Anamorphic Ethnography Study: A Contrastive Analysis of Two General Chemistry Teaching Methods Develops into a Professional Development Opportunity

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Abstract:
What seemed like an ethnographic research project contrasting two general chemistry teaching methodologies developed into a period of professional development as the author’s understanding of ethnography developed and the process-oriented, contrastive, and recursive nature of the research method brought out unanticipated professional development opportunities.

Introduction:
In oblique anamorphosis art, the apparent image you are looking for is obvious, you see what you expect to see if you have an underlying understanding of what you are approaching to view. But, over time, hidden aspects of the artwork become apparent as you develop a different perspective to inspect the artwork. Take the painting below called The Ambassadors (see Painting 1), displayed in the National Gallery in London, England (NG, 2016). At first glance, are two educated and young powerful men. On the left is Jean de Dinteville, aged 29, French ambassador to England in 1533. To his right, stands his friend, Georges de Selve, aged 25, bishop of Lavaur, who acted on several occasions as ambassador to the Emperor, the Venetian Republic and the Holy See (NG, 2016).

Painting 1: The Ambassadors, 1533, Hans Holbein the Younger
In the bottom of this artwork is a light brown oblong shaped object, seemingly a wooden log to the untrained eye, but when looking at the picture from a different perspective (close left eye and tilt head left), the distorted image of a human skull (see Image 1) becomes apparent (Kent, 2016).

My research project first started out as a contrastive analysis of two general chemistry teaching styles; a process I first thought entailed of watching videos and then making stark generalizations between the two methods. But, when reading and developing my understanding of ethnographic research, and how it differed from my initial perspective, I was able to extract other important aspects from the main research data that helped me professionally reflect and develop as an educator.

During AY16-1, the Chemistry and Life Science Department at the United States Military Academy implemented a new general chemistry teaching methodology called guided inquiry. Compared to the prior “traditional” teaching style (see Photo 1, Left) where students focus their attention on an instructor and the students learn chemistry based off of multiple discussions and exchanges of ideas between themselves and the instructor, guided inquiry (see Photo 2, Right) utilizes experimental data followed by successive guided inquiry questions to facilitate the discussions of chemistry concepts between small groups of students. The initial purpose of this study was to conduct a contrastive analysis of the two teaching approaches, but as I created and analyzed data from the collected records, the process served as a vehicle for my own professional reflection and development as an educator.

Photos 1 and 2: (Left) Photo of “traditional” USMA general chemistry classroom (Circa 1909). (Right) Photo of guided inquiry USMA general chemistry classroom (AY2016).

Literature Review and Conceptual Framework:

When considering an analytical tool to contrast the two teaching styles, the use of statistical methods seemed too antiquated. The reason for this is because graded events between the two teaching methods are structured differently based on how and what students are learning. The traditional method of learning general chemistry greatly
involved solving mathematical equations related to chemistry concepts whereas the guided inquiry method uses scientific data as the basis for deducing scientific concepts and making connections (see Appendix A for Instructor Interview Transcript, lines 8 to 30 and 106 to 116). A statistical analysis is possible to find standard means and standard deviations of each graded event to compare the two teaching styles, but because the focus of how general chemistry is taught changed, using quantitative means to compare them does not adequately reflect what students know. For example, students under the “traditional” method would memorize trends of the periodic table, but not fully understand why those trends existed. Due to the deduction of scientific concepts from scientific data, students under the guided inquiry method learn the concepts behind why the trends in the periodic table exist. If students under both teaching methods applied the periodic trends on a graded event, they would come to the same conclusions. The statistical data comparisons would never identify the fact that the students learned the trends differently.

In an article called, *Why Big Data Needs Thick Data*, the author states that organizations are too heavily reliant on quantitative data, or Big Data (Wang, 2013). After the Big Data is standardized, gathered, and clustered, it is stripped of its context, meaning and stories (Wang, 2013). The author states that Thick Data or qualitative data gathered from ethnographic research is “the sticky stuff that is difficult to quantify” (Wang 2013). It comes in the form of a small sample size and researchers get an incredible depth of meanings and stories that would be lost with the sole use of Big Data (Wang, 2013). Big Data requires a great number of data points and Thick Data requires a small number of data points to see human-centered patterns in depth (Wang, 2013).

I utilized an ethnographic perspective to collect qualitative data to study naturally occurring processes and practices in both traditional and guided inquiry classrooms. Gee and Green state (1998) the ethnographic perspective “involves analyzing the choices of words and actions that members of a group use to engage with each other within and across time, actions, and activity.” This data will be used to compare the two teaching styles and would have gone unnoticed if only a statistical analysis were employed.

The science and education community recognizes ethnography as an empirically-based research practice (NRC, 2002). Ethnography involves a contrastive perspective allowing ethnographers the ability to make visible different aspects and practices of a culture (Green et al., 2003). The contrastive perspective entails triangulation which is the juxtaposing of different perspectives, data, methods and theories to make visible the principles of practice that guide members’ actions of everyday life (Green, 2003). In this study’s case, the way students construct knowledge during the social interactions of both teaching environments. In addition, Green (2003) states, “ethnography is a dynamic, interactive-responsive approach to research, involving a reflexive disposition and a recursive process. Through this process, questions are generated, refined, and revised, and decisions about entry into new settings and access to particular groups, as well as data collection and analysis, are made as new questions and issues arise in situ that need to be addressed.”

Kalainoff (2013) states this type of educational ethnographic research is based off of ontological understandings or beliefs about how the world works and epistemological theories or the origins of knowledge. The conceptual framework of this research is made up of many interpretative meanings and relationships of orienting theories that collectively influence the study’s logic of inquiry-the process used to conduct this ethnographic
research (Kalainoff, 2013). The logic of inquiry of this study consisted of an initial question, followed by the gathering of course artifacts, an instructor interview recording, and multiple video recordings of “traditional” and guided inquiry lessons under the same instructor. Next, based off of the initial question and interview of the instructor, the researcher entered the video recordings with a refined research question. Following this, the researcher then made data to understand the patterns of the cultural environment to each teaching method. This allowed the researcher to then focus on the respective patterns of each teaching method that allowed the researcher to empirically gather data to address the refined research question. Ultimately, this data was then analyzed to determine how students construct knowledge.

The conceptual framework I’m using states that the students understanding of the classroom workings is socially constructed. Vygotsky says “scientific concepts” are abstract frameworks learned systematically from interactions with others and/or through experience with the world (Vygotsky, 1978). Rooted in social constructivism within an ethnographic perspective, ethnography is the study of cultural practices utilizing process-oriented, holistic and contrastive perspectives (Green et al., 2003). Culture is defined as socially patterned actions (Goodenough, 1981; Spradley 1980). Members within the culture group develop an understanding of their accepted roles, relationships, rules and obligations of the group by experiencing how things are done within the group (Kalainoff, 2013). Heras (1994) states classrooms are ideal for individuals to construct knowledge:

> The range of lived opportunities, possibilities and constraints opened up in classrooms and schools depends on the configurations made possible by the institutional organization of the school and classroom and by the social and academic interactions constructed within these institutional spaces. From this perspective, knowledge is related to the real or actual opportunities members of a group have and construct as they engage each other in and through the events of everyday life within a classroom (p. 277).

With the conceptual framework in mind, this study will focus on the social interactions that students have and how those social interactions help them construct scientific knowledge in the classroom.

**Methods and Methodology:**

**Overview**

Within an ethnographic approach, three methods were used to obtain records: videotaping of “traditional” and guided inquiry classrooms, an interview of the instructor and the collection of course artifacts.

**Video/Audio recordings.**

Green et al. state (2003), “the task of the ethnographer is to uncover the ways in which members view their world; how they construct the patterns of life; and how through their actions (interactions), they construct values, beliefs, ideas and symbolic
meaningful systems.” Cultural patterns are important in this study because if we are to study students constructing knowledge, then it is important for us to understand how students view their world and what is expected of them during each event of each lesson. In order to seek understandings of the cultural patterns and practices of each teaching style from an emic or insider’s perspective, video recordings or “raw data” were collected from the same chemistry and life science instructor utilizing the “traditional” lecture method one semester and utilizing the guided inquiry method the other (see Figures 1 & 2). This study used the chosen instructor because this instructor was the most experienced instructor who had video recordings of both teaching methods.

Not all videos of each teaching lesson were utilized, but instead, because ethnography uses a holistic perspective, an analysis of a grouping of videos from each teaching style will represent the cultural patterns of the whole archive of videos collected. Because we can show recurring patterns in each lesson, we therefore could analyze small sections of data (Thick Data) that would represent the on goings of the whole.

**Figure 1:** Timeline of “Traditional” Teaching Method

**Figure 2:** Timeline of Guided Inquiry
Interview.

It is important to note that in ethnography, observers do not begin watching videos with a “predefined checklist, predefined questions or hypotheses, or an observations scheme that defines, in a priori manner, all behaviors or events that will be recorded” (Green et al., 2003). With this in mind, in order to understand the culture of each teaching method, and to not solely rely on the videos as sources of information, an interview was first conducted of the instructor. This interview not only helped define and reinforce triangulated data obtained from transcripts and course artifacts, but it also helped pose initial questions when observing the video. The main research question in mind before the start of this study was: How are “traditional” and guided inquiry teaching methods different? Key questions asked during the interview were:

Question 1. How would you characterize what is most commonly considered as a “traditional” approach to teaching General Chemistry?
Question 2. Could you walk me through how you conducted a “traditional” class?
Question 3. How would you characterize what would be commonly considered as a “guided inquiry” approach to teaching General Chemistry?
Question 4. Could you walk me through how you conducted a “guided inquiry” class?
Question 5. What do you see as some of the key differences between the two approaches?

The interview served as the anchor that allowed us to enter the video records and focus our attention on how students construct knowledge during each teaching approach (see Appendix A, Instructor Interview Transcript).

Course Artifacts.

In order to facilitate data collection and triangulate meaning to the interactions between students, instructor and course material during each teaching styles lesson, this study utilized course artifacts such as course textbooks, course syllabi, and lesson assignment sheets containing learning objectives for each lesson.

Data Analysis Methodology:

Forms of Data. Data in this research refers to a product constructed using designated records to address a specific purpose or to answer a specific question (Kalainoff, 2013). Forms of data produced from the interview and video records, and course artifacts were observation tables, event maps, transcripts and a flow chart of cadets constructing knowledge utilizing the guided inquiry method of learning general chemistry. Following the interview, observation tables were made of four traditional videos and five guided inquiry videos. Observation tables consist of two columns, one labeled activity and the other labeled notes. Time-stamps with actions are recorded under the activity column and side notes of the data are recorded under the notes column. Because of the practice oriented approach of ethnography, and the desire to understand cultural patterns, the observation tables were used to make event maps (see Figure 3) showing the cultural patterns of each teaching style. Lastly, a diagram of students constructing
knowledge utilizing the guided inquiry approach was created through discourse analysis or the triangulation of data from video and instructor interview transcripts, and course artifacts.

Data Analysis:

During the interview, the instructor made a key comment when asked to explain how a guided inquiry class is conducted. He stated that as students work in their small guided inquiry groups on chemical activity sheets, they have a safer environment to present their thoughts on subject matter as opposed to the “traditional” environment, see Appendix A, Instructor Interview Transcript, lines 42 to 61. During the “traditional” lecture environment, the exchange of ideas and information is typically done between the instructor and one student in the company of the rest of the class. The “safer environment” comment was instrumental in this study because it led to the next research question of: How do students construct knowledge in both teaching styles? By answering this question, one is able to better understand how students learn and develop their knowledge of information. Not only that, but it can have the potential to identify key concepts in lessons that are possibly the most challenging for students to process.

Following the development of the new research question, event maps of both teaching styles were constructed (see Figure 3, Left: “Traditional” and Right: Guided Inquiry). The event maps show us how students spend time on each lesson for each teaching method. During the “traditional” method, students focus on one lesson during a single class session. They have a reading and homework assignment the night before, learn of that subject matter during one class session by way of student-instructor discussions and the reinforcement of learning objectives through individual board work (see Photo 3) and then repeat the cycle. Whereas, in guided inquiry, students are on a different learning cycle. In guided inquiry, students start one lesson following the review and completion of an instructor quiz from the prior lesson. For example, lesson 17 on Molecular Shape & Hybridization, students first learn of it (Instructor LO Overview and Group Work) after reviewing and completing a quiz on Lewis Structure IV from the class prior. At a later time following class, students then have a homework assignment on Molecular Shape & Hybridization to complete before the start of the next class. At the start of the following class, which was lesson 18, Valence Electron Energy and Partial Charge, the students review lesson 17 material before going on to learning lesson 18 material. By producing this event map, one can deduce that students in the guided inquiry class have time after class to individually process and reflect on information they just learned, and then during the next class, they have the opportunity to continue the construction of their knowledge of certain chemistry concepts with a review between the class and instructor.
The second class time in guided inquiry to reengage material might better afford students to construct challenging concepts compared to the opportunities afforded to cadets in the “traditional” teaching method.
FIGURE 3: Event Map of “Traditional” (Left) and Guided Inquiry (Right) Teaching Methods
More importantly, from the event map, we can see the cultural patterns in which student’s process information. In the “traditional” class, students are individually interacting with the instructor either during classroom discussions or during board work. During guided inquiry, students are predominantly processing information in groups of three to four students. The information from this data, then led to discourse analysis of how cadets construct knowledge. This is important because it allows instructors the ability to understand how students process information and learn subject matter. In order to do this, we used course artifacts and transcripts from video recordings to triangulate the flow of constructing the knowledgeable difference between intramolecular forces (bonding forces between atoms) and intermolecular forces (electrostatic attractions between molecules) (see Figure 4).

![Diagram](image)

**Figure 4:** Flow of constructing knowledgeable difference between intramolecular force and intermolecular forces.

In a guided inquiry group of three cadets, we can see that they did not exactly follow the same path to construct their understanding of the difference between intermolecular forces and intramolecular forces, see Figure 4 – Group Processing. Before the group work, on three separate occasions, they were given information to prepare their minds to receive and process information concerning the difference between intra and intermolecular forces of molecules. That is interesting to note because the flow of construction didn’t start just with the cadets working in their groups, but their minds were prepared to receive that information during three separate instances, see Figure 4 – Individually Processed. First, the instructor provided foundational knowledge of intermolecular forces being a result of dipole moments during lesson 19 on Bonds and Dipole Moments, see Appendix B, Transcript lines 6 to 12. Secondly, from examining the course artifacts, students then did a homework assignment the night prior for the actual lesson on intermolecular forces, lesson 20. Thirdly, before group work on intermolecular forces, the class had a discussion on intermolecular forces with the instructor, see Appendix C, Transcript. Not only is the actual experience of learning the information
important, but what is done to prepare student minds to receive that information is important as well.

During group work, the three students did not come to the common understanding of the difference between intra and intermolecular forces at the same time, see Figure 4 – Group Processing. One member of the group did not understand the difference between intra and intermolecular forces after collaboratively working on critical thinking question 1. This became apparent to the researcher during the second critical thinking question 11, see Appendix D, Transcript lines 135 to 201. One member was confused of the material from critical thinking question 1 as the other two members were focused on the next critical thinking question. It was important to understand the cultural pattern of the guided inquiry method because the researcher came to an understanding that it is acceptable for students to not get a key chemistry concept at the beginning of a lesson or at the same time with other group members. Guided inquiry allowed for group members to process information at different times. Either group work at the table or interaction with the instructor would bring the students to a knowledgeable understanding of key chemistry concepts. In this instance, the defining moment that brought the three cadets to the same common understanding was from a group member recalling comments the instructor made during the instructor discussion before the start of the group work, see Appendix C, transcript lines 14 to 20 and Appendix D, transcript lines 192 to 200. In working critical thinking question 11 together, the group then came to a common understanding between the difference between intra and intermolecular forces.

It is important to note the researcher wasn’t able to clearly track the flow of student learning during the “traditional” method during discourse analysis. The individual discussions of the instructor with one student during classroom discussions or board work rarely provided insight to whether or not a student properly constructed their understanding of a particular chemistry concept. During typical class sessions, the instructor would model a mathematical problem on the board and ask one word response questions as he walked the class through the problem solving process. The class was reliant on the instructor to keep the flow of the class moving and in doing so, the researcher never really observed moments where you could fully triangulate the construction of knowledge by a student utilizing the “traditional” method of general chemistry. This difference shows the utility of providing a safe space where students can make their connections and understanding visible without scrutiny of their instructor or the majority of their classroom peers.

**Reflection:**

Conducting this research was a great tool to professionally develop as an educator. Through the production of the event map and the discourse analysis of the guided inquiry and “traditional” transcripts, I was able to witness and track how students construct knowledge. Guided inquiry allows educators to listen in on the thought process of students as they work out their processing of information with each other in a safe environment. As the AY17 course director for organic chemistry, it makes me think of how I can utilize guided inquiry to better understand where organic chemistry students are having issues as they are trying to process challenging concepts. For example, students learn of enolate chemistry during the second semester of organic chemistry. Enolate chemistry is generally more challenging for students to grasp compared to other
material. If I were to implement guided inquiry, and videotape those sessions of group work, I would then be able to possibly identify problem areas where students typically have issues constructing knowledge tied to specific learning objectives. That information could then better help me design better opportunities to prepare their minds so they are better able to receive and process the organic chemistry concepts in enolate chemistry.

An unexpected instance of professional development I experienced during this research was developing a greater in depth knowledge of multiple general chemistry concepts while watching the video records in order to construct the observation tables. For example, before this research, I knew the Henderson-Hasselbalch equation dealt with calculating the pH of a buffer system, but, I didn’t know how it was tied to an equilibrium expression of the original dissociation equation. Through watching the traditional lecture video recording of a seasoned instructor giving a lesson on acid-base buffer systems, I was able to better my understanding on the use of the Henderson-Hasselbalch equation and why it applies to solving for the pH of acid-base reactions. I was also able to better my understanding of many other general chemistry concepts from watching both “traditional” and guided inquiry video records.

During the course of watching the videos and annotating the instances where I was professionally developed by watching another instructor teach a class, it became very apparent to me that a video archive of each lesson is a very resourceful teaching tool for inexperienced instructors. Incoming instructors not only have to better understand their teaching material, but they also have to understand how to run a class utilizing the guided inquiry method. During new instructor training, new instructors must run their own mock guided inquiry class with other instructors acting as students. In addition to that development opportunity, they can also watch video recordings of a seasoned instructor to gain a frame of reference of how to go about running a guided inquiry class. Not only will they understand how to run the guided inquiry class, but they will be able to get more in-depth understanding of the subject matter from watching the experienced instructor. More excitingly, they can watch videos of student group work, and through discourse analysis between the students, new instructors can better understand how students construct chemistry knowledge for each learning objective.

In doing this research project, and being the AY17 organic chemistry course director, I am interested to learn if students who learned general chemistry the guided inquiry way perform differently in organic chemistry than students who learned general chemistry the “traditional” way. In my experience, even though it is a perquisite for organic chemistry students to understand general chemistry concepts before the start of the course; that is not always the fact. I usually have to review such material so I know students minds are prepared to receive the information concerning organic chemistry. Now understanding ethnography as a tool for educational research and experiencing the implementation of it, I would like to do an ethnographic study where I compare student performance in organic chemistry between students who learned general chemistry the “traditional” way versus the guided inquiry method.

Lastly, as a result of this research, I am aware that each class and instructor have their own different cultural norms. Taking substitute teaching into consideration, there might be times where I have to teach a class where I am an outsider to their established cultural norms. Apgar states, “Culture starts when you realize that you’ve got a problem with language, and the problem has to do with who you are.” For example, I take a very
methodical approach that follows the textbook when teaching organic chemistry. If another instructor takes a different approach, like asking students to identify what issues they experienced with their homework and teach the lesson from there, I do not want my inability to understand the classroom culture to be the reason why a student did not get a certain chemistry concept during class. This makes me want to prepare myself to teach another class by sitting in on a couple of classes taught by the other instructor to get an emic or insider’s perspective to how the class runs.

Conclusion:

What I thought to be an opportunity to just do research developed into a very rewarding professional development opportunity. I learned of educational ethnography and its use as a different lens to study and analyze classroom culture. I improved my depth of knowledge of various general chemistry concepts. Most importantly, for an educator, I was able to track students constructing knowledge. This was critical because it showed how essential preparing the mind is for student learning and how students are more prone to share their thoughts in a small group setting. Guided inquiry provided a way for students to construct knowledge in a safe and comfortable space among their peers whereas “traditional” did not.
References:


Appendix A – Transcript of Key Segments of Instructor Interview

Fallot_Interview1_2

[Time Stamp: 5:05] – Instructor discusses how safe of an environment guided inquiry is for students to present data to a small number of group peers.

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Interviewer</th>
</tr>
</thead>
<tbody>
<tr>
<td>So, now we are going to go to the guided inquiry. How would you characterize what would normally be considered as a guided inquiry approach to teach general chemistry?</td>
<td>So, now we are going to go to the guided inquiry. How would you characterize what would normally be considered as a guided inquiry approach to teach general chemistry?</td>
</tr>
</tbody>
</table>

Guided Inquiry approach
You give the students some form of activity
And as a group they would work through that activity, the activities
For the guided inquiry are generally set up to where they get some kind of data
Some kind of experimental results, some kind of measurement
And the inquiry takes them through a series of questions that has them explore that data in a meaningful way to come to conclusions about chemistry based on their own analysis of the data
As opposed to the more traditional approach that skips right to the conclusion and tells them the answer which they tend to try to memorize

The guided inquiry approach is nice, in the fact that students are very apt to try to go into
Instructor          Interviewer

Receive mode and their ability
To receive certainly varies
From student to student
Whereas in this guided inquiry
Of small groups of cadets
They have less of a chance to hide
And it is safer for them to
Present their thoughts
For example, if you are speaking
In front of the entire class
You are less likely to say
Something about which you
Are not sure
Which if you are speaking
In front of a couple peers
You are much more comfortable
Taking a risk by presenting
What you think is true for analysis
And scrutiny and it is safe
Umm, because you are not being
Judged by the entire class
And the instructor, from a student
Perspective

[Time Stamp: 11:31] – Instructor discusses main difference between two teaching approaches being intellectually stimulating guided inquiry conversations

Instructor          Interviewer

So, now
I want to go in
Hone in
Like an outline
Of key
Differences
Between the two
Approaches
And one that you start
Out with
And I'll throw that
Out there is
As far as
Students working
In groups and
Can now present
Their own ideas and
Not Being Scared of
Retribution by
The entire class
As a key
Difference
Um, do you have any
Other key differences
That you’ve highlighted
Yourself and compared
The two teaching
Methods?

From my perspective
Or the student
Perspective?

Your perspective
What have you
Noticed different
Between traditional
And Guided Inquiry

The biggest difference
Is just how
Intellectually
Satisfying,
If you will
The conversations
With students have
Become
The previous iterations of
Chemistry
Have not always been falsely
Accused of an applied
Algebra class
Which, kind of slights
Some things we thought
We were doing with concepts
A lot of the problems
Were math based
If you look at our WPR I
From this block
50 from the 200 points
Instructor: Were calculations

120 The rest of it were explanations
And conceptual understandings
This last WPR, I can’t think of any
Math that was on it
So a student who is not good at
Math, isn’t predisposed to fail
Chemistry.
Which I think is important
It allows students who aren’t good
At math to say,

125 Just because I’m not good
At math, doesn’t
Mean I’m not good at science
It might be a barrier to
Them getting an “A”,

130 But they could feel good
About science and
Explain phenomena.
And the way it manifests
You know, I have students

135 Who just come for AI
They’re not asking about
You know, necessarily
Specific problem types
They are asking about

140 Concepts
They are asking about
You know, how the
Atomic structure effects
The Average Valence

145 Electron Energy
Or how that is related to
Electronegativity
Or, why fluorine only winds
Up with a partial negative

150 Or why it only ends up with a
Single bond
As opposed to
When the points were
Largely tied to

155 Mathematical applications
Of data
They were asking what
Instructor

Happened to the units
On the gas constant when
You divide by it
And, philosophically
That is just not intellectually
Stimulating or as rich of a
Conversation

Because you're helping them
With something mechanical
As opposed to something
Conceptual
And, so, I think the
Conversations are much
More satisfying
Because they are actually
Understanding stuff and then
Repackaging it as they talk in
Their small group, which is
They reformulate it
For themselves and present
It to other students
As opposed to just trying to
Getting a fact that they can then
Reproduce on a graded event
So, I find it makes then, the
Conversations, the Al's
Just much more satisfying
Experiences for both
Student and Instructor.

Interviewer

So, guided inquiry
Your saying
Has more
Intellectually stimulating
Conversations
Because they are more
Conceptually based
Versus the mechanical
Instructor

Bond polarity matters, shape matters and those things allow us to determine dipole moments. And dipole moments matter because the way molecules interact and some of their physical properties are based largely on those dipole moments. So we are going to take a quick field trip. This will be a short one.

So if you would, you can just get up. We are going to look at the behavior of a polar molecule and how it is different. (Class get up to go across the hallway to look at a window) We can just form a semi-circle Right here Around the window

This is the subject of today’s Demonstration (Instructor shows application of electric field to show how window becomes gray when you apply an electric field)
Appendix C: Transcript of Key Segment of Instructor Discussing Intra and Intermolecular Forces with Students

151016_CH101_1_2

[Time Stamp: 13:04] – Discussion of Intermolecular forces with class

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermolecular forces</td>
<td></td>
</tr>
<tr>
<td>Are a measure</td>
<td></td>
</tr>
<tr>
<td>Or a description of</td>
<td></td>
</tr>
<tr>
<td>How particles</td>
<td></td>
</tr>
<tr>
<td>Interact with other particles</td>
<td></td>
</tr>
<tr>
<td>Not how particles interact</td>
<td></td>
</tr>
<tr>
<td>Amongst themselves</td>
<td></td>
</tr>
<tr>
<td>What keeps them together</td>
<td></td>
</tr>
<tr>
<td>As a particle.</td>
<td></td>
</tr>
<tr>
<td>But how particles interact</td>
<td></td>
</tr>
<tr>
<td>With other particles</td>
<td></td>
</tr>
<tr>
<td>One way that helps me think About it</td>
<td></td>
</tr>
<tr>
<td>I think of</td>
<td></td>
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<tr>
<td>Intramural sports</td>
<td></td>
</tr>
<tr>
<td>A college is competing within Itself</td>
<td></td>
</tr>
<tr>
<td>Intercollegiate athletics</td>
<td></td>
</tr>
<tr>
<td>A college is competing</td>
<td></td>
</tr>
<tr>
<td>Against other colleges</td>
<td></td>
</tr>
<tr>
<td>So intramolecular forces are Ionic, covalent and metallic</td>
<td></td>
</tr>
<tr>
<td>Bonding types we’ve been talking about How particles hold themselves</td>
<td></td>
</tr>
<tr>
<td>Together.</td>
<td></td>
</tr>
<tr>
<td>Whether molecules, soft crystals or Slabs of metal.</td>
<td></td>
</tr>
<tr>
<td>Those are intramolecular forces</td>
<td></td>
</tr>
<tr>
<td>When we talk about</td>
<td></td>
</tr>
<tr>
<td>Intermolecular forces</td>
<td></td>
</tr>
<tr>
<td>Now we are looking at Are they polar or not Because the dipole of One molecule</td>
<td></td>
</tr>
<tr>
<td>Will interact with a dipole Of another molecule And that electrostatic attraction Can hold them together.</td>
<td></td>
</tr>
</tbody>
</table>
If the electrostatic attractions
Are strong.
Or the kinetic energy is very low.
We can see intermolecular forces
Hold particles together
In the form of a solid
If they are starting to be even,
Kinetic energy is close
To the strength of intermolecular forces
But can’t overcome them
We can see that substance
Exist as a liquid.
Where they are still interacting
But moving around each other.
And then if thee kinetic energy
Overwhelms the intermolecular
force entirely
We'll see these particles have
No electrostatic interaction
And they will go into the gas
Phase
The strength of those intermolecular
Forces
Defines the physical state
Under a certain set of conditions
Of temperature and pressure
We’ll find
There are the three intramolecular forces
CDT Phelps, stay with me now
I know I’m a boring monotone
I’m doing my best here
Up here
I rehearsed in front of a mirror
All night
Stay with me
Where’d my slide
Deck go.
For those who have spencer
You can take a look at
Some of these things
So spencer lists
A variety of
Intermolecular forces
And notice
All of these intermolecular
Forces
Are between two Different particles, so here we have 2-porpanoen also called acetone. This carob oxygen double bond, we know oxygen is more electronegative than carbon. So this is going to be polar with a particle negative near the oxygen and a particle positive near the carbon so if this acetone molecule comes in contact with another acetone molecule they can line up partial positive to partial negative. And that is electrostatic Interactions where the positive is drawn to the negative, we saw how polar molecules behave on the window across the hall. They will snap to an electric field and so they can also interact with each other by those same electrostatic interactions. And we see that the dipole-dipole interaction on average 5 kJ/mole, roughly the attraction there. When we contrast that with the covalent bonds within an acetone molecule we see that intramolecular force are two orders of magnitude larger than the intermolecular force. So the covalent bonds, the intramolecular force that holds an acetone molecule together,
must stronger than
the intermolecular force
that holds multiple acetone
molecules near each other
to form a puddle.
But it is there.
Given enough energy we can
get it to overcome that
and it will go into the gas phase.
Then there is the dipole-induced
dipole,
for a dipole-induced dipole,
we take a polar molecule
like acetone
which has a permanent partial negative
and partial positive on it
and it comes near the polarizable
electron cloud of a non-polar molecule.
Here carbon tetrachloride.
If this partial positive,
is forces next to this nonpolar molecule,
it can induce a very temporary dipole
on this nonpolar molecule
long enough to interact with it
and then this electron cloud
will relax back to being non-polar.
And that interaction will be complete.
But it can happen,
a dipole can induce
a temporary dipole
on a non-polar molecule
long enough to interact with it.
Yes, CDT Gibons

So, what happens in a lab
If you try to test it
Like, what would be the
real
life application of it

This is going to tell you
whether you will be able
to dissolve something,
ah dissolve one substance
in another or not.
For example, thee,
if you got an aqueous,
most of us, especially in biology
classes will be dealing with aqueous substances because people are mostly composed of aqueous solutions and you want to deliver a medicine in a cell that is nonpolar. In order to get that to happen you have to somehow functionalize that nonpolar molecule with some kind of polar component so it will interact and go into solution.

Instructor continues to discuss example of sucralose. Instructor also draws example of hydrogen bonding by way of sugar with hydroxyl group with water. Uses that as an example to explain hydrogen bong interaction. Student discuss dipole-dipole first, two polar molecules but then instructor discusses hydrogen bonding.
Appendix D: Transcript of Key Segment of Student Constructing a Knowledgeable Difference Between Intra and Intermolecular Forces.

Instructor prompts class to starting working on ChemActivity 27, Intermolecular Forces. Cadets start out discourse by working critical thinking question 1: When water evaporates, are any bonds between H atoms and O atoms within a molecule broken?

[Start Time: 1:12]

F Top    M Top    M Bottom
I explained mine (Chuckles)
I said yes
Wait, let me read the question. 5
You say yes? (at M Bottom)
Did you say no or yes? For the first one? Huh?
10
You thought it was yes?
It depends on the H atom you are talking about
No, because You’re looking at intermolec. forces Not the intra So
15
20
(Erasing, Changing Answer) (Erasing, Changing Answer)
Ah! Well it’s no. The molecule itself wouldn’t be broken apart
25
The intermolecular forces would be broken
Oh, yeah, yeah (Erasing, Changing Answer)
30
35
In terms of Inner-molecular forces It would be like no because
It would actually be
Within the substance

The molecules are bound
together

And the hydrogen
Never actually
breaks apart
Into H-2 and O-2 atoms
Eh, or ions
But if you're talking about
Intramolec. forces
It would be yes,
because
the whole molecule is
breaking apart
Moving freely
like a gas
(congratulatory snap
and thumbs up)
No, I'm just kidding.

[Stop Time: 02:20] Cadets discuss topics unrelated to IMF and ChemActivity 27.
[Start Time: 03:12] Conversation back to work on Model 2, CTQ 10. Is the
strength of intermolecular forces determined by the bond strengths within the
individual molecules? Explain your reasoning?

For number 10
Did you say yes, or
no? (To M Top)

(Silent)  
Wait
What are we
Working on?

Is it because of the
charges
Right?
(Inaudible Comment)

(Silent)  
Wait,
What are we
Working on?

Like, whether it is
positively or negatively
charged (Silent) (Whisper) What are we working on?

I was just asking about number 10 on Model 2. Because I didn’t get that one.

It’s just I used an example Of ketones because You have a double bond Between carbon and Oxygen And it’s intermolecular. Forces are less Than alcohol Which doesn’t have Double bonds Between its atoms. (Shakes head, no) (Shakes head, yes) Yeah Any correlation would be random.

[Stop Time: 03:55] Cadets discuss topics unrelated to IMF and ChemActivity 27.
[Start Time: 05:19] Conversation back to work on Model 2, CTQ 7a (Find an alkane, a ketone, and an alcohol with roughly the same MW (within 5 g/mole). Rank these compounds in terms of relative boiling points.

<table>
<thead>
<tr>
<th>F Top</th>
<th>M Top</th>
<th>M Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td>(silence)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(silence)</td>
<td>I put the alcohol or the… alkane, ketone, then alcohol number 1</td>
<td></td>
</tr>
<tr>
<td>(silent)</td>
<td></td>
<td>Which is your top one? (to M top)</td>
</tr>
</tbody>
</table>

Alcohol
Ok, alcohol, ketone
Alkane?

Yeah

Ok, that’s what
I got too.
Did you get
that? (to F top)

Yeah

Ok, cool
Ok, the general pattern
Is that the…
Alcohol
Has the higher boiling
point.

Yeah,
has the highest boiling
point.

Alkanes have the
lowest.

[Stop Time: 06:04] Cadets discuss topics unrelated to IMF and ChemActivity 27.
[Start Time: 06:50] Cadets move to discuss Model 3, CTQ 11: What is the
difference between intramolecular bonds and intermolecular forces?

F Top  M Top  M Bottom

Ok
Working on 11.

Yeah
(reading)
Wait a second…
Intra…
Inter…

Yeah
(reading)
(reading)

(giggle)
Ok, do I have
this backwards?
Intramolecular bonds
holds molecules
together?

Yeah
You have it
backwards

Yeah

No, no
Intra is between
atoms

No, intra is one atom
eh, intra is one molecule
(state at each other)
Intra is the force within a molecule

Intramolecular bonds?
Is inside the molecule

between like an oxygen and hydrogen

So, like H-2-0

F Top  M Top  M Bottom

It's going to be the one that binds
er, uh, bonds the hydrogen to the oxygen

But, like, when you are bonding two hydrogen

But actual hydrogen Bonds is intermolecular forces
Because it bonds H-2-O's to H-2-O's

I have them backwards

Yeah

Ok

It's really confusing. They shouldn't have chosen such words

To me They have opposite meanings. Because inner makes me think inside the molecule

But, it's the opposite

Think of what he said Intramurals Intramural sports

Yeah, that's true
Intercollegiate efforts
That actually made sense

Already in order right
Yeah

Strongest intermolecular
present?
Would that be a hydrogen bond?

Yeah
What did you say
Hydrogen bonds for?
Oh, shoot
I have to think about that one more.

The strongest intermolec.
force would be a hydrogen bond, right?

For what?

For b.
On 13

[Time Stamp: 11:13] – Model 3, CTQ 13b. In the alkanes, what is the strongest intermolecular force present? Note: Group has trouble understanding that molecules can have different intermolecular forces based off of the functional groups present in a molecule. Workbook references text for “descriptions of the types of interactions that produce attractive forces between molecules.”

F Top M Top M Bottom

Yeah, hydrogen bond
Because it is the Strongest one
If it’s there, if it’s there

That seems correct by the textbook
I have no clue on that one
I’m not sure what
they want. Gosh, I can’t picture it.

(Reading text) (Silence) The ion-dipole force is (inaudible)

240 Wait a second… (Writing) (Silence) (Inaudible speech)

There’s not a hydrogen… I don’t think there is a hydrogen bond present in a…

alkane (Silent) alkane it can’t be because it has the lowest boiling point

yeah that is what I was thinking (Silent) So the way it interacts must be, ah

250 Is C-H-2 and C-H-3 (Thought) (Pointed finger up) Dang it. M Top, what do you have?

260 For b? For any of, yeah 13

induced-dipole induced-dipole

270 For 13a. Induced-dipole Induced-dipole?

Yeah (head nod) Because, normally (inaudible) I guess we can
I’m drawing, um
C-H-H-H, ok…
This is what this says
Which makes sense
of why it is induced-dipole, induced dipole
The strongest intermolecular force…
is a carbon-to-carbon bond
(confused silence)
I honestly cannot
think right now.
I don’t know how to answer number 16
I know it increases proportionately.
But, I don’t know why.

[Time Stamp: 18:54] Model 3, CTQ 16 – In terms of intermolecular forces, why does the boiling point of a particular type of compound (for example, an alkane) increase as the molecular weight increases?

F Top  M Top  M Bottom

(silence)  (silence)  (silence)

[Time Stamp: 20:13] After quietly reading and looking through workbook, M Top raises his hand for the instructor and the instructor approaches. Instructor used a personal anecdote to help explain intermolecular forces to another group, which leads to his initial comment to the group.

F Top  M Top  M Bottom  Instructor

Yes?
I precipitated back out
With my girlfriend
It worked out
(chuckle)  (chuckle)  (chuckle)

That’s the Nicholas Sparks ending
On, ah, number…
(silence)  13, 14 and 15…  (silence)
We have what type of intermolecular forces
But, what do they mean by strongest force present?

(silence) (silence)

So, every substance can have one or more intermolecular forces.

So, Kind of in that ranking

You did over here (Points in notebook) If it has hydrogen then it could also have

(silence) (silence)

Ok, so then we just say

What is present, then the strongest one that’s…

Yes

F Top M Top M Bottom Instructor

So list all the possibilities and identify the strongest.

Ok
Thank you, sir.

[Time Stamp: 20:55] After having a discussion on CTQ’s 13, 14, and 15 with the instructor, the instructor leaves and the group continues to work within itself.
Gosh, yeah…

Ummmmm….

Kind of hard

There’s a

possibility for all…

[Time Stamp: 21:06] Instructor cuts off group discussions to give a summary of the learning objectives for the day. Group turns their attention to the projector. Learning objective summarizes all of the intermolecular forces and their relative strengths to one another. Instructor tells class that if a water molecule has Hydrogen bonding then theoretically, it can have all of the other weaker intermolecular forces present. “Philosophically, if it has one, then it has all of the weaker ones too.” Instructor continues to clarify to the whole class of how to go about solving 13, 14, and 15. Identify the type(s) of intermolecular forces present and then identify the strongest force present for alkanes, ketones, and alcohols, respectively.