



LET'S TALK ABOUT 'MY' CONCEPT MAP: USE OF DIALOGUE TO ENHANCE CONCEPT MAPPING

Roshan Lamichhane and Amber Simpson
Indiana University • Bloomington, Indiana

Anna: So I think you should at least change what physical change is.

Susan: Ok.

Anna: So that...or at least describe it differently.

Susan: So where should I put this? Should I just put it...like...

Anna: I just think it needs different connection.

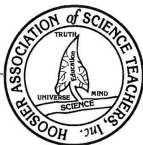
Susan: Yea.

Anna: So molecules coming together and forming new molecule is chemical change but physical change. It's like when you mix two molecules they do not form ...like...anything new. Like salt and sugar.

Susan: Yea. Like, they do not make something different.

Is this the kind of dialogue that you want students to have in the classroom as a teacher? What can you say about the knowledge structures of Anna and Susan discussing physical and chemical change and how they changed based on the exchange of ideas?

This is not a hypothetical situation, but dialogue captured between two students when Anna was constructively critiquing Susan's concept map (examples of concept maps shown in *Figure 1 and 2*). Dialogue and collaborative learning have been shown to improve students' learning of chemistry (Fechner, 2008; Hogarth, Bennett, Campbell, Lubben, & Robinson, 2005; Johnson, & Johnson,



1991; Sandi-Urena, Cooper, & Stevens 2012). Some other benefits of dialogue, apart from learning gains, include the promotion of social interaction skills, stimulation of critical thinking, and learning how to criticize ideas. Concept maps have been researched extensively and have been shown by researchers to enhance students' metacognition and aid in students' learning (Fechner, & Sumflett, 2008; Lopez et al., 2011; Novak, & Gowin, 1984). They facilitate students' mastery of content and development of cognitive skills and have proven their value not only in chemistry, but in accounting, applied statistics, biology, conceptual astronomy, geoscience, marine ecology, and nursing as well (Nilson, 2010).

Methodological Approach

Participatory Action Research (PAR) is an approach commonly used in many fields, including science education, for improving conditions and practices within one's teaching (Feldman, Paugh, & Mills, 2004; Meyer, 2000). It involves "action, evaluation, and critical reflection and – based on the evidence gathered – changes in practice are then implemented" (Koshy, 2010, pg. 2). The goal of this action research study was to examine how combining the two instructional strategies of dialogue and concept maps affect students' knowledge base of foundational chemistry concepts and investigate students' views about the process. This action research involves the action of students involving themselves in dialogue after the construction of the concept maps, and an evaluation was completed to see if it had any effect on their learning of foundational chemistry concepts or other skills.

Procedure/Methods

This study was conducted during the summer of 2016 in the Chemistry Department laboratory at an institution located in the Midwestern region of the United States. The first author taught an introductory chemistry course for rising 9th grade high school students through the Foundations of Science and Mathematics (FSM) program, which is a two-week summer camp with a total of 12 hours instructional time (2 hours a day, 3 days a week). The participants in the study were the 10 students enrolled in the course and consent to be a part of this study was provided by the students and their parents.

The students were taught about the construction of concept maps and how to use linking phrases, direction of arrows, and number of connections on the first day of the course. This particular study focuses on Day 2 (Physical and Chemical



Change) and Day 3 (Atoms and Molecules), and thus makes a claim about students' learning of concepts embedded within these two days. The topics taught during Day 2 and 3, and the concept terms given to the students to construct their concept maps are listed in *Table 1*.

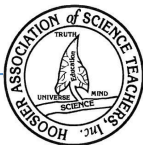
Table 1. Days and concept terms.

Day 2: Physical and Chemical Change	Day 3: Atoms, molecules, elements and the periodic table
Mixture	Atoms
Physical change	Molecules
Chemical change	Elements
Freezing	Periodic table
Melting	Physical change
Condensation	Chemical change
Properties of substance	Models of atoms
New substance	Proton
Temperature	Neutron
Color change	Electron
Separation	Atomic Mass
	Negative charge
	Positive charge

These concepts are the foundational topics in the learning of chemistry. As noted in the Indiana Academic Standards (2016), the content standards that were targeted in Day 2 (the top three) and Day 3 (the bottom two) were:

- C.1.1 Differentiate between pure substances and mixtures based on physical and chemical properties.
- C.1.3 Recognize observable macroscopic indicators of chemical changes.
- C.1.4 Describe physical and chemical changes at the particle level.
- C.2.1 Using available experimental data, explain how and why models of atomic structure have changed over time.
- C.2.2 Determine the number of protons, neutrons, and electrons in isotopes

These are the steps one may take to employ the pedagogical strategy mentioned in this paper in a typical class:



1. Towards the end of the class after the students have completed the hands-on activities and other activities, they draw a concept map based on the concept terms relevant to the lesson (refer to *Table 1* for concept terms for Day 2 and 3). Additionally, students should be allowed to add additional concept terms. In this particular context, students were allowed to add up to five more concept terms. There is not a set number of concept terms that a teacher can ask the students to add to their concept maps, but giving students flexibility may make them more comfortable with expanding upon the mandated concept terms.
2. Students get together with a peer to explain and critique each other's concept map, as well as provide suggestions.
3. It is up to the student if they want to take or leave the suggestions. If they choose to make changes, this is done with a different colored marker.
4. Students are to write a brief rationale on the back of their work as to why they added or removed concept terms from their concept maps after the dialogue with their peer.

As a way to consider the effectiveness of peer dialogue coupled with concept maps, nineteen concept maps were examined for any changes made by students which likely depended upon the dialogue they had with their peers with whom they shared their concept maps. For this, the first author utilized a coding scheme developed by Lopez et al. (2011) and went through all the concept maps where the students made the changes based on what he/she discussed with a peer and coded all of them (See *Table 2 and 3*).

A focus group interview was conducted at the end of each session on Day 2 and 3 after students critiqued each other's concept maps to understand their thought process about the pedagogy employed.

Quality of Dialogue/Changes (Day 2 and Day 3)

We coded the changes made by the students under four categories: 1) scientifically correct and precisely stated, 2) correct but scientifically 'thin' (i.e. technically correct but answers are too general and/or vague), 3) partially incorrect, and 4) incorrect or scientifically irrelevant (*Table 1 and 2*). The rationale that the students wrote on the back of their concepts maps aided was very useful during the categorization of the coding schemes. For example, on Day 3, a student connected the concept term "atom" to "models of atoms" after



her dialogue with her peer. She wrote Atoms (linking phrase: are shown through) models of atoms. This at first sight, sounds impartially incorrect or could even fall under the category of ‘incorrect.’ But upon reading her rationale, “I realized that the models show the atoms by labeling the protons, neutrons, and electrons,” her changes were coded as correct but scientifically ‘thin’. *Table 2* below shows the changes and their codes along with some examples from student artifacts from Day 2.

Table 2. 9 concept maps (CMs) examined which had 24 changes in total.

Changes	Number	Examples
Scientifically correct and precisely stated	19	i) Mixture (can be) separated. ii) Chemical change (can form a new) state of matter. Vinegar and baking soda produces gas.
Correct but scientifically ‘thin’ (i.e. technically correct but answers are too general and/or vague)	3	i) Properties of substance (only structure changes) physical change. ii) Mixture (is a form of) chemical change with Rationale: you can mix two liquids and get a new chemical.
Partially incorrect	1	i) Condensing + freezing of water (is an example of) state of matter.
Incorrect and scientifically irrelevant	1	i) Condensing (is an example of) mixture.

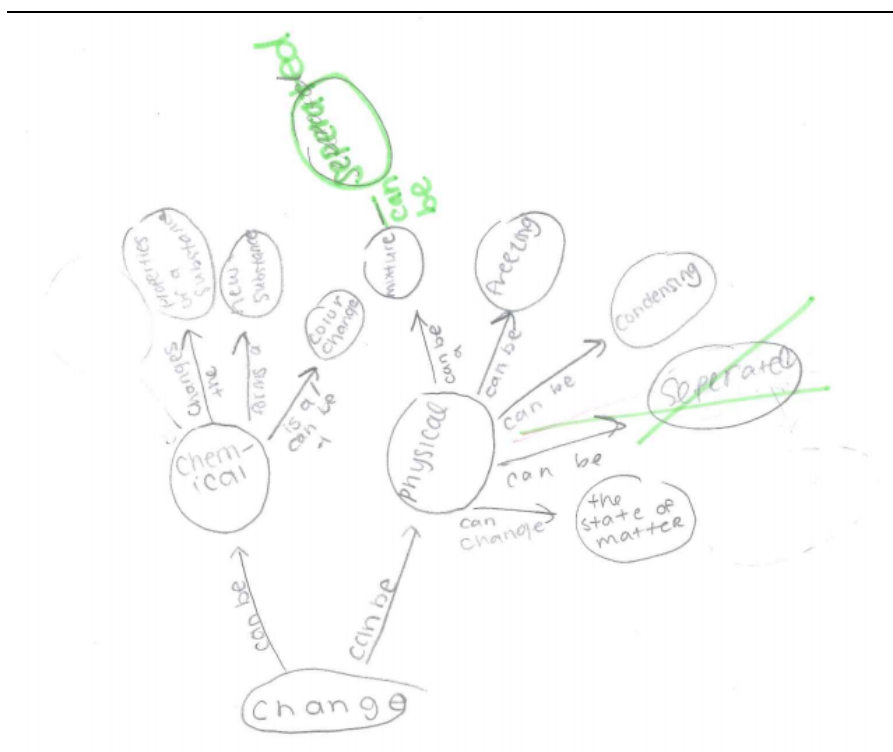
Note. The phrases/words in the examples within the parenthesis are the linking phrases.

Out of 24 the changes from the nine different concept maps examined, only one change was incorrect and scientifically irrelevant. The dialogic process coupled with the concept map seemed promising with about 2.5 changes per concept map on average. See *Figure 1* for an example of a student’s concept map with changes shown in green marker.



This change was made while the student was explaining her concept map to her peer. She realized that “it was not the physical change that can be separated but the mixture that can be separated”. The student did not use her peer’s feedback for this particular change. But the dialogue that is highlighted at the beginning of the paper shows the changes that her peer made based on this realization regarding the ‘physical change’. Therefore, the changes made in the concept map seemed dependent on the dialogic process.

Figure 1. Example of a concept map with changes shown in green marker.



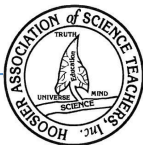


It was really surprising to see none of the students adding any incorrect or scientifically irrelevant ideas after the dialogue process out of 23 changes made based on their dialogue they had with their peers on Day 3 as seen in *Table 3*.

Table 3. 10 CMs (8 of 10 made the changes) were examined which had 23 changes in total.

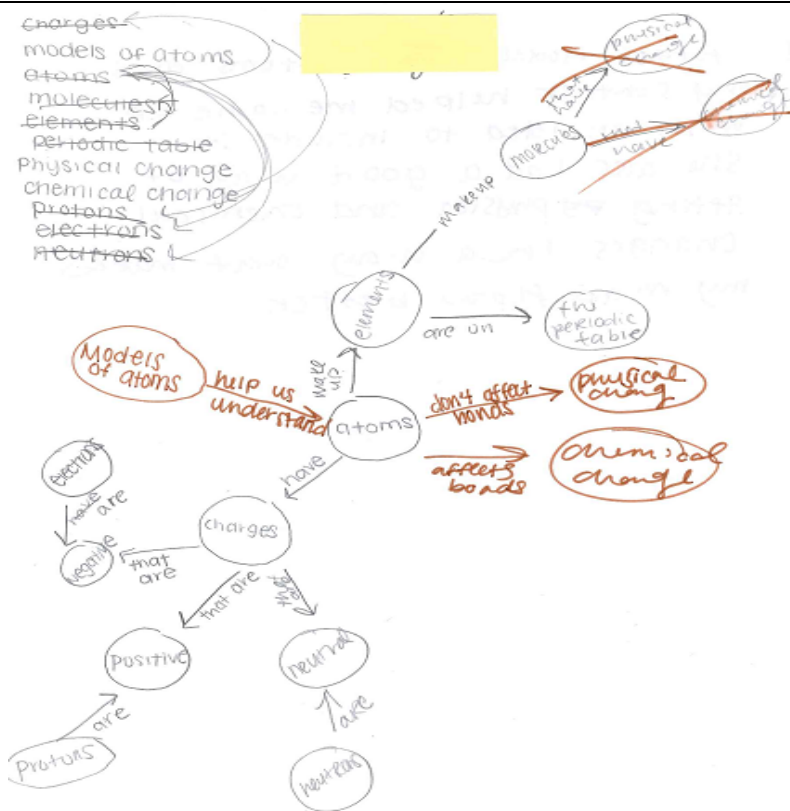
Changes	Number	Examples
Scientifically correct and precisely stated	17	i) Neutrons (have) charges. ii) Elements (consist of) atoms. iii) Molecules (can go through) chemical change.
Correct but scientifically 'thin' (i.e. technically correct but answers are too general and/or vague)	3	i) Models of atoms (help explain) atoms. ii) Atoms (do not affect bonds) physical change.
Partially incorrect	3	i) Physical change can affect molecules. ii) Atoms have charges.
Incorrect and scientifically irrelevant	0	

When students are involved in dialogue, it is not necessary that all the scientifically relevant concepts are transferred during the process. For example, on Day 2, a student had "Condensing (is an example of) mixture" after engaging in a dialogue with a peer that is a scientifically irrelevant idea. The number of connections on the concept map with scientifically thin and impartially incorrect in Day 3 were minimal compared to the number of correct and precisely stated changes by the students that was the case in Day 2 as well. Of the 2 students who did not make changes to their concept maps, one of them did not write any rationale as to why she did not make any changes. While the rationale on the other concept map was "My partner did not provide any criticism but I could have added the people who designed the atom models Bohr, Thompson, etc. I could have added the shells as part of the atom too". This shows how the writing of rationale for the changes made or not, does allow



a space for students to think and make or add changes during the process. One example of a concept map from the student whose one change fell under the code “scientifically thin” is shown in Figure 2. The statement “atoms” (linking phrase) “do not affect bonds” (linking phrase) “physical change” is too general or vague and is not clear. The physical change is where atomic bonds are not broken or created; only the physical properties of the molecules changes. The use of atoms without the use of molecules make this statement fall under the ‘scientifically thin’ category.

Figure 2. Example of a concept map from Day 3 with changes shown in brown marker.





Student's Views About the Process

To examine the students' views of the learning process, the focus interview was videotaped. We, as educators, do see the value of many evidence-based pedagogies, but it is not necessary that students see it as well. We wanted to explore students' feelings after going through the whole dialogic process coupled with concept maps. Quotes from students regarding ideas as to what, how, and why something was helpful during the whole process of critiquing and receiving feedback from their peers during peer dialoguing around the concept map can be found below.

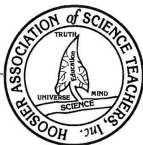
Quotes from focus group Day 2

- "I think it was helpful to explain the concept to other people to kind of show the connections. That made me think".
- "She helped me with some of the connections that were not evident to me".
- "Mixtures was one of the concept terms, and also separation. And he said that I should connect the two".
- "Some of the concepts were made clear to me".

Quotes from focus group Day 3

- "She helped me with the pointing of arrow in the right direction".
- "I think looking at some other people's connection helps you see other people's way of thinking and that helps you see things in a different way".
- "Looking at other people's concept map helps you see what you might have missed".

The students' quotes from the focus group interview show some positive impacts. There were not any negative aspects that the students talked about during the focus group in either Day 2 or Day 3. The students could have been more biased towards the positive aspects as the first author conducted the interview and was their teacher. However, we believe the positive impacts from both Day 2 and Day 3 speaks favorably about the dialogic process during concept mapping and how it can help students learn and grasp foundational chemistry concepts.



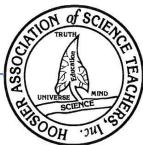
Discussion of Findings

The current study demonstrated the importance of using peer dialogue during the concept map construction process. The findings in this study indicate most of the changes (only 5 out of 47, with 4 being impartially incorrect and 1 being incorrect) that students made after the dialogue were scientifically correct changes which speaks to the importance of dialogue. The incorrect changes can be used to unearth students' naïve conceptions or misconceptions about topics, as discussed earlier. Additionally, the quotes from the students taking part in focus group interview speak highly of how students view sharing their concept maps with a peer and how talking about it has a positive impact on their learning. Our results have several implications for instruction, especially in a large classroom where the teachers cannot attend to all the students in the classroom individually. Encouraging dialogic process coupled with concept map construction is potentially a good way to aid students' learning of foundational chemistry concepts, be it in a small classroom setting, such as this study, or a larger one.

Employing a new pedagogical process does come with challenges. Issues were noted when listening to the audiotapes of the students' dialogue from Day 2 and 3. Ways to address the challenges have been noted in *Table 4*. Implementing this approach in the classroom requires teachers' thoughtful setup and discussion of classroom norms before beginning their own concept map activity.

Table 4. Summary of challenges and how to address them

Challenges	How to address this challenge
Students reviewing their peers seem to be satisfied with their peer's explanation of the concept maps most of the time	Students could first start talking about good things and connections they see in their peer's concept map that was not in their own concept map.
There often little or no critique provided on how the concept maps could be improved upon.	Students who are not as comfortable critiquing their peers should be encouraged to identify for their peers what important elements might be unclear or absent from their concept map



The teacher cannot eavesdrop on all dialogue between students and there is a big possibility that some alternative conceptions could potentially be transferred from one student to another during the process.

This is probably the greatest challenge. To tackle it, a teacher can thoroughly look at all the concept maps to make sure that there are not any alternative conceptions being shown in the concept mapping or the rationale portion. If found, the teacher should address them accordingly.

There are chances that a person who talks a lot can take over the dialogue and influence other students to consider concepts that may be incorrect as being 'correct' or concepts that are correct as being 'incorrect'.

When students receive critiques on their concept map they could be required to explain and justify their reason for change. The rationale for change will help both students and teacher to highlight or clarify any naïve conceptions.

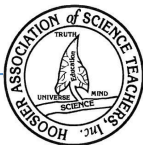
Some students did not feel their peers did enough critique of their concept.

Students are sometimes reticent in providing or reading feedback in the fear of being disrespectful or being disrespected. Students need to see and experience how critique can be constructively provided and always done in a respectful manner.

Finally the overall process and coding scheme serves as a formative assessment tool for both the teacher and students. Depending on where in the lesson or unit sequence this concept mapping activity is placed students and teacher can assess or reflect on how their ideas have changed over time. Students at the end of the unit could be handed back their concept map to assess the scientific accuracy and preciseness of how they presented their ideas.

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