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Engaging Students with a Thinking Routine in Chemistry

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Instructional Strategies

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Keeping students engaged and interested in chemistry was challenging before the Coronavirus, and became even more difficult through distance learning. I know that now I am not only competing with the normal distractions in a classroom, but also with others that I cannot see. However, I have found a teaching technique that is effective for keeping my students actively processing information during this challenging time, known as a *Thinking Routine*.

Ron Ritchhart and Mark Church introduced their idea of Thinking Routines in their 2011 book, *Making Thinking Visible*[1], and more recently published *The Power of Making Thinking Visible*[2]. Thinking Routines are a way to better see how students are processing information and getting them to think more deeply. After learning about how effective Thinking Routines are, I have consistently used them. I highly recommend reading these books as well as *Project Zero's Thinking Routine Toolbox*[3] online.

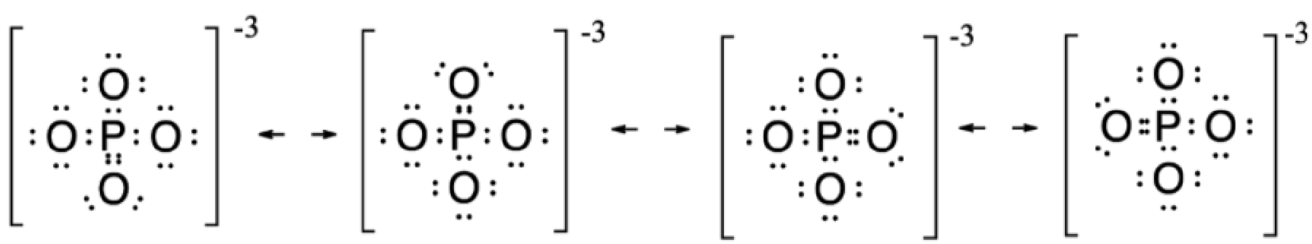
All of these resources provide a variety of approaches that you can adapt to the concept you are covering. *Project Zero's Thinking Routine Toolbox* shows a wide variety of Thinking Routines, from the covering. Project Zero's *Thinking Routine Toolbox* shows a wide variety of Thinking Routines, from the commonly-used See-Think-Wonder model for demos, to the I Used to Think… Now I Think model to reflect at the end of the unit, to the Connect-Extend-Challenge model when building previous content onto new content. I recommend watching the *Using Color-Symbol-Image Routine in High School Chemistry*[4] YouTube video to see another application of the Thinking Routine approach, as used at the end of a stoichiometry unit.

Before distance learning, I often used Thinking Routines for a variety of purposes, ranging from introducing a new topic to reviewing material. Each time I used a Thinking Routine, I observed that students showed deeper engagement with the material, more agency, and greater understanding. With Thinking Routines, students showed me through images and words their understanding of abstract concepts.

From my experience, Thinking Routines often take longer to complete in class, but the rewards are much greater, as the students tend to retain the content longer and in greater detail. After completing a Hess' Law Thinking Routine for an entire class, for example, my students' results on an energetics test were better than in years past. Spending more time looking closely at a diagram, data, or other content pushes the students to observe more carefully and analyze more deeply.

Parts, Purposes and Complexities Thinking Routine

Recently, when my General Chemistry students were reviewing for a bonding test, I gave them a Parts, Purposes and Complexities Thinking Routine with an image of the resonance structures of a phosphate ion. The image I chose was one that they were not familiar with; it was also challenging, and contained content that they would be tested on such as electron domain geometry, molecular geometry, total number of valence electrons, and the concepts of ions versus molecules. I wanted an image with whose general features they were familiar, yet not one they had seen specifically.



Parts What are its various pieces or components?	
Purposes What are the purposes of each of these parts?	

Complexities How is it complicated in its parts and purposes, either in the relationship between the two, or in other ways?	

Figure 1. *Students are given a Thinking Routine to help guide them through the analysis of a resonance structure of a phosphate ion.*

I scaffolded the activity by electronically sending the students the document seen in Figure 1 (through a Google Doc that they copied), and saved in my shared drive. At the beginning of class, while I had individual conversations with students, the other students filled in the responses to each question in the blanks provided in the document. As it took at least 10 minutes to check in with each student, I wanted to give the students ample time to look at the image carefully and write meaningful comments. Although they were familiar with Lewis dot structures, polyatomic ions, and resonance structures, I had never showed them a specific image of the resonance structures of phosphate Lewis dot structures before.

Once everyone completed his/her own individual Google Doc, I then shared my screen with the class' shared Google Doc. Then I asked to them to silently add their own comments to the shared class document. The students were encouraged to write at least one thing from their own sheets as well as to write comments about other student's comments. I reinforced that we were in a positive, safe place, and encouraged them to take a risk by sharing ideas and questions, while being positive toward each other.

Parts What are its various pieces or components?	• *3 single and one double bond* • *Resonance structures* • *There are brackets separating the compounds from different stages. The double bond is rotating around each phosphorus in the Lewis dot diagram.* • *There is a charge (3-)* • *The different parts don't seem to be bonded in a normal way.* • *Elements (oxygen and phosphorus)* • *No lone pairs on central atom* • *32 valence electrons*
Purposes What are the purposes of each	• *The different examples of the ion show resonance*

What are the purposes of each of these parts?	• *3- charge* • *there are three more electrons* • *Identify the lone electron pairs/electronegativity* • *Is there a reason for why each molecule is oriented differently or does it matter?*
Complexities How is it complicated in its parts and purposes, either in the relationship between the two, or in other ways?	• *Without the three extra electrons, the oxygen's outer shell of electrons would not be full.* • *There are bonds and intermolecular forces → how they work together.*

Figure 2. *Student responses for a Thinking Routine for the evaluation of a resonance structure of a phosphate ion.*

Once every student contributed, I asked what each comment meant. I feel it is important to validate each student's idea and show they are making important contributions. Sometimes I keep a list of names and check off who is participating. On a GoogleDoc, it is also possible to look at the revision history to determine who is participating. I often used the follow-up question, "What makes you say that?," to make sure the students did the thinking and explaining in class. These discussions then reveal any misconceptions that they may have about the content.

As we discussed the responses, I saw that a student had written, "Is there a reason for why each molecule is oriented differently or does it matter?" in the "Purposes" section. This led me to ask if there was anything incorrect about the student's question. It took few a minutes before a student stated that this was an ion, not a molecule. We then discussed the important distinction between polyatomic ions and molecules. I said things like, "How are they similar?," "How are they different?," and "What makes you say that?"

Since this activity was available as a live shared document, students were making improvements to the document as we went along. For example, someone had miscounted the number of total valence and, when asked about it, made the correction.

I liked that this strategy allowed me to see a student's thinking. For instance, when a student commented, "The different parts don't seem to be bonded in a normal way," I asked what normal bonding was. I asked why this diagram was different than a Lewis dot diagram. I didn't know which student had written each statement, so when we went over the chart, I asked students for clarification on what was written.

I also liked that a student had discussed bonds and intermolecular forces in the "Complexities" section. This led to a discussion of how intermolecular forces exist between molecules, and was a reminder that we were analyzing a polyatomic ion. I pointed out that I liked that they knew there was bonding within the polyatomic ion. Following this, we discussed what types of bonding are in a polyatomic ion compound.

During our discussion, I was disappointed that no one addressed the molecular or electron domain geometries. However, I directed students' attention to this idea when we discussed the complexities section, and I asked them to address the shape of the molecule.

Color-Symbol-Image Thinking Routines

For the last class of the year, we completed the Color-Symbol-Image Thinking Routine to reflect on our learning. I shared it as a Google Slide (see Figure 3) and asked the students to make a copy and share the document with me. I offered the students the option of using Google Draw format as well. However, when given this option, students did not draw images, but instead searched for images and symbols on the internet.

Instructions:

- Choose a color that you feel best represents or captures our semester of Chemistry.
- Choose a symbol that you feel best represents or captures our semester of Chemistry.
- Choose an image that you feel best represents or captures our semester of Chemistry.

	Sample	Description
Color		
Symbol		
Image		

Figure 3. *Students use a Color-Symbol-Image Thinking Routine to reflect on their year-long learning in chemistry class.*

Students had at least 10 minutes to complete their documents while I checked in with each student. Following this, I encouraged students to share what they had written with the class; however, students were not as comfortable sharing their work, so I projected my work as an example. In the end, about five students presented their work and I looked at the other shared examples after class.

	Sample	Description
Color	Green	I associate green with chemistry because my folder

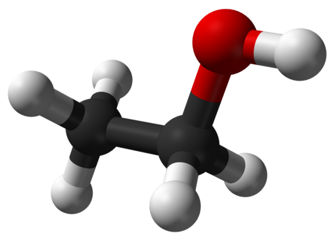
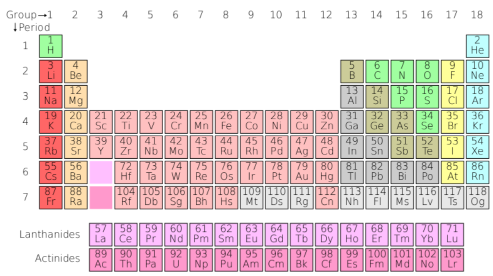
Color	Green	I associate green with chemistry because my folder and notebook for chemistry are green.
Symbol	Molecule: 	We have done a lot of work related to molecules (polar, nonpolar, types of molecules, etc.) and so I feel this sums up a lot of what we learned.
Image	Periodic Table: 	We have used the periodic table throughout the year for determining what makes up molecules and other things too.

Figure 4. *An example of student work for the Color-Symbol-Image Thinking Routine.*

I liked that some students shared specific topics that were covered, as shown in Figure 4. Other students shared more general ideas, such as an infinity symbol to represent the continuous learning available in chemistry. Following class, I looked at all of the shared documents and it helped me get a sense of which labs and topics the students enjoyed. I loved the range of images — from a large period representing an electron, to a complex molecule. I also gathered new ideas to help me when I teach the coming year, such as when the student showed the image of the complex molecule to show that she fully understood Lewis dot structures and shapes after seeing a complex molecule. This has encouraged me to stretch my students with larger complex molecules next year.

Considerations and improvements

When I gave students the Parts, Purposes, and Complexities assignment with the phosphate resonance structure, I instructed them to complete the entire chart before any discussion occurred. When I do this again, I will go over the Parts and Purposes as a group, then allow the students some time to reflect before adding ideas to the "Complexities" section. Also, I will encourage them think about how it may relate to other concepts within bonding, or real-world experiences. If students complete these two sections similarly, I will ask them to relate the complexities to the shapes of the molecules.

While I have only used this Thinking Routine for a synchronous distance learning class, I think students could also complete a shared Google Doc during an asynchronous lesson as well. The document could be shared with all of the students, then each student would be required to complete the document outside of class. A teacher could either comment after the submission deadline or during the next synchronous class.

Before distance learning, I used this approach frequently with my IB HL Chemistry classes as well. With my second-year IB HL Chemistry class, I showed them images of the oxidation of primary, secondary, and tertiary alcohols. Instead of me pointing out the different products and functional groups, they figured it out on their own. Again, with enough time to think and process, they were the ones making the powerful connections.

One of the benefits of doing this in a classroom is that students can draw images like electrons or mathematical symbols. Even with Google Draw, students are not as comfortable drawing, and prefer to find images. I have found that having students do Thinking Routines in a classroom with a white board is more powerful, as students can easily illustrate their thinking while using different colors.

Thinking Routines take a lot longer to do than having students take notes. Instead of covering a topic in 10 minutes, I may use an entire period to have the students digest a topic. However, I feel that students are much more involved and their understanding is much deeper. This example highlights some of the responses that students have. Other times that my students have completed Thinking Routines, their thoughts have been much deeper and more abstract, especially when introducing a new topic. I really enjoy seeing their thought processes.

Feedback from students

When I ask my students whether or not they like Thinking Routines, there are mixed responses. Some students do not enjoy them, because they aren't as comfortable with thinking for themselves and taking risks in front of the group. I do find that sometimes quiet students are more likely to write their ideas on the board than speak up in class. In addition, class discussions are more student-driven, and I can see what the students are thinking.

There are a wide variety of Thinking Routine examples that can be found in both books by Ritchhart and Church and Harvard's Project Zero website on Thinking Routines. I recommend looking at all of these resources and adapting them to your needs and expectations. Ritchhart's expectations are that you will adapt the Thinking Routine to your needs, so you may modify some of the wording if necessary. For example, there is a great "See Think Wonder" routine that I often use when I do demonstrations for my classes.

Related ideas

I've found that using Thinking Routines during distance learning is an excellent way to motivate my students, have them show their thinking, and help me to clarify any misconceptions that they may have. I think this tool and other Thinking Routines could be used for a variety of different levels of chemistry classes. I encourage you to try using this strategy in your own class, as it will stretch your students and classes. I encourage you to try using this strategy in your own class, as it will stretch your students and push them to do the thinking. It is a wonderful way to get them active during distance learning, and you will be impressed with some of the creativity that they show you.

References

1. Ritchhart, R. and Church, M. *Making Thinking Visible: How to Promote Engagement, Understanding and Independence for All Learners*. San Francisco, Jossey-Bass, 2011.
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4. Using Color-Symbol-Image Routine in High School Chemistry. The Power of Making Thinking Visible, www.youtube.com/watch?v=eSSY6AQ4b44 (accessed June 4, 2020).

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About the Author

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