochemistry. She stated that:

> For example, you mention about electrons and current when you are teaching electrochemistry. OK, but, you have to emphasize concepts of voltage, and resistance when you are teaching concept of currently. Therefore, students may understand which electrons form currently.

She also mentioned that electrochemistry was related to physics, and physics could be used in the redox reactions and electrochemical cells in the second interview. Moreover, she talked about electrochemical cells and tried to make a connection between physics and chemistry concepts during the second interview. For instance, she drew a circle diagram on paper when considering electrochemical cells and mentioned about the resistance of the conductor at the beginning. She also showed the flow of electrons and the flow of electric current. She emphasized that electron flow and current flow had opposite direction in the circuit.

Based on our findings, it was realized that while pre-service chemistry teachers could give a specific example while explaining physics within chemistry, pre-service physics teachers had difficulty in giving an example for the chemistry concepts within physics. For instance, Emine emphasized in both interviews that these two subjects are "a bit related" to each other. She mentioned that atom models, fusion, and fission, which were considered in physics lessons, could be given an example as chemistry integrated into physics. She also stated that Coulomb force was taught as physics concept in the chemistry lessons. However, since she did not know enough information about the CI between physics and chemistry concepts, she had difficulty in giving detailed information regarding the CI between them. Emine did not make any connection between adhesion and cohesion forces and intermolecular forces while explaining the surface tension concept.

The other pre-service physics teacher, Alper said that physics and chemistry are "a bit related" in his second interview. However, in the first interview, he had emphasized that physics and chemistry were "separate". Alper did not know the meaning of the CI since he gave an example of the common topics in chemistry and physics such as density, heat, and temperature. He did not make any integration between surface tension (adhesion and cohesion forces) and intermolecular forces in the second interview.

Merve stated that these two-course concepts are "separate" in her two interviews. When it was asked her to give an example about the CI in the first interview, she told us "rate and ratio" example. She explained why she gave this example as:

> I am trying to think the concepts together. When we consider chemistry and physics together, I recall things like reaction; therefore, I don't think that they have many relations with each other. I said rate-ratio because I used that topic on chemistry.

By this example, she emphasized that there is no relation between the concepts of these two subjects. However, when a researcher gave an example of surface tension in explaining which adhesion and cohesion concepts of chemistry are used, it was seen that Merve had no idea about this phenomenon and she emphasized "It was very rare that chemistry concepts were used to explain physics concepts and these two subjects were not related to each other".

In her second interview, Merve underlined the same things she reported in the first interview and when a question was asked again, she answered it as: "There may be a relation among them, but they are different. I think there is no need to mention chemistry while explaining physics. I consider them being separate. They are different from each other". When the same phenomenon was told, it was seen that

she could not make the distinction between physics and chemistry on surface tension and she could not make any integration between them.

Background Usage of Interviewee and Their Teachers about Conceptual Integration

When we asked if pre-service physics and chemistry teachers used the CI in the past, two of them, Murat and Merve stated that they applied the CI in their learning processes. For example, in the first interview Murat said that he used frequently the relations between physics and chemistry concepts. He stated "It is my way of learning. I use conceptual integration not only for physics but also for other disciplines. I believe that when I use conceptual integration, my learning will be meaningful".

Also, Merve stated that she sometimes used the integration of physics and chemistry concepts in the past:

> For example, in physics, there weren't topics like atoms and there wasn't an emphasis on chemistry. However, I think I used that. I'm not sure. I cannot say specific things right now. I don't know the reason but when the question was first asked, I recalled mathematics, in general, for example; things related to the rate - ratio. While we were making calculations in physics and chemistry, we could use them. However, I think this is an example for mathematics. However for the integration of chemistry with physics, heat- temperature may be given as an example. I think that I am trying to connect them, since the both of them are related to the matter.

Due to her statements, it was realized that this pre-service teacher did not know what the CI is. Thus, even she had said she had sometimes used the CI in the past; she should be considered as she did not use the CI.

Moreover, the others directly stated that they did not use the CI in their past. For instance, Alper was explaining this like that:

> I almost never use them. In fact, we talked last day with our teacher. He also explained that while he was a student, he felt the lack of usage of these concepts. As the concepts within physics were not used in chemistry, concepts of chemistry were not used in physics, too.

When it was asked if their teachers have used the CI, the responses of the participants indicated that none of their teachers applied the CI. It was asked if it had been changed from high school to university, they stated that both of the teachers in high school and university did not use the CI. The same question was repeated to the pre-service teachers in the second interviews and the same responses were obtained again.

Attitude toward the CI

When it was asked what they think about the importance of chemistry concepts while they are learning or teaching physics or vice versa, it was seen a difference between answers of pre-service physics and chemistry teachers as seen in Table 2.

As pre-service chemistry teachers said that using the CI is valuable and significant, pre-service physics teachers generally thought that using the CI is not valuable. Even pre-service physics teachers who said that it was valuable in the first interview, they changed their minds in the second one. For instance, in the first interview, Alper said, "Chemistry is something in physics. … I will teach as it is

Table 2. Attitudes toward conceptual integration

Attitudes	1st interview	2nd interview
Valuable	Emine, Merve, Murat, Deniz, Handan	Alper, Murat, Deniz, Handan
Not valuable	Alper	Emine, Merve

physics. It isn't necessary for students to learn chemistry concepts in physics, and it isn't important for them to learn". In the second interview, he also stated that chemistry is inside the physics. After the first interview, he had learned what the CI was, and then he had thought about it and changed his idea as the CI was valuable. Moreover, he declared that "if I had known the relation and distinction between physics and chemistry as the subject matter knowledge, I could have used it in order to provide the integration between physics and chemistry".

Merve and Emine changed their mind from "it is valuable" to "it is not valuable". In the first interview, they said that using chemistry concepts in physics is important as they confused the CI with conceptual similarity. For instance, Emine stated that: "In chemistry, we have used conservation of mass and conservation of charges in redox reactions; in physics, we have also used conservation of mass and conservation of energy." The period between the first and second interview supported their views and they mentioned "Physics is more important than chemistry and there is no need to chemistry while learning physics."

Deniz stated that using the CI is important since students can learn meaningfully by applying the CI in their lessons. Handan stated that science is a whole. Thus, the CI is necessary for students to learn science completely. Murat is the most excited pre-service teacher about the CI and he stated in both interviews that science is a whole. Therefore, the CI is important.

Difficulty

During interviews, questions about whether they have difficulties while applying the CI were asked to pre-service teachers. They gave various answers about the difficulty during the interviews as seen in Table 3. Emine and Merve said that they had difficulties in integrating physics and chemistry in both interviews. Emine explained that she knew physics concepts in detail, but did not know about chemistry.

Although, Deniz stated that he did not have any difficulty in integrating chemistry and physics in the first interview, he said that he had difficulties to link between chemistry and physics in the second interview. The reason for the change in his idea is that he did not think about conceptual integration before the first interview. He stated that, during the class discussions, he realized how to use the CI in chemistry lessons and then he decided that it is not easy to use the CI.

In the second interview, Murat explained "If I had information about conceptual integration of chemistry and physics, I could not have any difficulties in integrating chemistry and physics concepts." Similarly, Handan said that she did not use any the CI in the past. However, if she used the CI between chemistry and physics concepts; she could not have any difficulties regarding it.

Alper did not know the meaning of integration of chemistry and physics in the first interview and he also did not think about how to use the CI until the second one. Thus, we could not ask whether he possesses difficulty or not by applying.

Contribution

In the interviews, we asked students if they use the CI in their lessons when they are a teacher, and then, it was asked why they will use or not. The responses to these questions gave us information about pre-service teachers' views on the contribution of the CI (see Table 4).

Table 3. Difficulties in applying conceptual integration

Themes	1st interview	2nd interview
Having difficulty	Emine, Merve,	Emine, Merve, Deniz
Not having difficulty	Deniz, Handan	Murat
No information	Murat, Alper	Alper, Handan

Table 4. View of pre-service teachers about the contribution of the CI

Participants	1st interview	2nd interview
Emine	Meaningful learning Better understanding Extra information	Better understanding No contribution
Merve	Meaningful learning No contribution	Better understanding No contribution
Deniz	Meaningful learning Better understanding	Meaningful learning Better understanding, Understanding daily life
Alper	Different looking aspect Extra information	Different looking aspect Acceptation as science
Murat	Meaningful learning Better understanding	Meaningful learning Better understanding Acceptation as science
Handan	Meaningful learning Concreteness Better understanding Acceptation as science	Meaningful learning Concreteness Better understanding Acceptation as science

Pre-service chemistry teachers believed that the CI has some contribution to students' learning. All of them said that the CI should be used because it helps students to make learning easy and long lasting. Moreover, Murat said that

> It helps students to accept science as a whole. Besides, Deniz stated that the CI helps to understand daily life in the second interview. He pointed out that the CI makes learning meaningful and meaningful learning leads to understanding daily life. Thus, the CI facilitates understanding daily life.

Views of pre-service physics teachers were different from views of pre-service chemistry teachers. In the first interview, Emine thought that the CI results in better understanding and then meaningful learning. Also, she stated that the CI helps giving extra information. However, in the second interview, she declared "The CI has no contribution." She also stated "there is no need to using chemistry concepts in physics." This should be the reason that she did not know what the CI is in the first interview and she learned after that. Hence, her response in the second interview was more meaningful. Likewise, Merve said, "I would not use the CI in the future due to having no contribution."

Different from these two pre-service physics teachers, Alper directly said that he could not understand what the CI is in the first interview. After we had given examples on the CI, he said that it should be used in order to provide extra information or to gain students different looking aspects.

Frequency

In each two interview, the question, "How often will you make the CI between physics and chemistry concepts when you teach chemistry in your lesson in the future?" was asked to all pre-service teachers. During the interviews, as seen Table 5, only one pre-service teacher, Handan, thought that she would use the CI as "always" in the future. She explained her ideas as:

> I will always make the conceptual integration in the future since it takes my attention. Students like it too. I think that making connections between physics and chemistry is good. For example, I liked the lesson when my teacher made connections between them. You can easily understand the topic in this way. I think there are many abstract concepts in the chemistry, but abstract concepts must be converted to concrete concepts in the chemistry by making connections.

Table 5. Views of pre-service teachers about how frequent they will use the CI

Frequency	1st interview	2nd interview
Always	---	Handan
Often	Deniz	---
As much as possible	---	Murat
Not so much	Merve	---
When necessary	Handan	Alper, Deniz
For common topics	Murat	---
No usage	Emine, Alper	Emine, Merve

During the first interview, although Deniz stated that he would frequently use the CI between physics and chemistry, he stated that he would use the CI when it is necessary for the second interview. He also emphasized that he would not use it if his physics content knowledge were not enough. The other pre-service chemistry teacher, Murat were coded as "as much as possible" in terms of the usability of integration in the future. Moreover, he stated that he would employ the CI for familiar topics.

Merve said that she would not use it so much. She also thought that conceptual integration was not necessary for the physics lessons. The other pre-service physics teacher, Alper, said that conceptual integration will be used when it is necessary. During the first interview, Alper thought that there was no need to use the conceptual integration. He explained that if it had been placed in the curriculum, he would have been used it in his physics lesson. He also stated that he did not talk about chemistry concepts in physics lessons even students did not ask anything about it. Likewise, Emine expressed that she would not use it in her physics lesson in the future.

Teaching Methods/Techniques/ Activities

In each interview, we asked for the pre-service teachers that teaching methods or techniques they will use while applying the CI. Besides, a topic, surface tension (adhesion and cohesion forces) for pre-service physics teachers to see whether they use intermolecular forces while explaining interactions between molecules and Rutherford experiment for pre-service chemistry teachers to understand whether they employ Coulomb law while explaining how the alpha particles pass through the plate, was given in order to reveal their actual views. Moreover, it was wanted them to tell how they would teach this topic to their students and what teaching methods or strategies they use. After the in-depth analysis of the interviews, Table 6 was generated that lists down which methods the participants would use.

Since all pre-service teachers do not exactly know the meaning of the integration and how to use it in the class, they asserted that they would use direct teaching to make the CI in the class. For instance, Emine stated that she would not use any teaching method to integrate physics and chemistry concepts in the first interview. However, during the second interview, she said that she would use direct teaching in order to achieve the CI between physics and chemistry.

Only Murat said that he would use discovery learning while making the CI between chemistry and physics in the first interview. He reported:

> You cannot naturally say it in the beginning and you manage to do an activity related to the integration. Students do something on it. Then, they find out some conclusions about the related topics. At the end of the activity, you must obviously explain the conceptual integration between these topics.

In the first interview, Murat, Deniz, and Handan thought that questioning would be used in order to achieve integration in their chemistry lessons. These three interviewees mentioned namely about this method, but they did not talk about how

to use it in their lessons in detail. In the second interview, Murat stated that if he makes the connection between chemistry and physics, role playing can be used in his lesson.

Merve, Deniz, and Handan said that analogy would be used to integrate related concepts in their lessons. For instance, Handan reported:

> If students knew the meaning of acceleration, I would use an analogy while teaching reaction rates in my chemistry lesson. For example, when a reaction slows down, it blows up and then it is slowly going. Likewise, I would use acceleration concept in an analogy. That is, when the acceleration of car decreases, the rate of a car decrease and it slowly goes.

Even though Handan said that she would use an analogy in applying the CI, the example she gave about the utilization of an analogy in the CI was not an appropriate example.

Assessment and evaluation

When asked "Do you expect your students to know physics concepts for the chemistry exam or vice versa, and if yes, how will you assess?" the participants gave similar answers. Two pre-service physics teachers (Emine and Merve) and two pre-service chemistry teachers (Murat and Deniz) stated that they would not ask anything about the integration of physics and chemistry, the other pre-service teachers said that they would ask questions that include integration between chemistry and physics.

Emine thought that if those kinds of questions asked in physics examination, students would get confused, and they could not even give correct answers. She stated that:

> If I hold an examination just on physics, I will not expect students to know too much information on chemistry. I mean, I will tell things about chemistry while I am giving a lecture but when it comes to asking a question in the exam, I will not ask the chemical parts.

She said these ideas in each interview. In the second interview, when the same pre-service teacher was questioned about how she could ask the question about surface tension, she said that she would ask why the surface of the liquid displays a convex meniscus. She also stated that even the question might be directly superficial; she insisted on not asking anything including chemistry in her examination.

Merve, in the first interview, stated that there was no need to assess the integration between physics and chemistry. When she was talking about surface tension phenomenon in the second interview, she stated that she would ask direct relation between adhesion and cohesion forces. She did not want students to explain intermolecular bonding. She stated "It is enough to give the explanation of the phenomena regarding physics. Students who have extra knowledge would provide

Table 6. Views of pre-service teachers about which methods they will use

Participants	1st interview	2nd interview
Emine	I do not know-no usage	Direct teaching
Merve	No need to teaching methodology	Analogy
Deniz	Analogy Questioning	Direct teaching
Alper	Direct teaching	Direct teaching
Murat	Discovery learning Questioning	Role playing
Handan	Questioning Analogy Direct teaching	Direct teaching

additional information about chemistry in the exam. I would not ask a question about chemistry in my examinations."

Although Murat stated that he deleted emphasize on the integration in both interviews, he would not prefer to ask questions which include integration. He explained that: "In fact I prefer not to use integration in the exams, it seems much better as general knowledge. I think the integration is the thing which attributes to faster the analysis of the daily life examples." He also emphasized that the CI did not play a significant role in his evaluation. When the question 'Do you expect students to explain the Rutherford experiment by using Coulomb forces in exams?' was asked to Murat in his second interview, he told that he anticipated students to explain the phenomenon if he asked essay type questions.

Finally, Deniz expressed that he would not evaluate students' skills of making integration between physics and chemistry in his exams. He pointed out that he did not have enough physics knowledge. Thus, he did not prefer to use the CI.

One of the pre-service teachers who would ask questions that include integration between chemistry and physics, Handan, explained that:

> If I teach physics concepts in the chemistry lesson, I expect them to know. Moreover, if the physics teacher taught that physics concept, I also expect. I want to see it in practice; that is to say, I ask comprehensive questions rather than calculation.

Although this pre-service teacher made similar explanations in her second interview, it was understood that she would ask more simple questions. She said that she would use multiple choice items and concept maps to diversify questions.

The other pre-service teacher, Alper, said that he would use fill in the blanks and multiple choice questions about the CI in the first interview. However, he did not know how to integrate the concepts of physics and chemistry. Thus, it does not mean that he would use these types of questions to assess the CI. In his second interview, the pre-service teacher made explanations by being much more aware of these integrations and he again explained that integration of physics and chemistry would take part in his exams like that: "If I teach both physics and chemistry concepts in surface tension, I will ask not only the part physics explains but also the chemistry explains". When he was asked 'How do you ask it?' he answered that:

> If I ask a question about surface tension, I ask the concepts as open-ended items in which they explain both of the concepts regarding surface tension briefly. I can write a question that wants them not only the definitions of the physical dimension but also the definitions of chemical dimension.

When his answers were explicated more deeply by the researchers, the pre-service teacher gave more accurate example of the question about integration of physics and chemistry:

> I will make an experiment in the class in which water constitutes bubbles, I mean I will ask the observations on that experiment and want them to give explanations and these explanations would include chemical explanations, too. I think, with that question, I will take the feedbacks of everything I teach and show in the class. I ask it like that.

Curriculum

When it was asked to pre-service teachers whether they examine the curriculum or not; most of them said that there were not the CI in the curriculum, even though physics and chemistry concepts were integrated with each other at high schools chemistry and physics curricula (e.g. adhesion and cohesion forces, intermolecular forces, Coulomb law) in Turkey or they did not pay attention to this subject

Emine stated that she examined ninth and tenth-grade physics curricula but not 11th and 12th physics curricula deeply. When researchers asked that whether she saw the chemistry concepts in the physics curriculum, she said "I don't think so." On the other hand, Murat stated that he did not examine whole curriculum but the part of it that he taught. Deniz stated that he did not investigate the curriculum but chemistry books. However, Handan said that she did not examine the curriculum in the first interview, but she said she examined it in the second interview.

While talking about curriculum and the CI, it is also asked students that what they thought about sufficiency curriculum about the CI. They almost stated that the curriculum was not sufficient in terms of the integration of chemistry and physics concepts. Only one of them, Merve said that the curriculum was enough in terms of integration in both interviews:

> I want to mention about the first topic of the textbook. For example, I think we didn't learn anything about the gas and plasma when we were in high school. There weren't topics like modern physics and atom physics, but now these topics are in the curriculum. There are more topics that are good and enough. There are atom models in physics, but we didn't learn these in our lessons.

Ozge thought that the CI was not necessary for the curriculum and explained that: "This subject is not required. We did not make integration earlier; the CI is not important I think." She admitted that she knew her subject area well and there was no need to teach chemistry concepts in physics lessons. Emine also said that it was not necessary to make these processes in the first interview, but in the second interview, she changed her mind and stated that the CI should be in the content of the curriculum.

Moreover, Alper and Murat declared that the integration of physics and chemistry concepts must be in the curriculum. They thought that there was a lack of such integration in the past and students would learn in a better way due to the CI. During the interviews, Handan stated that the CI between physics and chemistry must be in the curriculum. This pre-service teacher pointed out "I think it is necessary. Two of them must be integrated with each other scientifically so that students can understand everything. There are the parts in which two disciplines learn from each other." However, Deniz stated that the CI is necessary for the curriculum in the first interview; he changed his mind in the second one and pointed out that the CI was not needed but should be in the curriculum.

When 'if the integrations of the physics and chemistry concepts were not in the curriculum, would you prefer to teach these in your lessons?' was asked to pre-service teachers, pre-service chemistry teachers said that they would use, but pre-service physics teachers said they would not use this integration.

CONCLUSION AND DISCUSSION

This study examines how pre-service physics and chemistry teachers think about conceptual integration. Based on our findings, in general, chemistry and physics pre-service teachers' understandings of the CI and the way they practice varied. First, according to the answers given by the pre-service teachers, it was observed that while pre-service chemistry teachers think that chemistry and physics concepts are related to each other, pre-service physics teachers reported that these two subjects generally are not linked to each other. This finding well suited to other studies in the literature (e.g. Goedhart and Kaper, 2002; Taber, 1998). Second, even though the pre-service chemistry teachers had difficulty in providing an example of the chemistry concepts

within physics, they could give concrete examples while explaining physics within chemistry. However, the pre-service physics teachers had difficulty in giving an example of the chemistry concepts integrated into physics in both interviews. The reason for this finding might be that the CI was explicitly discussed in the course pre-service chemistry teachers took.

Third, it was concluded that the pre-service teachers except two participants had no the CI experience in teaching and did not integrate chemistry and physics in the past. Also, they all stated that none of their teachers at high schools and university used the CI in their lessons. This finding is aligned with findings of research that Matthews (1993) and Taber (2008) carried out. Although it requires further research to understand the underlying reason behind lacking of the CI experience, it is clear that these pre-service teachers who had not integrated physics and chemistry before were never subjected to the CI until they graduate from college. Even most of them did not know what the CI means and were used for. This finding itself highlights the importance of the CI knowledge in teaching and teacher education by highlighting the possible consequences of, not using it.

In contrast to previous research (Taber, 2003a), pre-service physics teachers did not value the CI as pre-service chemistry teachers did. Generally, they thought that it was not necessary to use physics concepts in chemistry, but it should be needed to use chemistry concepts in physics because physics is a subject includes chemistry. That is to say, they thought the integration of chemistry and physics unidirectional and the opposite was not necessarily possible. It was seen that pre-service physics teachers do not have the awareness about the importance of the CI since they cannot understand physics concepts deeply without understanding chemistry concepts or vice versa. On the other hand, although all pre-service chemistry teachers stated different reasons for the importance of using physics concepts in chemistry, they all thought that the utilization of the CI is important and valuable. During the study, we discussed the CI the course that was taken by pre-service chemistry teachers in an explicit way. These discussions might help them develop their knowledge about the CI. Hence, these differences between pre-service physics teachers and chemistry teachers might result from different teaching strategies they used.

Another point discovered in the study was that pre-service chemistry teachers believed that the CI has some contributions to students' learning. All of them said that the CI should be used since it helps students to make learning easy and long lasting. This conclusion is consistent with the findings Duit and Treagust (2003) found in a previous study. However, the views of the pre-service physics teachers about students' learning were different from the views of the pre-service chemistry teachers. They stated that the CI helps giving extra information, which implies that the CI is an additional form of knowledge and it is necessary because it is a new knowledge. However, the CI is a reality of naturals sciences representing the interconnectivity of different branches of science. In addition, all participants asserted that they will use direct teaching to make the CI in the class. Based on this finding, we suggest that the way we teach the CI to pre-service teacher is also important because they perceive the CI as something can be taught through direct instruction rather than being a meaningful conceptual learning constructed based on the prior knowledge. Hence, pre-service science teachers should effectively use constructivist teaching strategies (Toomey & Garafalo, 2003) as supported by the results of previous studies.

Generally speaking, it was concluded that the pre-service teachers prefer not to use questions, which is necessary making the CI, in their exams, because that they did not know exactly how to make this integration and see themselves inadequate in order to integrate these subject areas. It was also concluded that the pre-service teachers' belief about the necessity not to ask the chemistry in physics and physics in chemistry lessons causes them to think in such a way. This result is parallel with the study of Taber (2008). Pre-service chemistry teachers believed that students learn better when they apply the CI integration in their lessons. Thus, they stated that whether the CI is included in the curriculum or not they will use it in their lessons. However, pre-service physics teachers mentioned that they would not prefer to use the CI in their lesson if it is not included in the curriculum. In conclusion, these students had some difficulties in making the CI between physics and chemistry concepts. This result is consistent with the findings of the study Taber (2008).

IMPLICATION OF THE STUDY

Chemistry and physics are two closely linked domains and may require conceptual integration for meaningful learning. The findings of this study are limited to the pre-service chemistry and physics teachers involved. Further studies on the CI between physics and chemistry should be conducted with other pre-service physics and chemistry teachers to get more information about details of CI in different groups. Furthermore, the CI should be studies with pre-service or in-service teachers in other science disciplines such as biology. Teacher education programs should deeply consider promoting meaningful learning that learners can employ pre-requisite knowledge or concepts in a certain science subject while they are learning a new concept or topic in another science subject. Moreover, pre-service teachers should be given opportunities to combine the CI into their teaching and assess their students' understanding of the CI on specific science context in the practice. In addition, science textbooks and curriculum should contain more the CI related topics for the pre-service and in-service teachers to achieve meaningful learning and provide the CI experience. Another implication is that as our results revealed using appropriate instructional strategies and assessment techniques is crucial for the CI. However, there are very few studies on this subject in literature. Thus, further qualitative and quantitative studies including teaching methods and assessment strategies on the CI should be conducted in other science contexts.

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APPENDIX-A

Pre-Service Teachers' Views of About Conceptual Integration

Interview Questions

We are examining pre-service teachers' views about how they use physics and chemistry concepts together. Your views will only be used for this research study. Your names will be kept confidential in the study, and no one else will have access to this information. With your permission, we want to record our conversation to be more accurate about your views. The interview will long approximately 45 minutes.

Demographic Questions:

- Your age?
- What high school did you graduate from? (Anatolian High School, Vocational Training Schools, etc)
- Your GPA if you do not mind?

Questions

1. What comes into your mind when it's said physics?
2. What comes into your mind when it's said chemistry?
3. Should there be chemistry inside physics? Why? How?
4. Should there be physics inside chemistry? Why? How?
5. Could you give an example about physics (chemistry) used in chemistry (physics)?

If interviewee could not give an example:

For pre-service physics teachers

Surface Tension:

Do you remember the concept of surface tension? Could you talk a bit about of it? (If interviewee could not explain the concept it will be explained by interviewer.) Can you see any parts which are related to chemistry? How is it related? Surface tension is a phenomenon in which the surface of a liquid, where the liquid is in contact with gas, acts like a thin elastic sheet. This term is typically used only when the liquid surface is in contact with gas (such as the air). If the surface is between two liquids (such as water and oil), it is called "interface tension." Various intermolecular forces, such as Van der Waals forces, draw the liquid particles together. Along the surface, the particles are pulled toward the rest of the liquid

For pre-service chemistry teachers:

Rutherford's experiment:

Do you remember Rutherford experiment? Could you talk a bit about of it? (If interviewee could not explain the concept it will be explained by interviewer.) Can you see any parts which are related to physics? How is it related? In the experiment Rutherford done in order to determine the structure of the atom, he has bombarded gold foil with alpha particles. He observed that alpha particles which were not close the nucleus were not scattered so much whereas particles which were close the nucleus scattered more. How do you explain the reason of scattering to the students? How does Coulomb force help you?)

6. Based on the example above what do you think about the importance of chemistry concept while you are learning physics?
7. Based on the example above what do you think about the importance of chemistry concepts while you are teaching physics?
    a. How often should it be used in teaching activities?
    b. How does it affect students' learning about physics?
8. Have you ever needed to look at the curriculum in order to learn about the scope of the content?
    a. What does the curriculum say about conceptual integration?
9. How could physics topic including a chemistry concept make be learned to students?
    a. How could you teach surface tension/ Rutherford experiment?
    b. Do you teach physics/chemistry concept to your students?
10. How important do you think for your students to know chemistry concept in physics topic?
    a. Could you expect your students to know chemistry/physics concept?
        i. How could this skill be assessed?