THE RELATIONSHIPS BETWEEN TEACHING PHILOSOPHIES AND METHODS IN UNDERGRADUATE ORGANIC CHEMISTRY

by

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(Under the Direction of Norman F. Thomson)

ABSTRACT

Every teacher has a teaching philosophy whether he or she realizes it. A teaching philosophy is important in knowing what works and what does not work in terms of conveying the material to the students effectively. There are many different philosophies in education, a few main ones being pragmatism, behaviorism, and constructivism. Organic chemistry is a very difficult class student's encounter in college. Being able to convey these difficult concepts in a manner the students can understand is important in student success. The purpose of this study was to investigate the relationships between teaching philosophies and methods in undergraduate sophomore level organic chemistry. This study was conducted in the Department of Chemistry in a large university in the southeastern United States during the spring semester. The participants of the research study were three male professors who were teaching organic chemistry during the current semester. Their philosophies were determined, first by giving a semi-structured interview, followed by classroom observations to see how their statements matched to their lectures. The three teachers showed evidence of both pragmatism and constructivism in their philosophies, and used similar methods when teaching organic chemistry.

INDEX WORDS: Teaching Philosophy, Chemistry, Organic Chemistry, Teaching Methods

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INTRODUCTION

Background

"A good teacher is not one who behaves in any certain way but who makes the best use of his own unique personality" (Emery, 1971). Defining what makes a good teacher has always been a major concern in education. Definitions of a good teacher vary greatly, and what makes one teacher great, may not work for another. Despite differences, the teacher is vital in transferring his/her knowledge to the student (Akhlaq et al., 2010). Teachers use different philosophies or methods to accomplish this goal.

There are many definitions for a teaching philosophy. Most definitions define it in terms of being written down. However, just because a teaching philosophy is not written down, does not mean the teacher does not possess one. Vaino (2009) stated, "In order to promote the development of students' scientific literacy, teachers must possess beliefs and gain competences that support this process." Every teacher possesses his or her own teaching philosophy.

Horne (1916) defines philosophy of education as "an interpretation of education in terms of the whole of experience." Cornell University (2011) defines a teaching philosophy as a "narrative that includes: your conception of teaching and learning, a description of how you teach, and justification for why you teach that way." A teaching philosophy is meant to convey your beliefs, values, and goals to others (Cornell University, 2011). The University of Minnesota (2010) defines it as "a self reflective statement of your beliefs about teaching and learning." Friesen, Schönwetter, Sokal, Taylor (2002, p. 84) defines a teaching philosophy statement as "a systematic and critical rationale that focuses on the important components defining effective teaching and learning in a particular discipline and/or institutional context." Friesen (2002, p. 84) also provides four purposes for a teaching philosophy statement: clarifying and providing a rationale for good teaching, guiding teaching behaviors and organizing the evaluation of teaching, promoting personal and professional development, and encouraging the dissemination of effective teaching. Though these definitions vary, they all have points in common. They all agree that a teaching philosophy is something that portrays a person's beliefs and values on how to teach the subject matter. A teaching philosophy gives insight to a person's views on how a class should be organized.

Several teaching philosophies exist. These include constructivism, behaviorism, objectivism, relativism, perennialism, essentialism, progressivism, existentialism, idealism, pragmatism, and realism.

Constructivism is the most dominant philosophy found in today's classrooms (Boghossian, 2006). The main idea of constructivism is simple: knowledge is constructed (Scerri, 2003 & Wheatley, 1991). This knowledge is not passively received (Wheatley, 1991 & Yager, 1991). The student is the center of knowledge (Boghossian, 2006) and they learn by doing (Patankar, 2011) Students construct and test their own ideas (Boghossian, 2006 & Yager, 1991) as a way to find meaning or to make sense of their experiences. (Driscoll, 2005 & Boghossian, 2006) According to Driscoll (2005), "learners are not empty vessels waiting to be filled, but rather active organisms seeking meaning."

According to Carson (2005), constructivists view reality as "dependent upon the perceiver, and thus constructed." This means that something can exist only if the person can perceive it (Carson, 2005). They do not accept the idea of truth as a correspondence with reality

(Yager, 1991). The purpose of education is not to arrive at the truth; it is impossible (Boghossian, 2006). Rather, knowledge can be constructed to offer explanations for our experiences as a way to interpret nature and cope with the world (Wheatley, 1991 & Yager, 1991).

Constructivist teachers often encourage students to work in groups because it promotes a mutually shared meaning of knowledge (Scerri, 2003 & Yager, 1991). They create a curriculum that is meaningful for the student by using students' questions, thinking, and experiences to guide their lessons (Yager, 1991 & Jofili & Watts, 2007). They value quality over quantity. The student rather than the discipline is important (Jofili, 2007). The teachers provide the students with exam questions that are open ended because only one right answer does not demonstrate understanding (Scerri, 2003 & Yager, 1991). To them, a given problem can have more than one solution. The content is there not to just exist and be mastered on a test then forgotten, but to be used to extend learning beyond the classroom (Yager, 1991).

In contrast, behaviorism is a philosophy that opposes constructivism. (Boghossian, 2006) Knowledge is not dependent on introspection, and it is acquired from outside resources, according to behaviorists (Boghossian, 2006). Wheatley stated that behaviorism "emphasizes breaking knowledge down into skills and subskills, writing behavioral objectives, and judging mastery based on a skills test" (Wheatley, 1991). Students are expected to memorize bits of information (Patankar, 2011).

The main idea of behaviorism is that students can be taught to acquire any skill by reprogramming them (Maya, 2007). The students undergo some kind of conditioning to change or rid them of a certain behavior (Boghossian, 2006). The student can also be conditioned to learn or perform anything by using a reward system (Maya, 2007). Behaviorist teachers are tasked to provide stimuli and reinforcements that promote certain behaviors from the student. This philosophy can be very useful for replicating behaviors, but not for understanding, synthesis, eventual application, and using information in new situations presented to the student (Yager, 1991).

The objectivist view contrasts constructivism, as well (Driscoll, 2005). In objectivism, truths are independent of the context in which they are observed. One goal is to transmit knowledge that has been acquired (Scerri, 2003). The knowledge is absolute and is attained through an individual's experience of it (Driscoll, 2005). Students are provided with exam questions that have only one answer (Scerri, 2003). According to Carson (2005), "Students must be engaged actively in the subject matter to learn." Obtaining knowledge requires obtaining data. This can be done via senses and reason (Carson, 2005).

Another goal is to discover what is and to provide strong support or reasons for it (Bernstein, 1983). Objectivists believe there is "a single reality external to individuals" (Boghossian, 2006). Even if the person cannot perceive it, it is still there. Humans only know this reality through reason (Carson, 2005).

A philosophy that denies objectivist's claims is relativism (Scerri, 2003) Scerri (2003) stated, "the central idea in relativism is precisely that all knowledge is relative." This implies that any knowledge can be equally valid even if it is derived from chemistry or voodoo (Scerri, 2003). A relativist may claim his or her position to be true, but since this philosophy believes truth to be relative, then "relativism itself may be true and false" (Bernstein, 1983).

Another teaching philosophy is perennialism, the focus of which Cohen (1999) identifies as "to teach ideas that are everlasting, to seek enduring truths which are constant, not changing, as the natural and human worlds at their most essential level, do not change." Perennialism is known to be conservative and inflexible, with principles that do not change (Cohen, 1999 & Kurtus, 2001). A perennialist believes “reality is everywhere and at every moment the same” (Mosier, 1951). This reality comes from fixed truths (Kurtus, 2001), defining truths as “conformity of thought with things” (Mosier, 1951). Students are believed to find truths through reason, which is taught using lessons and drills (Kurtus, 2001). In a perennialist classroom setting, every teacher is expected to teach the same lesson and students should initiate discussions to stimulate thought because student input is important. The teacher is the center of instruction that opens students’ mind to scientific reasoning. Perennialism and essentialism are similar (Maya, 2007).

Essentialism is a philosophy that dates back to the Greek philosophers. It became popular in the education field in the 1930’s by William Bagley through his writings and lectures. In essentialism, the teacher is the center of instruction, and student input is unimportant (Maya, 2007). Teachers focus on teaching intellectual and moral standards, such as facts and the basics such as reading and writing, so the students can become ideal citizens (Cohen, 1999 & Maya, 2007). Students should be taught hard work, respect for authority, and disciple in a systematic and disciplined way (Cohen, 1999). In this philosophy, the core curriculum may change, but it is usually very rigid (Cohen, 1999 & Maya, 2007).

In progressivism, learning comes from experiencing the world (Cohen, 1999). To a progressivist, “reality is everywhere and at every moment different” (Mosier, 1951). Teachers provide lessons or experiences where the students learn by doing or test ideas by active experimentation (Cohen, 1999 & Maya, 2007) “The learner is a problem solver and thinker who makes meaning through his or her individual experience in the physical and cultural context” (Cohen, 1999). Classrooms that use this philosophy focus on the whole child rather than the content or teacher (Cohen, 1999). The teacher realizes not every student can learn by the same approach, so he or she incorporates different methods in his or her teaching. The teacher's different methods could include thought provoking games, books, manipulative objects, experiments, and social interactions (Maya, 2007). According to Maya (2007), "this is the first philosophical approach that takes into consideration the three learning types (auditory, visual and kinesthetic learners) of students." The curriculum is driven by the students' questions and interests (Cohen, 1999). Its' goal is not to educate students for adulthood, but instead enrich the educational growth process (Maya, 2007).

Existentialism is a philosophy that does not enforce formal education (Maya, 2007). Instead, it nurtures the creativity and individuality of the student by allowing them to choose their own values and path to follow (Emery, 1971 & Maya, 2007). The student is allowed to select which subjects and courses to take that interest them (Emery, 1971 & Mercieca, 1967). A student who is weak in one area, such as foreign language, might excel in science, therefore the student should be given the opportunity to develop that talent. Individuality is very important in existentialism (Mercieca, 1967). The individual is the one who defines the reality of truth and goodness (Kurtus, 2001). The teacher is responsible for aiding children individually in knowing society and assisting them in their search for self-realization (Emery, 1971, & Kurtus, 2001). Even though the existentialist teacher has an extensive perception of the subject matter they teach, the teachers' attitude is more important (Emery, 1971). The teacher realizes all human situations are different from each other (Mercieca, 1967), therefore the methods he or she uses to teach are flexible (Emery, 1971).

Idealism and pragmatism are similar philosophies, but they differ by their definition of the idea of truth. They both define truth as agreement with reality but they disagree with the meaning of reality and agreement. Idealism is monistic and defines truth as an agreement between man's and God's idea (Antz, 1976). Idealism "believes that truth is in the consistency of ideas and that goodness is an ideal state to strive to attain" (Kurtus, 2001). To an idealist, personality is a supreme value (Antz, 1976) and reality is a world that is within a person's mind (Kurtus, 2001). They are concerned about the content of knowledge, and that "knowledge consists of only ideas or representations about reality" (Driscoll, 2005).

To a pragmatist, "reality exists but cannot be known directly" (Driscoll, 2005) John Dewey is famous for developing pragmatism (Antz, 1976). Antz (1976) believes pragmatism to be more of a method rather than a philosophical system. According to Antz (1976), it allows any philosophy that works to be true. Pragmatists look at life in terms of what is significant at the present time, not what may happen in the future (Hlebowitsh, 2006). It is very action oriented (Raij, 2012). Pragmatism is another philosophy that very strongly advocates learning by doing. An example would be students should learn English by speaking rather than memorizing words (Antz, 1976). A pragmatist believes actions are born from thinking (Raij, 2012). Knowledge is not absolute (Driscoll, 2005). Antz (1976) puts it as there is "no such thing as 'really is.'" "People must constantly acquire new knowledge and skills" (Raij, 2012).

In this philosophy, the student is the most important. Students create their own reality and gather their own situational facts. Learning takes place within the student, and if the student does not want to learn, there is no amount of support that can force he or she to do so. The teacher's role is to be both a guide and mentor (Raij, 2012). Education is for citizenship (Antz, 1976). The curriculum is comprehensive (Hlenowitsh, 2006). They change their teaching methods based on the situational needs of the students. They provide them with tools to accomplish real tasks. Students will be able to learn from everything they experience and use it in practical situations (Raij, 2012). Pragmatism believes that “if the idea works it is true” (Antz, 1976).

Realists see the world as it is, as what we can observe (Kurtus, 2001). Realism believes all things in the world can be known, and something can be detected if it is real (Driscoll, 2005). The role of the teacher is to teach students factual information usually using lectures as their method (Kurtus, 2001 & Raij, 2012). Students are asked to regurgitate the information back to the teacher. Realists believe their philosophy can describe how the world functions (Raij, 2012).

All of these philosophies are common in education settings, but there are still other philosophies that will not be discussed in detail here. Some examples are positivism, which requires observational or experimental evidence (Boghossian, 2006 & Scerri, 2003), empiricism in which the only valid source of knowledge comes from the sensory experience, and rationalism where the source of knowledge is reason (Driscoll, 2005).

Statement of the Problem

One of the classes I will never forget from my college experience as an undergraduate is organic chemistry. I started college right out of high school. However, I did not take the traditional journey. In addition to taking college courses, I had to work full time to provide for myself, so I decided to attend a technical college first with plans to transfer to the major university in my hometown later.

My college experience was very different since I did not follow the path most students take. At the technical college, most of my fellow classmates where much older than me, and they all worked hard because they wanted to better their lives. For me, college classes were easy. I do not know if this was just the technical college I went to, or if they are all like this, but I did not have to try very hard to get the good grades that I did. The other students seemed to have to work much harder than I did to understand the simplest of concepts, such as fractions, or memorizing definitions. I am not saying the people that went there were unintelligent, just that they had a hard time doing class work successfully. As a result, almost every teacher I had curved the grade tremendously. I had always heard college was all about studying twenty-four seven, with no time for a personal life, but this was not what I experienced at this technical college. Having this experience formed my view of college, which was much different from what everyone claimed it to be.

Before I came to the university, I transferred to a medium sized college. The teachers there did not curve as often, and I had to work a little harder. The students were close to my age or younger, but there were still a good number of older students as well. For the first time ever, I was around students who were not as motivated as the students from my previous school. This changed my view of college a little, but I still felt as if I did not have to do much to make good grades. I could start studying for a test the night before, and make an A without a curve. I was not prepared for what was in store for me when I transferred to the major university.

At the university, almost immediately I realized that I could not get away with as much as I did all those years at the other colleges. I felt I was working harder for worse grades. I also felt even more like the odd person out because now everyone was younger than me even though I was only 22 years old at the time.

I had always heard the horror stories about the organic chemistry courses, such as the almost fifty percent failure rate. However, I have always tried to keep an open mind for any class, and horror stories actually make me want to take a class even more to see what it is about.

When it came time for me to take organic chemistry, I instantly fell in love with it. I adored drawing and synthesizing molecules and learning how reactions took place. Everything about it intrigued me, so I had no problem with motivation to study or work problems all day long. It was like a hobby to me. I studied more for this class then I had ever studied for any other course, and it never bothered me. I knew the material inside and out. The teacher was amazing, and the concepts he taught felt like music to my ears. Next thing I knew, I failed the class. Needless to say, I was very upset, but I absolutely still loved the material more than anything.

So I took the class again. It was with a different teacher, but the material was the same. I went to class, worked twice as hard as the first time, and everything felt like review. I still did not mind reading or doing hundreds of practice problems. I even helped other students who were having a lot of trouble. I had no problem understanding the concepts, but once again, I failed it. Twice! I had never failed a class like that, and to fail it twice! However, as much as I hated making an F, and I hated it very much, amazingly I was still absolutely in love with organic chemistry. I even decided to do some undergraduate research in an organic chemistry laboratory. To this day it is still my favorite branch of chemistry. I was not misunderstanding the concepts; I was just failing, and did not know why. The third time around I finally made it through, but by the skin of my teeth. After that class, I have yet to have that much trouble with another subject.

When it came time to decide what topic to pick for my master's research project, my major professor suggested I do a project on philosophy. This intrigued me because after my experience with organic chemistry, I had always been curious about how and why the teachers taught and graded the class the way they did.

Just from my experience, I know organic chemistry is a subject many students struggle with. It is unlike any other chemistry class in both study methods and the amount of material covered. It also presents a new way of thinking about reactions, i.e. mechanisms. Because of its uniqueness, the professor needs to approach teaching it in a different way.

Chemistry is an important subject because its concepts can be directly or indirectly useful in other fields (Akhlaq, 2010). Chemistry can provide many valuable skills students can use in other areas or even every day life. Organic chemistry is particularly important because it can be applied to many branches of chemistry such as biological chemistry or materials science (Bhattacharyya, 2008).

Many college professors who teach the sciences do not hold a teaching certificate, nor have they had any teacher training. They obtain their degree in whichever field they want to work in, such as chemistry, and gain plenty of conceptual knowledge. They gain little to no teaching knowledge or practice, except for what they may observe from their own experiences as students. They usually have adequate content knowledge on their subject matter, but may lack the ability to properly convey it to students due to the lack of teacher training (Davidowitz & Rollnick, 2011). Conveying the concepts in a way the students can understand is important for student success.

Purpose of the Study

The purpose of this study was to investigate the relationships between teaching philosophies and methods in undergraduate sophomore level organic chemistry. It investigated three professors who teach undergraduate organic chemistry in large class settings at the same university in the southeastern United States. This study also compared the professor's teaching methods with their teaching philosophies, and compared the philosophies and methods to each other.

The main questions that guided this study were:

1) What philosophies, if any, do chemistry professors have that influence their teaching of chemistry?
2) How do teaching philosophies lead to different teaching methods in different levels of college chemistry?
3) How is the teaching philosophy reflected in the teaching?
4) Is the professor's teaching philosophy the same when lecturing and in the laboratory?
5) How do teaching philosophies and methods vary between different professors in organic chemistry?

This study could be helpful in determining what philosophies are important for teaching organic chemistry. The professors could benefit by gaining a better understanding of how their teaching philosophies relate to their teaching methods. This research may provide teachers with alternate views and methods on how to convey such a difficult subject to students.

It may also motivate the professors to compose their teaching philosophy. Creating a written philosophy requires time to gather, assimilate, analyze, reflect upon, and evaluate thoughts on teaching and learning (Friesen, 2002). Having a written philosophy may give the teacher a better understanding of what works and what does not work. It can provide insights to both the professor and others on how they teach and how the way they teach impacts student learning (Friesen, 2002).

Educators are always looking for ways to improve the quality of their teaching to better benefit the student. Reflecting on their philosophy can give them an idea where change might be needed. Knowing what lacks in teaching is one thing, but it is another to be able to enact a philosophy that works for you and your classroom.

Operational Definitions

Behaviorism: Educational philosophy where students can be conditioned to perform certain behaviors (Boghossian, 2006).

Constructivism: Educational philosophy in which the main idea is knowledge is constructed (Carson, 2005).

Pragmatism: Educational philosophy where learning takes place within the student (Raij, 2012) and students learn by doing (Antz, 1976).

Teaching philosophy: A teacher's views and beliefs on teaching and learning.

CHAPTER 2

REVIEW OF THE LITERATURE

When first reviewing the literature, the subject of philosophy of chemistry surfaced frequently. This should not be confused with teaching philosophies in chemistry. According to Erduran (1999), the philosophy of chemistry is an emerging and distinct field in chemistry. She states the history is generally included in the chemistry curriculum, but very rarely do you see philosophy. She believes that it is important to link chemistry with philosophy to be able to distinguish chemistry as a distinct branch of science. Erduran (1999) was concerned with "aligning chemistry education with the emerging arguments for granting chemistry a distinct epistemology where models play a key role." The main example she uses is the use of models in chemistry education. The author disliked the perspective many teachers have about using models in chemistry, particularly the use of concrete models for the student in the concrete operational stage, to gain an understanding of the concepts. She felt more time needed to be devoted to the teaching and learning of chemical models. Erduran (1999) uses "models in chemistry to elaborate on how development, evaluation, and revision of chemical knowledge through modeling is central to the science of chemistry and should be manifested in chemistry classrooms." Students are usually taught concepts and principles without engaging them in scientific inquiry (Erduran, 1999).

The "cookbook" problem is a major example that does not engage students in scientific inquiry. Erduran, Munby, and Van Keulen (1998) go into great detail about the cookbook problem, focusing on university organic chemistry laboratories. Her book is mainly dedicated to the development and implementation of laboratory instruction, which focuses on student inquiry rather than having them follow a "recipe." According to Erduran (1998), students cannot gain understanding of how the organic synthesis process works when they are following step-by-step instructions. This will not prepare students to perform research in organic chemistry. Erduran (1998) says this is an objectivist approach that needs to be departed from. Objectivist education is a view based on the transfer of facts from textbooks or teachers to students. Erduran (1998) suggests the experiments be based on a hermeneutic research cycle, "a sequence of interpretation, understanding, and application."

Poiniaszek (1989) developed a laboratory experiment for advanced organic chemistry that was more focused on student inquiry. The lab was intended to be used in a third semester organic chemistry class. The intention was to introduce students to methods of product analysis such as high performance liquid chromatography and capillary gas chromatography methods. It steers away from the more traditional way of students determining or analyzing unknowns, and gives them less of a recipe experiment. It was intended to help them feel at ease in graduate level organic chemistry research environments (Poiniaszek, 1989).

Student motivation is another issue teachers deal with everyday. Teachers are always looking for methods to motivate their students. According to Katz (1996), a student who has the ability to succeed, yet does not, is one of the most distressing problems facing teachers. Students may have weak motivation or a lack of self-discipline, which results in their poor achievement. She suggested student-directed learning as a way for the teacher to get the student to adopt a different set of learning techniques or strategies. Katz (1996) defines four common mistakes teachers make with their students: failing to appreciate the impact of emotions and attitudes on the learning process, failure to acknowledge the level of study skills required to succeed in organic chemistry, not accessing student performance accurately, and doing too much for the student. Student directed learning is meant to avoid those mistakes while developing student independence (Katz 1996).

Akhlaq (2010) was interested in the effects of motivational techniques used by teachers in undergraduate chemistry. The three goals of his study were to:

1) Identify the motivational techniques used during the teaching of chemistry

2) To investigate the effectiveness of traditional method of teaching and selective motivational techniques on the learning achievements of students, and

3) To compare the degree of effectiveness of teaching with motivational techniques and through traditional method on learning achievements of students in the subject of chemistry.

Akhlaq (2010) defined motivation as "a student's willingness, need, desire and compulsion to participation in, and successful in the learning process." He describes the functions, process, and sources of motivation. He emphasizes the factors that effect student motivation: parent involvement, teacher enthusiasm, peers and social environment, experiences of the learner, attitude, and competence. Akhlaq (2010) suggests important techniques to increase student motivation: praise, arousing interest, rewards, competition, and creativity. Akhlaq (2010) puts a lot of emphasis on motivation because he believes there is a strong link between student motivation and learning, stating that "students learn material they find interesting and challenging." The study used the pre and posttest technique with both a control group who were treated with traditional teaching and the experimental group where the teaching used his suggested motivational techniques on university students. Akhlaq (2010) concluded the learning achievements of the experimental group were better than the control.

Kane (2002) stated “research into teachers’ beliefs, conceptions, attitudes, orientations, (personal), practical theories, and implicit or subjective theories about teaching is grounded in the understanding that these concepts drive teachers’ practices.” There have been several studies that focused on teachers’ beliefs. Laplante (1996) explored how a teacher’s view of his or herself and their students influenced their classroom practice. He stated studies that could successfully establish links between a teacher’s beliefs and strategies used semi-structured interviews in the methods. According to Laplante (1996), students are “receptors of knowledge already constructed by others and transmitted by the teachers. They do not see themselves as inquirers in science, but rather consumers of knowledge.”

Vaino (2009) conducted a study to describe the beliefs of five chemistry teachers, mainly related to thinking and decision making in the classroom. Her goal was to identify these beliefs and determine if they could be changed. She hoped to shift traditional teaching styles into a style that emphasized student’s extrinsic interests. She discussed Fishbein’s Theory of Planned Behavior, which breaks down a person’s beliefs into three basic factors: behavioral beliefs, normative beliefs, and control beliefs. She sought the possibility to identify these beliefs, classify them as positive or negative, relate them to core and peripheral beliefs, and determine the usefulness of identifying beliefs that are unclear as emerging beliefs. She purposively selected five teachers in a district in Estonia. Vaino (2009) found all three of the beliefs could generally be identified and categorized as positive or negative. In general, negative attitude toward behavioral problems could be changed in a positive manner. Also, the beliefs could be interpreted as core or peripheral beliefs when they were beliefs prior to an intervention. Vaino (2009) believed the implications of this research could guide the teacher to incorporate peripheral beliefs into their teaching practices.

Al-Amoush and Markic (2011) did an exploratory study of both student and experienced Jordanian chemistry teachers' general overview of their beliefs. They mainly looked at what beliefs the teachers held, and what similarities existed between the in-service teachers and the pre-service teachers. Their study was both qualitative and quantitative. The qualitative part consisted of having the teachers perform the "Draw-A-Science-Teacher-Test Checklist" and apply it to open ended questions about the teachers' activities. The quantitative part consisted of a Likert questionnaire on the teachers' beliefs about the nature of good education and organization of teaching practices. They concluded from the drawings that both the pre and in-service teachers held traditional teaching beliefs in chemistry teaching, but the Likert questionnaire revealed the teachers valued more modern beliefs. In general the teachers understood learning is more than just memorization. They also found that student teachers tended to have more traditional beliefs than the experienced teachers (Al-Amoush, 2011).

Farré and Lorenzo (2009) focused on the beliefs, practice, teaching, and learning of the nature of science in first year college chemistry. They believe teacher beliefs develop from their personal experiences. They presented a case study about the relationships between beliefs and practice in higher education organic chemistry. Their emphasis was on the nature of science stating "the majority of works have teaching and learning as their main interest, but not the nature of science" (Farré, 2009). Their sample was four female organic chemistry teachers. This study used discourse analysis as the main research method to infer the teachers' conceptions and beliefs. They contrasted those teacher responses to a conventional questionnaire. Each statement of the survey used in this author's study referred to two models, traditional and constructivist. The traditional model mainly included the empiricist-inductivist philosophies.

Farré (2009) found that the four teachers they studied all expressed constructivist ideas, but practiced traditional positions.

Bektas, Boz, Kirbulut, and Uzuntiryaki (2009) conducted a study that explored eight pre-service chemistry teachers' beliefs on constructivism and how their beliefs influenced their teaching practices. The methods used were purely qualitative. They conducted semi-structured interviews, observed each teachers class, and collected lesson plans. The interviews were to gain an understanding of what each teacher believed about constructivism and other beliefs about learning, the role of the teacher in the classroom, and teaching strategies. The lesson plans were used to see each teachers intended objectives and strategies prior to teaching. They conducted observations to see if the teachers' beliefs were reflected in their instruction. They broke the beliefs down into three categories: weak, moderate, and strong views of constructivism. Their findings showed that most pre-service teachers had either a weak or moderate concepts of constructivism. They also found the teachers beliefs stated in the interviews were not reflected in their teaching, with few instances that did match. Many of the interviews contained beliefs of constructivist teaching, but their instruction did not reflect this. Rather, they reflected more traditional beliefs. A teacher with a conception of constructivism was more successful at integrating his beliefs into instruction (Bektas, 2009).

Davidowitz and Rollnick (2011) also did research on organic chemistry teachers' beliefs and methods. They were curious to find out "What lies at the heart of good teaching in undergraduate organic chemistry" (Davidowitz et al., 2011)? They focused on one professor whose students were very successful. Their methods were to observe his teaching strategies to try and determine the root of his students' success in the subject. They observed him for the first week of the class to see how he conceptualized the content he taught, what he considered the Big

Ideas in introducing organic chemistry, how the teacher used analogies, representations, and explanations, and why he was motivated to teach the way he did. During the first five lectures, the professor covered topics fundamental to understanding reaction mechanisms (Davidowitz et al., 2011). From the observations and the interviews, Davidowitz et al. uncovered three Big Ideas the professor focused on:

1) The stability of carbocations depends on the nature of the species attached to the electrophilic centre.
2) Three-dimensional structures of organic compounds can be represented in multiple formats, each of which highlights specific characteristics of the molecule.
3) Stereochemistry has a profound effect on the nature of the product in an organic reaction.

Davidowitz et al. found the professor used these Big Ideas in explanations. When discussing problems with students and representations of the molecules, the professor believed that drawing structures on the chalkboard versus using a PowerPoint presentation was more effective. The professor deemed interaction with the students as useful in gauging whether or not the students were understanding key concepts, but Davidowitz et al. found that during the lectures there were instances where students would ask questions, but the professor seldom asked them questions (Davidowitz et al., 2011).

Conclusions

Teaching philosophy is a subject that can frequently be found in the literature. According to Farré (2009), there is a fair amount of research on teachers' beliefs at the pre-college level, but the university level is underdeveloped. There has been many studies done at the primary, and secondary level of teaching, and even in chemistry, but few studies have been conducted at the tertiary level (Davidowitz et al., 2011). There are even fewer detailed studies on the professional practice of university lecturers (Davidowitz et al., 2011). Davidowitz et al. (2011) is one of the few detailed studies that can be found for college organic chemistry. This was a case study looked at one professor in great detail, providing insights to the professor's methods.

The majority of the research focuses on mainly on general chemistry not organic. The "cookbook" method is common in the laboratory, which involves using experiments where the student essentially follows a "recipe" (Erduran 1998). Although teacher beliefs have been the focus of many studies, teaching philosophies in organic chemistry is mostly not explored.

CHAPTER 3

RESEARCH METHODOLOGY

Data Collection Methods

This research project focused on a specific situation and subject matter. Therefore a random sample, a sample selected so that one member of the population does not affect the probability of selecting another member, was not used (Jurs & Wiersma, 2009, p. 478). For the results to be relevant to the purpose of this study, I selected a purposeful sample, more specifically homogeneous sampling (Jurs, 2009, p. 345). Homogeneous sampling focuses on a specific subgroup where the group is essentially alike. In this study the subgroup would be professors who teach undergraduate organic chemistry in large class settings at the same college.

This study was conducted in the Department of Chemistry in a large university in the southeastern United States during the spring semester. The participants of the research study were three male professors who were teaching organic chemistry during the current semester. These were the only professors teaching the course at that time. At this university, undergraduate organic chemistry is broken up into two semester long classes.

The first step was to obtain each professor's teaching philosophy. My methods involved asking each professor several semi-structured questions about their teaching philosophy and methods in a face-to-face interview. According to Seidman (2006), the purpose of an interview is to understand "the lived experience of other people and the meaning they make of that experience" (p. 9). A set of interview questions (Appendix A) were created before the interviews took place. They consist of five main questions, with each question having more detailed sub-questions if time allowed. They are open-ended questions because "the goal is to have the participant reconstruct his or her experience" related to the study (Seidman, 2006, p. 15). It allows the participant to answer the question taking any direction he or she prefers (Seidman, 2006, p. 84). These questions were used as a general guide, allowing myself to ask probing questions or request additional information if necessary in order to obtain clearer responses if the professor said something that deemed it necessary.

The interviews took place during a time that was convenient for the respondent. The time allotted for each interview was flexible, allowing the respondent to talk as long as he needed. During the interview I asked the professors to provide me with a written teaching philosophy if available. I also requested the professors' lecture notes, presentations, and copies of their tests if they were willing to distribute a copy. Each interview was recorded via an audio device.

The next step was to attend each professor's lecture and observe their teaching style and methods to see how it matched up to what they said in their interview. I attended two lectures for each professor. During this time, notes were taken regarding teaching methods used, how the teacher conveys the concepts, and if the teacher's philosophy is evident in the teaching. The lectures were also audio recorded.

After the observations, I set up a post interview (if the participant was willing) to ask any follow up questions about the pre-interview as well as any questions that were not addressed during the first interview due to time constraints (Appendix A). The observations were also discussed as well as any questions that were generated during the lecture. These interviews were also audio recorded.

Data Analysis and Interpretation

This research project was solely a qualitative study, because it relies completely on narrative data (Charles & Mertler, 2005, p. 29). All of the data that results from the analysis will be verbal since this is a qualitative study.

I started out by transcribing verbatim all of the interviews, pre and post. I then took each interview, read through them, and marked passages that were significant of interest or the most compelling. I made a copy of the transcripts so I could cut and paste (with a word processing program) to organize the passages by the questions that were asked. The original copy was kept intact to be used as reference. Next, I developed a profile for each of the three teachers with these passages. I used Seidman's (2006) approach to creating a profile (p. 120). Seidman (2006) believes that a profile "is an effective way of sharing interview data and opening up one's interview to analysis and interpretation" (p. 120). The profile is written in first person in the words of the participant. If the sentence is in my own words, or clarified, then it is noted using brackets. Any actions the teachers performed are designated with braces. To present the material clearly, hesitations such as "umms," "ahs," and "you knows" and repetitions have been omitted. Names of the teachers or places they refer to have been omitted for confidentiality.

For the classroom observations, the entire lecture was not transcribed. Instead, I listened to the audio a select number of times and only transcribed the areas that seemed important, or which would be relevant to what the teacher stated in the interviews.

To facilitate ease of finding a topic the teacher was speaking of, I coded the data. I marked on the printed transcript in the margins words that I felt summarized what the teacher was discussing (Rubin & Rubin, 2012, p. 192). I also highlighted words that were repeated frequently by each professor. The literature defines the terms coding, categorizing, and themes differently. Seidman (2006) defines coding and classifying as the same thing, “the process of noting what is interesting, labeling it, and putting it into appropriate files.” Brinkmann & Kvale (2009) explain there is a difference between coding and categorizing (p. 201). According to Brinkmann (2009), “coding involves attaching one or more keywords to a text segment in order to permit later identification of a statement” (p. 201). He defines categorization as “a more systematic conceptualization of a statement, opening it up for quantification” (p. 201-202). Coding is essential for putting the text’s meaning into a category which makes it possible to see how often themes are addressed (Brinkmann, 2009, p. 203).

Examples were coded whenever the teacher used the phrase, for example, “let me illustrate what I mean”, or some variation of that, and what it was example of what coded. Once I was done coding, I searched for connecting patterns in each category. Finally, I worked out explanations for what is described in the interviews to answer my research questions.

CHAPTER 4

SUMMARY OF FINDINGS

This chapter is divided up into subjects that were discussed. Each subject is separated into the three teachers that were interviewed. Teacher C's responses were not as lengthy due to time constraints. He was only able to meet with me for an hour. The background information on the three teachers can be found in Table 1. Lecture notes and exams for all three teachers can be found in Appendices B-F.

Table 1.

Background Information

	Years Teaching	**Teacher Training or Education Classes?**
Teacher A	**7 Years**	**No**
Teacher B	**20 Years**	**No**
Teacher C	**5 Years**	**No**

Views on Philosophy

Teacher A

[Philosophy] is very [important when teaching chemistry]. [My philosophy] would be one of inclusion. It would be one of questions. It would be one of interaction, as opposed to just lecture. I've fallen asleep in my share of lectures where you're just being lectured to.

Organic, for a lot of students, is quite a hurdle, and if we approach it simply from a lecture standpoint of just throw out the information and tell them, “Hey, just absorb it and regurgitate it back on a test,” we know that the success rate is almost nil. Organic is one of those first science courses that people take that is truly applications based. We don’t just show you a picture of a hammer, a screw, a nail, and a piece of wood, and then on the test show you those same pictures and say, “Identify,” where it’s just regurgitating fact. Instead, we tell you what each of these is used for and then on the test we say, “Now use them. Now build a birdhouse. Now build a doghouse.” We give you the pieces that are necessary, and then the assembly is up to the student.

I encourage a lot of questions in class, if possible. Now, there’s a balance to that. If you have everybody asking a question every five seconds, then obviously you can’t get through the volume of information. We have to find some balance between a good number of questions. We don’t want to have *no* questions, because that means that everybody just stares at me numbly and furiously writes down what we try to give them.

We try to circumvent that mentality, the takes-notes-first-and-then-understand-it-later mentality by giving the templates out, by saying, “Here is a portion of the notes, and then you fill in the little bits that I’m filling in on the white erase board.” Of course, I went to school before PowerPoint, before all that stuff, so the presentations we had were either overhead, which meant you had to furiously write down everything on the overhead, or it was chalkboard. [Someone who uses exclusively the chalkboard is often] ambidextrous: they write with one hand and erase with the other one, so if you’re not keeping up with them, it’s crazy.

A lot of people use PowerPoint. I’m thinking about switching over to PowerPoint. I’ve been using the Smart Board slides, which effectively are the same thing. PowerPoint has a little bit more style to it, looks a little bit more polished, but in terms of what you can present, it's no different. We don't embed a lot of videos. We do pictures, but anything can hold a picture file. So Smart Board is just an electronic white erase board. I just fill in [the templates] and they write along with [me]. That means that they can sit back and still think about the information that's being presented to them. This semester, I've actually got quite a few really good, forward-thinking questions. Without interaction there, I know there are a few discussions I've had with my class this semester that I never would have had.

When the students are coming back at me with their interpretation, it improves everything. I just had a discussion with a student this morning. He came in and had asked to meet me outside of class because he is afraid to ask questions in class. He doesn't want to feel "stupid." Of course I make the point that there is no reason to feel stupid. Sometimes the questions that are "lower end," [the ones that] show that the person doesn't truly understand the concept, are the best ones, because half the class is going to furrow their brow [and] the other half is going to say, "Well, it's reasonable what he just asked."

We have a silent majority, probably, that [doesn't] want to ask questions because they're afraid of feeling foolish. I try my best to not be nonplused when a question that's completely out of nowhere hits me, because [the question] does show that maybe there's some misconception, and we try to address that. I think the students are starting to realize, "Hey, I'm not going to be talked down to. I'm not going to be told that I'm wrong, and how dare I ask a question like that," which, unfortunately, it sounds like they've had that situation or had that experience in other classes. [Student questions are] the only way I'm going to know [where the class is]. Otherwise, I'm going to teach at the level that I normally teach, and if I don't know that I need to back it down a notch and shore up a few fundamental concepts before I can go back up [to my normal level]. Otherwise, we've got a whole section of the class that is left in the dark. I really would prefer [to] get the questions from the students that are having a more difficult time, because then that tells me what's working and what's not as far as the way that we're teaching. But unfortunately, they typically are the silent majority.

So [my philosophy is] an inclusive philosophy, an applications-based philosophy, which [means] we learn our facts, now let's do example, let's do example, let's do example. Rules can be clearly listed out point by point. What a lot of students do is they memorize those rules and say, "I'll figure it out on the test. I've got all the rules, it can't be that hard. I'll just apply the rules." Sometimes those rules are difficult to follow, given a specific situation on a test, so you've got to have repetitive examples. We try to foster that sort of an environment in class. Compare that with the questions, and the more examples we do, the more questions we have, which is great. If I'm just lecturing on the base material, I don't get that many raised hands, but when we start doing examples, then all of a sudden the hands come up and people start to get more interested: "Wait a minute. I thought it would react this way. What's the reasoning?"

Teacher B

Teacher B took two minutes and forty three seconds to think about my question before answering. He commented on how hard a question it was.

It's fair to say that I do have an underlying philosophy about education and teaching. When I read through applications, either for faculty positions or various scholarships, oftentimes there will be a request for a teaching philosophy. I've read a lot of them; I've even been asked to generate some of them. A common theme in all the teaching philosophies that I've read and [generated], [was] the purpose of teaching is to be able to effectively convey knowledge so that students can understand a framework to be able to continue to learn on their own.

Sometimes students feel like what professors are supposed to do is just crank open the cranium, dump in information, and then suture it back up again. In some respects, I guess we foster that because [of] the way we teach. [Posting lecture notes online] is a way for students to not be fully engaged. They think, “Oh, that means I don’t have to attend lecture today because ...” I’ve had students tell me this so often, I can’t [count] the number of times. “I don’t have to attend. I don’t have to be engaged because the notes are all up online. And all I need to do is just look at some other practice exam that a professor puts up or I’ll look at a previous exam because all of the current exams are just recycled questions taken from this and so if I go through enough of the exams, I will have seen all the questions.” When we [post notes and old exams online], we’re teaching students that they don’t need to learn how to analyze, they don’t necessarily need to learn how to think, they only need to learn how to memorize. And I think we do students a disservice. That’s not what the university is all about. Students have been rehearsing for many years and practicing their memorization skills. By the time they come to the university, they need to be doing more than just memorizing. They need to be analyzing.

Our lecture is to sometimes 375 students [and] it is a real effort to try to get them all engaged. And you don’t. Sometimes you can’t do it. Just today, I was lecturing, I was watching, and I was thinking, “Am I going to let that push my button or not?” Because way up at the top of the lecture on both sides I saw students just chatting away, hardly paying any attention whatsoever, being partially engaged. They’d stop talking long enough to think, “Okay, I’ll write this down,” and then they’d go back to talking. So they’re not following the logic. They’re not making sure that they really assimilate it in their minds. “Well, I’ll just write it down and then I’ll learn it later.”

I want students to be thinking. Sometimes there is a difference between thinking to memorize and thinking to analyze. There's a clear difference. Particularly in Organic Chemistry, it seems that students come up against this and many of them will say it's the first time they've ever encountered it. I don't mean "this" in terms of the discipline Organic Chemistry; I mean "this" in terms of the thinking that they have to do. They've never had to worry about it. They've learned how to memorize certain things, and that has served them pretty well, and they continue to do that here at the university. This is what students tell me. I don't sit in on other classes, so I can't speak from personal experience in that regard.

They tell me that this is the first time they've ever been forced – not in a negative way – but they're brought to the point where the skills they've mastered in terms of memorizing only gets them part of the way through mastering the material. The rest of it they have to learn how to analyze. They have to learn how to puzzle solve. They have to learn how to take this piece of data and this piece of data and this piece and put them together and make a coherent diagnosis, which is what many of them are going to be doing anyway when they take this class and they head on into medical school. They've got to be able to look at the various seemingly disparate facts that they're presented with by a patient and come up with a coherent diagnosis. It's an analysis.

My teaching philosophy is that I'm trying to help them to learn how to learn, to learn how to analyze things, to do more than simply memorize. I recognize that [most of] these students are not chemistry majors. The vast majority are Pre Meds, Pre Pharms, Pre Dents, Pre Vets, and pre professionals of that type. I'm fully aware that when they're in their professional careers they're not going to be reaching for their organic chemistry textbook and saying, "Now wait a minute, how did I do the such-and-such reaction?" They're not going to be referring back to the reaction types, pathways, or names of things in order to analyze correctly or to solve the problem that's before them, but they're certainly going to draw from those skills. And if they never learned the skills, it's going to be very difficult for them. At some point, they have to learn them, because memorization doesn't get them all the way to being the professionals that they're aspiring to be. So I'm trying to teach them how to learn and to find real satisfaction in learning.

It's not as if I have a teaching philosophy that I have written down somewhere and I read it every day to myself before I go to lecture, like my mission statement. I don't do that. But I do feel very strongly about teaching university students that what they're here to do is learn how to learn in a different way. I suppose it does govern the way I go into the classroom, the way I interact with students.

<u>Teacher C</u>

I teach mostly organic. I teach a graduate course in Polymer Synthesis and a couple of Engineering courses. In Engineering, I teach equilibrium, thermodynamics and salt materials. Essentially, every one of those requires a [slightly] different philosophy. My overall philosophy is to really challenge and push the students in every class. I think that is my job. I'm here to make the student better, this university better, and to increase our standards always. My goal is to challenge you, such that if you were taking Organic, you are going to be able to take and finish organic anywhere in the country, in the world with the same standards. I think that reflects the way we perform on the standardized exams.

In terms of teaching philosophy, I don't think there's one formula that works. I think that providing examples [and] relating the material to the real world helps. It's difficult because in organic, we have sort of this regimented amount of material to teach and the class is very fast paced. There is very little time to deviate too much in terms of the material, because we have a fixed amount of material that most students need. Most students are Pre-Med, Pre-Vet, Pre-Pharmacy, Chemistry, Biology, [and] Biochemistry majors and they want to do well on whatever the "pre" entrance exam is, MCAT, PCAT [etc]. We try very hard to get through all of the material that will allow them to perform well on that. That leaves very little wiggle room for too much deviation.

Honestly the last time I thought about teaching philosophy is when I applied for positions six years ago. You write this teaching philosophy and I think that it, it really depends on the students, the context of the class, and the context of the material. It's my job to do whatever I can to get the material across to the student. That requires different motivations, just like in research, when you work with different students. [You] have to push different buttons, you have to challenge in different ways, and I think being able to be flexible, and to realize that early, is the most important thing.

Reasons for Teaching

Teacher A

I actually went through grad school, like anybody else. The nice thing about science is that typically you [don't have to] pay graduate school because you're [a teaching assistant] the whole time. I had a professor that was under funded, so we ended up teaching [lab] every semester I was in grad school. For some, [that] was infuriating, but I found that I actually enjoyed the interaction. I liked being able to explain a concept to a student. We teach lab, and lab can be rewarding and frustrating at the same time because you're doing the same experiments over and over and over again, so it gets a little boring. You have a lot of different students. You have some students that are right on their game, know exactly what they need to do. You have other students that are goofing off and are in dangerous situations. So teaching lab is very different from lecturing, but it still can be rewarding.

I don't think [my enjoyment of teaching] really took hold until I started actually teaching the lecture. That happened by accident. My PI, the guy that I worked for, went out of town for a couple of weeks and I took over his class for about four lectures, and something about it just kind of caught hold. I just enjoyed it. I came from [a small] university [that] was 2,500 people. So my huge organic class that I thought at the time was bursting at the seams because we had to add two extra desks to the room, was 30 people. It was huge! When we were absent, the professor would ask us about it the next time. He'd say, "Hey, you weren't here, [Teacher A]. What's going on?" When I came into that room, I felt like I was standing up on stage telling people "the movie will start in a minute." But it actually turned out to be kind of interesting. The number of people didn't matter and the interaction was higher.

I ended up liking the interaction. I liked the different ways in which the students approached the material. I liked trying to find different ways to teach them because the standard line wasn't working for everybody. Then I was graduating and getting ready to move to Atlanta to look for jobs. And the department head came into our lab one day and said, "We've had a problem. We have somebody that isn't going to be here this summer. Are either of you two (and there were two of us [teaching assistants]) willing to take a class for the summer?" This was Chem One. And I said, "well, why not?" I didn't have anything immediately pressing that I was going to do; I was just in the process of moving, but I could look for jobs and move at the end of the summer just as easily as I could at the beginning. I ended up starting [teaching]. [It] just kind of caught hold, and I've been here ever since. It was kind of crazy.

I think it was the interaction, talking with the students, [and] trying to figure out a way to make it digestible to different individuals. I don't think I've found one tried-and-true method for everybody. There always seem to be a modification that's involved. Even though it's the same material over and over again, it doesn't get stale the way that some might expect. It actually is still interesting because I try and teach through metaphor. Giving examples and comparisons, using sports metaphors or just general life metaphors to try to explain some of these chemical processes can be fun. That seems to go over pretty well. I get positive feedback, and from some of the folks that it's helped the light bulb goes on and the connection is made. That's quite something.

I like clarifying. I like the light bulb going on. I like seeing students that were at this level{holds hand down low}, now all of a sudden achieving at this level{holds hand up high}. Sometimes it works, sometimes it doesn't. Teaching can be the most rewarding and the most frustrating thing that you can ever do, for that reason.

<u>Teacher B</u>

I enjoy teaching. Yeah, there's a real satisfaction when you watch someone's countenance change. I had a student come in here last week who was in [my] class last year. [She] worked really hard, and was pushing it really hard. This was a student who was very capable, had made it all the way through high school, and to this point in her university career without really ever having learned how to study. She was very bright, and she knew it, as a lot of these students do.

[The students] come to a point in this class where now, all of a sudden for the first time they have to learn how to study, how to figure out, [and] how to solve problems. Before, they had enough capacity that they could all just handle things in RAM. Now, they can't do it anymore so they're having to learn how to learn in a completely different way. There are students who come in here and there's a whole lot of boo-hooing and crying, and it's the first time they've ever run into something where they haven't known how to get through [it]. They don't really say it quite this way, but really what they're saying is, "I thought I was really smart, and now I'm thinking I'm not very smart." And I think, "Whoever taught them that? That to be smart means you're never challenged? Or you never have to work your tail off?" And they hear these things, they hear what Einstein said, and yet they never really assimilate it. I mean, genius is 99% perspiration, according to Einstein, and only 1% inspiration. You have to work your tail off, but when you do, you get these insights. That doesn't come without a significant investment.

So last year [this previous student and I] spent a lot of time in office hours, and she did a lot of crying because [organic chemistry] was pushing her really hard. Well, she ended up getting an 'A' in the class. She told me she had to leave [after the last day of classes], so she didn't stay here in Athens long enough to even see her grade. She checked her grades when they were posted [while] she was away, and she said she just started screaming and everyone around her wondered what [it] was all about. She was so excited she had done well. She came back here just the other day, and she was so happy that she had been through that experience. And you think, "Holy smokes!" There were times last year that you never would have guessed that this would be where she was. And she just thanked me profusely, over and over again. She was thanking me for showing her how to approach something for the first time that seemed to be getting the better of her, and learn how to master it.

That feeling, that confidence that comes, it sets you up for life, that you can meet any challenge that comes your way, but you can't do that until you test your fortitude. This class is the first some of these students ever test their mettle. What's really satisfying is to watch them when they see what they're capable of doing, because they've seen the devil, in their eyes. A lot of them come with these horror stories they hear about Organic, [but afterwards] they kind of say, "You know, but it was actually one of my favorite classes. Don't tell anybody!" It's really satisfying watching people when they realize what they're really capable of. They don't get that if they're just memorizing lists of things.

I couldn't do this if I didn't enjoy working with students and enjoy them, and enjoy the thrill of seeing them master something that's very difficult. I couldn't do this gig. I'd have to be a bench-top chemist somewhere.

One thing that makes me really happy is that I have students who year after year after year come in to tell me that they just took the MCAP or they just took the PKAP, or just got their results, and guess what section they scored the highest on? Or guess what section they didn't have to study because they knew it better than the Kaplan tutors did? It's organic chemistry. To me, that says we're doing our jobs. They're not having to pay twice to get what they should have paid once for. They're getting an education here. And if I'm giving them every opportunity, I feel good about that.

Teacher C

I really enjoy when a student grasps a concept that maybe they've struggled with for a long time. That's probably one of the most enjoyable things that you can do. When they realize, "Oh, that's how to do it!" or you realize that you've gotten that across, that you've pushed that student and their understanding and you've changed the way that they view science, that's what its' there for. That's what I'm there for. I really enjoy influencing the student and there is probably nothing more gratifying than the student realizing and doing well in the subject. Plus, I like to talk.

Research Interests

Teacher A

I don't [do classical research]. I lecture and coordinate the labs. I guess technically [I] research lab development. So it is research based, but it's not the classical research, which is more the privy of the research faculty. Mine is education based, it's "Hey we've done these same reactions in the lab for many many years. Why don't we try something new? Why don't we do something new and novel and put it out there for the students to work on?" You do have to research [on] that because an idea doesn't always translate into a good experiment. We've found that out many times. We've got an idea for how we want to proceed, but it doesn't always pan out. [However], I'm not grant [or] paper driven [or] anything like that.

Now, I do more of a chemistry-education focus, which hopefully means that I know my way around a classroom and that I know what I'm doing when I'm talking to the students. I make that a focus, a part of personal growth, personal training, where I go out and I look for effective techniques for teaching. Whereas, there are a lot of people at the university level that focus primarily on research. They teach when the have to, the two obligated teaching assignments per year. Some of them are naturally good at it, others are very good researchers, very knowledgeable in their field, but they just don't speak the students' language, and don't try to, essentially. If I went into the class and expected everybody to understand every single thing that we talk about, I wouldn't be a very effective teacher.

Teacher B

[My research interests do shape my teaching.] As a matter of fact, they kind of help each other, because one of the research projects we've started on is one that came as a result of a problem we were working with in one of my lectures. We decided we were going to take it on as a research group and figure it out. It was one of these problems that hasn't been solved. We're making some headway on that. Alternatively, we took on another research project, and it's been very fruitful. We're getting some really good results, and because of that, I've been able, this semester, to show some examples where it was related to what we were teaching, or what we were covering in the lecture, saying, "We've just been doing this," and give an example that's coming right out of our lab that hasn't even been published yet. It's just a couple of weeks old. They kind of like that, like they're the first to hear of some really new, interesting approach. So yeah, they do complement each other.

Teacher C

As I went through the tenure process, I have a committee of a few professors that are more experienced, that act as mentors to evaluate and give me tips on my teaching. In science, a big part of your [job is] running a big research group. You have to be able to effectively communicate your research to the community. So to be a successful research professor, you have to be a good salesman, a good speaker, a good communicator, and I've gotten a little out of training in that area and I think that really carries over into my teaching.

Philosophy in the Lab

Teacher A

We talk about a lot [of topics] in lecture but it's all theoretical. In the lab they've actually got their first opportunity to do practical application of [the topics]. Some of the things that students have difficulty grasping in lecture is the idea of a multi-step reaction, [i.e.] where we say [for the] hydroboration [reaction], step one [has] one BH_3 and THF and then [step] two [has] hydrogen peroxide and sodium hydroxide [as reagents]. They tend to blur out [step] one and two. They're like "As long as I've got the reagents there it doesn't matter if I've got the one and two." The lab is our opportunity to show them "Hey if you don't pay attention to what's added at what stage, oops your reaction failed. Why did it fail?" You have to go back and theorize as to what happened. We're training people to be bench scientists to a certain degree, getting [them] use to taking notes, recording observations, [and] keeping a notebook. We're letting them see some of the reactions that they've talked about in action, which is always good so they can get a sense of what works [and] what doesn't. It's more along the methodical pathway as you have to read and do exactly as instructed in order to get the final product.

The nice thing about lab is that you know when things don't work out. We do our best to use reactions that are fool proof, much more so than you'll ever find in a research lab. Ninety percent of the reactions you do in graduate school fail and ten percent are successful. That [ten percent is] what your thesis is based on essentially. [However], that's not the way it is in undergraduate, ninety percent [of reactions] should work. In reality one hundred percent of the experiments [should] work, but [it is] ninety percent because we got ten percent of the students that tend to find the kink in the armor or some sort of problem.

[When this happens] we say "Alright fine, it didn't work. If you can tell me why it didn't work and what happened then you don't have to worry. You're not getting an F on the experiment." It's about that deductive reasoning that says "Ok, well if I did something wrong, [and] I can figure out what it was [then] I can speculate on how I could have changed that."

Then they can still get a majority of the points. It's focusing them on observation, critical thinking, things like that essentially.

<u>Teacher B</u>

We're trying to [use the same philosophy for the lab portion of the class]. For the main sequence instructional labs, it's really hard to do because you have to design experiments that are going to get results. There's nothing harder on the students – and harder on us – than to go in and spend 3 hours and get no results. Then [the students] feel like they're going to be graded on what they did for those 3 hours. These instructional labs have to be designed in such a way that the students will get results, or get a cake at the end. You want to be able to see them get the cake at the end. The problem with that is baking the cake is a pretty simple process. You've got the cake mix, some water, and a few eggs; you mix them up, plop them in here, heat it to a certain temperature, and boom, you've got it.

[The labs] tend not to be very challenging, exploring, or adventurous because sometimes with adventure, you fail. That doesn't work very well in this instructional setting, so we have to be careful that we use [labs where the] students are going to be able to get results that they can analyze. [For this reason], the labs have been kind of cookbooky. Right now we're doing a lot of work in revising the labs and developing new [ones] that are a little bit more adventurous, but still have a very high likelihood of success. If the students do what they're supposed to do, they're going to see results. But still, they are not so cookbooky like baking a cake, that there's nothing to think about.

<u>Teacher C</u>

The lab was not discussed with this teacher due to time constraints.

Difficult/Easy Concepts to Teach

Teacher A

[It's] tough [to identify the difficult concepts to teach]. Stereochemistry definitely is one that is tough from first semester because students just aren't thinking three dimensionally. Most everything that we're doing is two dimensional, flat on the page, and [when] we start getting into the three-dimensional aspect it can be very difficult for some students. That's where the molecular models make such a difference. A lot of people don't want to spend the money on them and I completely understand and have no problem with it. [However], I think that once they've tried them it makes a big difference. That is also the reason [we use] the Spartan program. It's a program that we offer for free up in the [chemistry learning center] which essentially is an electronic model kit so you can build things in three dimensions on the screen and rotate them around.

Some of the students use it for studying for lecture. Synthesis is probably the toughest across both semesters. Line reactions [are] simply starting material reagent products, it's one step along the way. When you start stringing multiple reactions together, [synthesis], that's when people tend to have a hard time connecting the dots. The other difficult part is there is no flash card [for synthesis]. Synthesis can be any combination of any reagents, so it can be very difficult for students to…they're not seeing the same reaction. It's not something that they can memorize, right it's amorphous. You have to adapt to it. That part which is the most fun, I think is also the most aggravating for the students because it requires knowing all of your line reactions without a hitch, otherwise you can't do it. You essentially give somebody a bucket of Legos and say, "Ok, well today we want you to build a castle, and then alright the next day I want you to build a space ship, alright the next day I want you to build a boat." They don't know what they're going to be asked to do so they have to understand their building blocks very well.

Teaching line reactions, I don't wanna say it's easy, it really is up to the student as to whether they study them. I can make a list on the board and say this to this, this to that, this to this and feel like I've taught it to the best of our ability. It's what the student takes away and does with it after that point. Synthesis definitely [is] something that is that is tough cause that ferrets out a lot of the consistencies of their line reactions. A student will try and combine something that cannot be combined with that starting material or they start to they show a weakness in their conceptual understanding of various types of reactions.

An example that I'll give you: I saw [a student] studying, and they had alkyne chemistry. {writes on board} We know that sodium amide, that's the base that he protonates the terminal hydrogen on [from] an alkyne., but they would do something like this {draws molecule}. Now we look at this {points at molecule}. We've got an alcohol on one end and an alkyne on the other. What [the student] would do in their synthesis is they would deprotonate the alkyne, then move on, but we know that the alcohol is much more acidic than this terminal hydrogen{points to a hydrogen}. This means that this {points to base} is gonna deprotanate the alcohol not the alkyne. Those are the conceptual misunderstandings that creep in. They'll do that with a Grignard, they'll have an alcohol group on a Grignard, a ketone, or a carbonyl-containing group. If they start [studying] early enough and go through enough examples, they can catch that sort of stuff. [However], if they're cramming for the test the night before, or even a couple of days before, it tends to make it a very narrow focus on what their looking at.

I don't know if I've run across the easiest [concept to teach] yet. The easiest should be nomenclature because nomenclature is a series of rules. If you apply those rules appropriately, there's your answer. Now it's the easiest to teach, but I don't think that the students do as well on it in a test sense as they would like. Again that's where the caveats and limitations of each naming system comes in.

Teacher B

I think it's pretty easy for students to get their heads wrapped around what a reagent [starting material] will do, what product you get from it. They can understand transformations. Putting them together into a logical sequence, starting from [the beginning] and then going through several steps to get to [a] product, [also known as] synthetic sequence, is not necessarily hard to teach, per se, but it's one of those things that is a little bit more challenging for students.

Mechanisms are challenging because oftentimes a student will look at something, and if they can't see all their way to the end, they're completely offset by it. They don't know what to do. [For a] mechanism, you see where the logical starting point is, [and] why [the] two things that are going to react are interested in each other. One's a nucleophile, one's an electrophile; you see where their initial interest is. Then you go to that [first] point. Then you look at the next step. We trace these logic steps actually by following the electrons, because the electrons are the breadcrumbs. You follow those [then] you know where things are going.

I think teaching these logic pathways that come either through synthesis – multi-step syntheses – or multi-step mechanisms, those are hard to get command of. They're not necessarily hard to teach, but they require more effort to help students to see how to tackle them. Most of the time when students see where they can get a toehold, they know how to get to the end. If they can't from the beginning see how to get to the end, then they're offset by it because they think they ought to be able to look at something here and get all the way to the end. They don't trust themselves getting into doing analysis. Here we are back to analysis again. They can't think about how to get into it and get to a certain point in the analysis and say, "Okay, now I see the way." You have to get into the woods to be able to see where the path is taking you sometimes. You can't see the other side. And they don't have enough experience with that.

The easiest [concepts] are the things are the simple one-step, almost like the fill-in-the-blank-type questions. It's a flash-card-type thing. There's a single answer for it. "What reagent converts to this?" You memorize the reagent. You've got it or you don't. So memorization in that sense, that's the easiest type of question. And I suppose it's fairly easy to teach, because you're just saying, "Memorize this reagent. This does this to this and makes that." Learning how to string those together in a multi-step process, logic process, is more challenging.

Sometimes I tell the students, "This is a thing for your flash card library. You have to memorize this reagent. This is what it does." And they acknowledge that. It's like mastering any language. Organic is a language, after all. It really is. Like mastering any language, you have to memorize the name for 'door' or the name for 'desk' or any other object or thing. The usage is the harder thing. Students can learn and they can memorize names of things; they can memorize how to say 'paper' and 'door' in a language, but then they go out of the country and think, "Wait a minute. I don't speak Spanish (or French) at all." That's because they haven't learned the usage. They've learned a little bit of usage by memorizing phrases, so they can say, "Where's the library?" in French. In fact, that's one of the few things I remember from my high school French is "Où est la bibliothèque?" You know, I remember things like that. [It] comes in really handy if when I'm in France [and] I really actually [have] to ask someone where the library is. But if I don't need to ask where the library is, then that has limited usefulness. Being able to take these things and formulate them into something you can actually use is where the mastery comes in, the mastery of the language.

What we're trying to do with these students is get them to the point where they're actually conversant, not just having memorized vocabulary words. It's a big push. I lived in Argentina for a couple of years, so I became fluent in Spanish. I'll have students come to me and tell me that they're in their third semester of Spanish. I'll start talking Spanish to them and they look at me all terrified, like, "You mean you're actually going to speak the language to me?" It's because they've learned some words and phrases, but the usage is something they just are not mastering at all. Here in Organic, we push them to learn the usage and they're not used to that. They have to learn to use this language, not just memorize a few words and phrases. The words, the phrases, things like that are pretty easy to teach and fairly easy for students to learn. All the other elements of language and then putting it together to actually be able to apply it in various circumstances, that's what's difficult. It's more challenging to teach, and it's more challenging to learn.

Teacher C

I think that the most difficult topics are close to the end of the semester when there is more than one possible outcome that can happen in a reaction. For example, if we talk about carbonyl derivatives being used as nucleophiles, like enols and enolates, or carbonyl derivatives being used as electrophiles. I think that gives the students some difficulty because you can have a reaction [that] can have rearrangements. You can have acid-based chemistry [or] you can have nucleophiles and electrophiles that are the same species. That concept is difficult for the students because so much of their study habits, is based on blind reactions, or memorizing this reagent and less to do with, "Why does that reagent do that or why does this happen or what is the mechanism of this reaction? Why do we use this solvent?" When you get to something that has more complexity, this preparation shows. I try to hammer, since day one, that this is going to happen. The class gets increasing more difficult, increasingly more complex as the semester goes, but sometimes it's not taken to heart in the beginning.

There [are] not [many concepts that are] easy. I think the easiest part of this semester or the easiest part of every chapter is the nomenclature. I do not spend much time on [it]. I think that the student can memorize the rules. The part of organic where you can memorize [is] the rules [because] they're fixed. There is really no deviation from those rules. I think Nomenclature is probably the easiest, no doubt. It's always there on the exam basically as a gimme to the student.

Teaching Methods

<u>Teacher A</u>

Because of the [class] size, the way we work mainly is lecture style. [I use the Smart Board to teach], which is just [a computerized] white page you write on. [I give the students note templates to write on as I lecture.] Note taking is a tough one, because when I went through school, we had chalkboard and overheads, but chalkboards were the way that pretty much everybody went. There was no PowerPoint at any stage. When we did seminar presentations, we used flip charts from Office Max. You would draw a chart and then flip the page and flip it again. I don't say that to date myself or to say "Oh in the old black-and-white days," but it has bearing on the way that I approach [teaching] now. The templates are valuable to the students that use them in the right way. The idea here is that I want the student engaged during class. I want them listening to what I'm saying as opposed to furiously scribbling down every word. If they are furiously scribbling, then I never get any questions [and] nobody ever really thinks about the information in class. That's one of the main times that I want them to ask questions as long as it's not excessive. Obviously every professor wants questions, but if they are too excessive then you can't get through the material. The templates are there to have some of it filled in so that they can go in and fill in the rest, as we are drawing structures and what not. [General chemistry] does PowerPoint presentation[s], where everything is already written out. They just jot a few notes down in the margin. In organic, practicing the structures, practicing 3-dimensional drawing is essential, so we can't have that stuff already filled in.

The bad side is a lot of the students either don't come to class, because they know that I am going to publish the [completed] notes later. Now originally we started doing that because, if someone is sick, or if someone is representing the university at an athletic competition or [anything] that [can] legitimately take them out of the class, we would want them to be able to catch up as easily as possible. What oftentimes happens, unfortunately, is that people will just not come to class, and they will just download the notes and go from there. It is limiting in that regard because having the finalized notes after I have gone over them, but not hearing me talk about them, is only one-half of the process. Some students are going to use that resource poorly, but that's a battle you can't really fight.

Everybody's an adult, [if] they chose not to come to class, they chose not to come to class. We do have the participation score, which is an effort to force that attendance, to say "Look, you need to be here." Again, some people decide that's not a big deal until it would have made the difference in their grade at the end of the semester. The students come in saying, "But I only need one more point." The opportunities to get those points have already passed, but they did not take advantage of them.

We do get blinders on, thinking that our class is the only class in the universe. [Organic is] the only thing I'm concerned about; therefore, I'm not thinking about the other four classes or five classes that they've got. I do understand complex schedules and, of course, we all do, because we have all been through college. [However, attendance is one of the] simple things that should be taken advantage of, the day of, the one thing that you have always got time for, is coming to class. When you've got people who don't come to class, it's difficult. They miss out on too much.

[I have always given out my completed notes after lecture.] The students shouldn't depend on them as the only source. It should be one of those, well, "When you post them, I'll fill in the blank that I missed." That's another way to compel them to take the notes rather than just sit there and not do anything. I was always a big believer in re-writing my notes because part of that was the way it was taught when I went through school. It was chalkboard. Write with one hand, the professor erases with the other, and you have to keep up, which was imperfect. I would re-write them because I wanted them to be neat, I wanted them to be organized and organization is essential for organic chemistry. You gotta have all that stuff compartmentalized and listed.

We don't use a graded homework. It's a self-assessment for students. We assign problems and tell them that these are the ones we think will be the most helpful, and have them work them. They have a solutions manual. There are too many for us to do a graded assessment. [General chemistry] does it is through 'J' exam. You have to do it on the computer. We don't have a computerized homework problem that works with Organic, and grading homework sets for 1,200 people is the pro and the con of a large research institution. At [the small university I went to], we could turn in a weekly homework assignment and have it graded for points. That [was] part of our experience. Here, we just don't have the manpower to do that. There are homework programs on the horizon that are starting to look promising. I think we will have something in place where we could actually have them do homework that can then be graded.

I would like to have a homework assignment that's turned in, but I don't think the grading aspect of it is important to how they're doing in the class. We know that students work together. We know that some students have other people do their homework for them. We can't observe and make sure that everybody is doing their own work, which is the most important thing for homework. This is the only way that you get anything out of it. Students will turn in homework that has been either done by someone else and they copied or which they worked in collaboration with another student. They'll turn that in for a certain grade and then say it illustrates his/her understanding of the material, but in reality, it doesn't. It's kind of a misleading thing. So we're kind of wary of it.

So with Organic right now, [homework] is purely a self-assessment tool. It's something that they do not [do] for a grade, which hopefully means that they'll be doing it realistically. They'll be doing it on their own because they know that there's no benefit to cheating. [However], I don't want to paint everybody with that brush. The majority of students do their own homework and that's fine, but we've seen enough of them. You get a little jaded over the years. You've seen enough of them that are furiously copying down lab reports and homework up in the lobby before lab begins. We want something that will give them an unbiased assessment of where they stand, so we want them to do these homework problems themselves. We know that when we get to the test situation, we want to mimic the test as much as possible. You can't have your friends sitting there with you. It's got to be you.

The way we do examples in class is supposed to foster that idea of: you look at the problem, not try to remember an answer from a previous solution. Too many of them approach homework as, "Well, show me the answer key. I'll just study the answer key." Again, they're not preparing themselves in the fashion that you would want to for a test. You want to prepare in the same way that you're going to be expected to perform, so you don't want to look at the answer key and say, "Oh, I understand that." Understanding the right answers is very simple. Generating the right answers when you've got a big blank page staring at you is very different entirely. We want them to get as much of that type of practice as they possibly can get so that the anxiety level goes down, the shock goes down, the performance goes up. That would be true for anything that you would do. If you always trained appropriate to what you'll be asked to do on the final deciding factor, whatever contest you're doing, whatever test you're taking, academic event that you're entering. That's a challenge, because there are a lot of mock exams out there, there are a lot of old tests out there, and the students tend to really focus on those, as opposed to doing homework and working examples. They really try their best to find old exams and say, "Well, I assume that the test questions are similar to these." And when [the test questions are different], it devastates them.

It was very obvious on our second test this semester. We changed several problems subtly so that they resembled problems on old exams. Now that sounds underhanded, but it wasn't done that way. It was done to basically say, "Are people really looking at these problems or are they just looking at old exams and trying to take those answers and modify them to fit the current situation?" We found a lot of the identical answers from old exams, even though the problem should have generated a different answer. That made us very wary because then that's not conceptual understanding. That's regurgitation of our own work, of our own answers.

In organic you can do a lot of reverse reactions. We have a lot of equilibrium reactions that can go either way. We had a question on the last test that talked about a mechanism for imine formation. The reverse mechanism is the same. All the intermediates are the same. So we said, "Okay, fine. What we want you to do is show us the mechanism for imine to a ketone and imine." [The students say], "What is this? We've never seen anything like this." But we had. There was so much tunnel vision in the way that they had looked at the material. We're trying to break them out of that shell a little bit, give them some questions in class and on the tests that force them to think outside the box. People always talk about how med schools value the grade in organic as a good barometer for how they're going to do. It isn't because they are going to be performing hydroborations in med school, or asking them about chemistry. It's critical thinking. If we can't break this cycle of memorize old exams and regurgitate answers, then we've done everybody a disservice. If they have not learned critical thinking, then they really haven't gotten what they need out of organic chemistry.

If somebody is going to be a chemistry major, then that's great. They're going to need that chemistry for the rest of their life. If someone is going to be Pre Med, Pre Dent, Pre Pharm, they won't [need that chemistry] to a huge degree, but they do need the critical thinking skill. Most of our assessments are attempting to get that critical reasoning to a higher level. We make podium lecture[s] filled with written examples and clicker examples. We try to make those examples as complex as we can so that thought process has to kick in. "Why is this one different from this one? Don't they look similar? But wait a minute, this one is not just a ketone, it's a conjugated ketone, so that reacts a slightly different way." So an attempt to really get the juices flowing, so to speak. Break them out of that shell, which is, "I'll just look at old tests and I'll do fine."

We're using clickers, where we go through and ask a series of questions and have them give their responses using their remote controls. We can use that to probe, "Do they really understand the concept or is it something that they're just answering to answer?" So the response to the clicker questions can then drive the second part of the lecture, which is, "Alright, how do I approach this? Did everybody do very well? Did they seem to understand the concept? Or were they having a lot of difficulty and it is obvious that there is real issue here?" So that can drive how and when you shift to a new topic.

When we're using the clicker questions we purposely put questions on there that are going to be the nit-picky questions, the type of questions you'd expect from a test situation. [They] look like they would react one way, but there's one little caveat, one little thing that we've learned that tells us that it's going to react another way. [It] sounds terrible, but I want them to get it wrong in class, because that's where they can get it wrong and it makes no difference. It shows them their miscue, so when they get to the test, they don't get it wrong. We'll trip them up as much as we can in class to show them the different things that work, don't work, why they work, why they don't, so that when we get to the test [the anxiety level] will be more manageable. The anxiety level is always going to be high. I don't want to pretend like it's ever going be low. [But] people will feel like, "Hey, I've seen a lot of examples. I feel confident in what I'm going to see, and go from there."

Teacher B

Most of the time what I do when I'm lecturing, is I will write my notes freehand on the Smart Board. What I've found is that gives them time also to be writing, and they'll see what I'm writing, they'll hear what I'm emphasizing, and there's a little bit of a pause, so they're not just scrambling like students do sometimes and not paying any attention to what's being said. They'll write and then we'll pause and talk about it and then they'll write a little bit more. When [I'm] generating it, then they also have a chance to assimilate, because their brains, if they're trying, can work.

And that takes me to what I observed today. I watched [a pair of chatting students] and decided not to say anything in lecture. What they're doing is they're not coming engaged. They're thinking, "Okay, I'll write down what I see written down and then I'll go back to talking." That's not the learning part of their brain, that's just a transcription part. Their thinking is, "Oh, I'll learn it later." Well, oftentimes they don't. And these are the students that don't do well. The students that do well are making the connection between what they just wrote down, which is what I had written down on the Smart Board, and what we're talking about, and then they can also make little annotations in their notes about, "I have to remember this," or "This is why this is important."

[I don't post my notes online] because I want students to be as invested in this class as I am. For your best students, that's not a problem. For your weaker students, that's a big problem. Students that still are not disciplined and mature enough for the university can all too easily say, "Oh, I don't feel like going to Organic today. I'm going to take the day off. I'm not going to go and I'll get the notes from somebody else." Or, "The notes are online, so I don't need to go, anyway." That's the problem. We've seen that it can get almost to where it is a detriment to the students. In other words, the reason why professors post notes is so students will have some complete record of the lecture but then it's only a record of things written down. It's not a record of things that are discussed verbally. It's just a template. It works well with PowerPoint. Sometimes it's justified. Professors will say, "Well, if I have a student who misses a class, then they have this backup. They can go online or they can have all the notes we discussed that day."

[In general chemistry], it got to the point where not only is there a CD, which has all the PowerPoint slides on it, but there used to be a lecture outline that students could buy and have most of the notes in there as a template [with] parts that you could fill in. I don't have any argument with the objective. The objective is to make sure that students have a complete set of notes to work from, that they're not missing something in class. I think it's a good objective. Where I have a problem is when everything is provided to the students in terms of all their lecture notes that the professor has made up and then [made] available for the students online. There is a detriment [and] downside. The downside that I have noticed is that students can tend to be less engaged. They won't pay as careful attention because in their minds, "It's okay, it's on the slide," or, "That's going go be [online] later on, I can chat with my friend now, or I can be texting and not paying a whole lot of attention."

It's based on the supposition that the students are engaged, that they're giving it all they have, and they just missed something. That's not always true. As a matter of fact, I would say that in many cases, that is rarely true. Oftentimes what happens is that students will come and they're partly engaged, even more so now than they used to be 10 years ago.

One of the concerns that's raised about being in a large institution is you have large lecture halls. When you have 300 students or more, it isn't unusual for us to have 370 students, in a large lecture hall, [and] you're not working really hard as a professor, if you're staying in one fixed point at the front of the room, you can easily lose the people, for no fault of their own, [that] happen to be sitting in the back because the room is full. Maybe they have a class that was twelve minutes away from this lecture hall, and they came as soon as that class was over. By the time they got here, the only seats that were open were those in the back of the room. So they sit back there. If you're fixed at one point in the front of the room and not moving back, then you can easily lose them.

We had candidates here interviewing for a faculty position and they were lecturing in [general chemistry]. I'd stand up at the back of the lecture hall so that I could see if the candidate was actually projecting and connecting with the students in the back of the lecture hall. It's a real interesting thing. I've seen it on more than one occasion, to be standing in the back of the room and see what these students are looking at on their laptops. It's not chemistry. It's Facebook, it's gaming stuff, it's a whole bunch of nonsense that has nothing to do with chemistry. I don't allow it in my class.

Do you think they'd be doing that as casually and as frequently if they realized if they don't get these notes this time when the professor is delivering them in class, they're out of luck, because they're not going to appear later online? I mean, it's telling the students that they need to come and be a part of their education. They can't dismiss it. They can't multitask. What they call multitasking, it's half-tasking. It's just paying half attention to things. That's the last thing we need to be training now, is people to become half engaged, easily distracted. More and more, as professors we're dealing with students that have done this all their lives, and are half engaged with a class, and they cannot focus for the length of the class. They're much, much harder to reach, much harder to teach. My feeling is that you have an understanding of the students up front that, "I'm going to work as hard as I possibly can to help them understand, and I expect the same of them." I know this is hard, and I don't want to hear after the fact, "Oh, this was so hard, and I tried everything I could and I hired a tutor, and I still failed. Why is that [the teacher's] fault?" It's not my fault, because I've worked my tail off to teach them. The discipline is hard, that's true, but these things that they will cite, that "I've been to class, I've hired a tutor, and yet I still failed. What do *you* [the teacher] do wrong?" is just fallacious.

[If] the structure or the content is so difficult to generate that to do so would require an inordinate amount of time in lecture, I'll pull out a visual and show it to them. Those I make available to students. I'll tell them, "This is going to be [online], so right now you don't need to worry about all of the details of this, but I want you to look through this, watch me as I'm discussing this, and then you'll have this available." When we're doing spectral analysis, they can't generate the spectra. It's just too difficult to do an individual spectrum and copy one for their notes, so I do make those available online. What I do in class is, we see several examples of them and I show them what to look for. The same way, for example, a cardiologist would look at an EKG and then, by the shape, would be able to determine maybe where there might be some malfunction of the heart muscle. Or if there's either a pre-ventricular contraction or a pre-atrial contraction, they can see that on a trace. So that's analogous to what I'm talking about here. Rather than drawing out an EKG, which is a little bit pointless for students to do that, they'll have several examples of it. It will be available to them, but I'll show them how to look at these things and how to analyze them, what they're looking for, to be able to understand, or what they can extract from it.

One of the reasons I don't use PowerPoint [is because I'm] constantly try[ing] to amend and learn from the way I'm trying something. I'm constantly trying something new, and when I see that it works, then it becomes part of my lecture presentation. I find that PowerPoint may work for some things. I don't think it works very well for these types of courses [organic chemistry] because there's too much analysis involved. You have to go through it in a careful way and say, "This is what we're looking at here, and this piece we need to look at here. We need to put these together and see what they're telling us." That type of analysis doesn't lend itself well to PowerPoint. We generate it there in class, but we still cover everything we need to cover in the semester, and the students who are engaging do quite well.

Students have to come engaged. There's just too much involved in this material. This isn't "study the night before and you get it." You can't learn this language by studying it the night before. Posting notes online, encourages students to not be engaged every day, [i.e.] completely engaged with understanding the material, asking me questions in lecture. [When I teach, I try] to elicit from them: "Are you with me? Tell me what you don't understand. Are we together on this? This is where you got your toe hold, this is where you are going to work from." [I'm] constantly trying to pulse them to see where they are.

If they come and [are] asking me questions, saying, "I don't understand," it's a good thing. They typically ask questions and not just those few students on the front row. Lots of times when they're asking it, they're asking it for a lot of other people, that same question, but just didn't quite have the courage enough to ask it in a large lecture hall. Those types of inhibitions break down the more we start talking in lecture, the more I go up the stairs and talk right to them, rather than stand in front, in one place.

Students have to understand that they can't come with an intention of being partly engaged. It's a disservice to them. That's not what they're here for. They have to be invested in their education. I'm not going to do anything that's going to encourage them to sit back there gaming, texting, or listening with half an ear while they're chatting with their friend because they think, "That's okay, I don't have to pay attention to [Teacher B]. The notes are going to be online later." That's why I don't [post note online]. I want them with me in lecture.

I'm not a fan of multiple-choice exams. [They have their] advantages and disadvantages. The advantage is that if you have 4 or 5 possible responses, then you have a 20-25% chance of just guessing the right answer. The disadvantage is, it's all or nothing, so if you miss it, you know you understood most of that, but just missed on element of it or whatever, then it is counted as if you knew nothing on that topic. [We use the standardized multiple choice American Chemical Society exam for the final because] it's the easiest way for uniform grading to provide national norms [and] statistics. There is no wobbling or ambiguity at all in the grading.

I always use written exams because I can tell what students know better from a written exam than I can from a multiple choice exam. I can ask more with a written exam than on an ACS exam because a written exam is a much more flexible answering format. "What do you know about this? Where do we need to re-mediate? Where do we need to keep working, or where do we push forward a little bit faster?" The written exams are the best way to determine that for me, because I can look at these questions and say, "Oh, they didn't do as well on that as I thought they would. I'd better ... " Or, "Wow, they have this cold. I can move on. I maybe spent too much time on that one…"

I rarely [recycle exam questions]. Every once in awhile what I will do is, I will give them homework problems on the exams, some end-of-chapter problems, I'll pluck one out and plop it on the exam. I don't tell them which one is going to be there. The thinking there is it's a good way to see if they're actually practicing, if they're rehearsing these skills. Again, not just memorizing, but rehearsing them. [There are many] problems that are in the end of the chapter and they're really good practice for them. [They get] them thinking more. So again, they're not just memorizing a specific answer to a specific problem, but they're learning a problem-solving method.

It's hard work, too. I mean, the easy thing would be just to give multiple-choice exams. Then I don't have any partial credit considerations at all, it's either right or wrong. [I could] give a whole batch of sample exams, to recycle exam questions, to put my notes everywhere so that students can opt to come or not to come to lecture if they so choose, because they figure they can get it later. [I would be so] disengaged from the learning process that I could just kind of throw it all at them and say, "Alright, I'll go in and yap at them for 50 minutes 3 days a week and then I'm done. They've got everything else online or whatever.

[I don't use the traditional] 90-100 is an 'A,' 80-90 is a 'B,' 70-80 is a 'C,' 60-70 is a 'D [system]. I don't know who came up with 90-80-70. I ask people, and no one ever knows. I think everyone remembers it from elementary school, but who came up with that; who was it that decided that that was to be uniformly applied to every distribution everywhere? Maybe it was just some understanding that has become so permanently entrenched in our educational culture that we can't get rid of it. I don't do it in my class because 90-100 is not the 'A' for organic chemistry. Students will think that, "Well, I've been doing poorly all semester long, but certainly there's a curve." I don't know where they get this notion. Essentially, I've relaxed from the 90-80-70 to make it what I feel to be a fairer evaluation or assessment of a student's mastery of the material. Learning this difficult language requires some accommodation in the cut lines, and so that's why I flex them down a little bit. In other words, if our students are performing in the 75 region here in the first semester, they're more than adequately prepared to understand the material that comes in the subsequent course for which this course was a prerequisite, then they're in the 'B' range. If they're prepared, they're in the 'C' range. That means they are prepared for what comes after this. If they're in the 'D' range, they're not as well prepared.

They're going to have to step up a notch because they're not ready for what's coming down the pike, and if they fail, they just can't go on.

I don't curve, other than relaxing the standards a little bit. The standards, the grade cut lines are relaxed so that based on the years of experience that I have, all the years I've done this – because that's the best fit that I have found over all these years – and I've taught over 20,000 students – that's the best fit I have to match their demonstrated mastery of the material with how well prepared they are for what's ahead of them. Curving doesn't do anything. Curving is nonsense.

I had a colleague here several years ago, they used to write exams that had averages in the 40s. What does that tell you? It's easy for me to write an exam that has an average in the 40s. I could write an exam that has an average in the 20s. That's easy to do. When you have a PhD in an area and you've taught for many years, it's easy to bury kids in a difficult discipline that are seeing it for the first time. So giving an exam that has an average in the 40s is ridiculous. It doesn't tell you anything about their performance. Well, what this colleague used to do was then curve it by 35 points, so students would say, "That's okay, I can score in the 40s and I'm still then scoring in the upper 70s or near 80 with the curve."

You've heard that term: with the curve. Now, what does "with the curve" mean? With the curve means that you're doing some kind of an artificial and arbitrary adjustment to fit into some arbitrary grading scale (90-80-70) so that students are happy with the grade they get. It's so completely detached from a good measure of their command of the material, and it started with the professor. It's that professor's fault for writing exams that have an average of 40. It's ridiculous. How can you tell what the student knows – what your class knows overall – if your average is a 40? You can't.

Teacher C

So, well, typically my teaching style is to use the latest technology that is available to us. In order to change, in order to keep the material fresh, I use a combination of a PowerPoint templates, and the sympodium. In the large room, it's difficult to use chalkboards, because if you are sitting in the very back of the lecture hall, you can't really see the chalkboard. We project this sympodium on the screen that allows us to draw the molecules, push arrows in different colors and it allows the student to sort of see mechanisms, [and] see how to approach synthesis problems. I use mostly the sympodium.

After the lecture is finished, I essentially save all the notes, record what we've drawn on the sympodium, make a PDF copy, and give to the student. What happens in my course, I teach at 5:00 p.m., [is] a real big problem with attendance. It's correlated to the low grades that are shown in the course. I still believe if I teach it, since we move at such a rapid pace, I give every note that we've talked about or discussed to the students, [made] available [online]. I also like to, instead of doing demonstrations in the lecture room, it's actually difficult to do in such a big lecture hall, if there is some concept that we can see, I use YouTube to do that.

We also use the clicker technology to gauge how effective a concept is learned by the student instantly. The instant feedback that you can get, particularly if an answer is right or wrong, can allow you to decide on the fly how much more time you need to spend on a given material. The clickers are pretty effective. We also use that as an attendance record for the students, some attendance points are built into the scale.

We try to use the latest technologies that are available [but] that's difficult because every year something new is coming. This year all the students are using [the] iPad to take notes, whereas, you know, two years ago, I didn't see this. It's kind of interesting in terms of all of the latest treatments that new technology allows us to do more. When I took Organic, in the year probably 1997 or '98, and this is classic of all teachers who teach now, we would have a professor filling eight chalkboards with material and he would be just constantly [writing]. You rarely see his face. He's turned around to the back of the chalkboard constantly writing and you're constantly trying to keep up. That was good and that was how we learned it. Now, using new technology, it allows us to communicate more effectively in terms of reaching the student. It also allows us to cover more material. We can push the content of the course a little bit more than when I took it a few years ago.

[For the tests] the way that the course works is we take tests on Wednesday nights. There are multiple sections of the same class, for example, this semester, [Teacher A] is teaching one section and I'm teaching the other. We get together every week and make sure that we're on the same page. We also prepare the test together, so 50% of the material comes from me and 50% comes from him. So the tests are the same for both classes, because the material is the same for both classes. That's just the way that we do it here. We believe in handwritten tests are the only way to take organic and so that's the way we do it.

Student Motivation

Teacher A

For organic, [it's] hard [to motivate students]. We're aware of what we are. The motivation factor is the hardest thing. This is a basic science, so we're not getting to macro level stuff [such as] drug interactions [or] biochemistry. We're doing baseline molecular organic chemistry, and we've got to know a lot of stuff before we can reason correctly through more complex situations. The way you can pep things up is through a demonstration here or there, although [the college] has now told us that we cannot do demonstrations anymore. The best thing that we can do is try to videotape and show the video. We used to be able to do these elaborate demonstrations, but now they've told us it's too dangerous. It isn't. This is the way administration and society are changing. The things that used to be done so simply before now all of a sudden are incredibly dangerous, [but] there are whole generations that survived. We weren't irradiating [or] poisoning the class. There was just a little fireball that got everybody excited for class that day.

Even the simplest acid base demonstrations they've said, "No, you cannot do it." Which is really terrible, because when I think back to the most poignant moments when I was getting interested in chemistry, it was usually some sort of flamboyant demonstration that made me go, "Oh, wow! I can't believe that!" I had a professor at [the small college I attended] that shot a helium-filled balloon across the room with a YAG laser and set it on fire. A huge boom and a fireball went up to the ceiling. Fantastic! You know, that was the nerd moment. Everybody was jumping up and down. You can't do that kind of thing now. They're limiting us. We have to try to videotape things.

Most of [the students] are there because Pre Med, Pre Pharm, [or] Pre Dent has told them to be there. They don't see the usefulness. I would hazard a guess that the motivation that they would indicate on their reviews would change dramatically if you polled them again once they were in med school, once they were in pharm school, and they realized, "Oh, no. I've got to use this stuff now." Then all of a sudden the appreciation kicks in a little bit more. We've got a lot of students that are still at that stage of their education where they're being told exactly what to take, and they're not getting to those macro level classes in their area of interest.

So for motivation, what I can do is I inject humor. I try to tell a joke or two here and there. I'm better at it some days than others. There are some days when [it] fails miserably, and that, in and of itself, can be funny. Sometimes they're laughing at me as opposed to laughing with me. It just depends. Either way, I don't care. But you can tell a few jokes, you just have to be a little bit more alive. You can't be the monotone droning lecturer. You have to get moving, you have to move around the class, you have to ask people questions.

By and large, we're a nuts-and-bolts organic chemistry class and we've got a lot of information to go over, so we've got to move, and it doesn't give us a lot of time for extracurriculars in class. We can't do a ton of demonstrations and things like that because it just takes up a lot of time. When you're doing drug discovery classes and things, that's when you can. You can throw in some real world examples. Those always make people perk up. "Oh, I've heard of that drug. I heard about the effect of that drug. I read about that in the newspaper the other day." You're not going to hear much basic organic chemistry in the news. It's higher-level stuff that wouldn't be very useful from a teaching standpoint for them. The main thing for us is just trying to not make it monotonous, try to be a little bit more energetic, be lively, tell jokes, smile, [and] get student feedback. Usually, that will get people interested, but you've still got some closed eyes, no matter what you do.

<u>Teacher B</u>

One time, I don't know what got into me, last fall, I think it was in the fall. I was up [near the top of the] steps and we were talking about a stereochemistry example, where you had to look at the molecule from a particular sight line on the screen. I was asking them [if they could see it], and from looking around the room I couldn't tell if they were seeing it. Honestly, I wasn't thinking and this wasn't planned, I just bolted down the stairs. I just kept running, and I jumped up on top of [the] bench behind [the computer] to get on [the] side of the screen so we were looking at it all from the same way. I wanted to get there so that they would see where they needed to be looking at [it] from. My eye line was where I was telling them they needed to be.

Well, it was really funny because when I looked around – I mean, this all happened within a second or a couple of seconds, it was really fast –they broke out into spontaneous applause. Then I saw their cell phones come up and they were all taking pictures of [it]. I'm sure they were thinking, like, "I didn't know the old guy had it in him!" I did this simply because I wanted to make sure they had the right sight line. It just hit me: "I'm just going to get up there and do this." I had a little bit of spring that day, I guess I'd gotten enough sleep the night before – which isn't very common –so I just bounced up on the desk and looked at them. What's interesting is, they remember those things. You read the evaluations and they talk about things like that helped them. They'll say, "I never forgot that," or, "I'll always remember this," and it gives them something to latch onto, to anchor some learning objective to.

I have students come back that have been away for years and years and years, or I'll bump into them somewhere, and they'll say, "I'll never forget the day when ..." and they don't. They remember what it is that we were talking about that day. That type of spontaneity is critical because it brings them in. If you stand up there yammering at them for an hour, from a pre-prepared PowerPoint presentation, they just gloss over, or they're texting, or they're thinking, "I'll look at the notes online later." That's an element of the spontaneity of the lecture. When students see that, it brings them in because they wonder, "What's he going to do with that?" It engages them.

[It's] really hard [to motivate students that want to sit and chat.] You can't. And I don't mean to throw up my arms and be a pessimist. You give them as few opportunities as possible to view their education as a passive exercise. You don't provide notes for them. You don't provide for them study packets and review sheets for exams. I tell them, "You do your problems, you're ready for the exam."

Teacher C

When you teach in the large lecture room that has 365 students, essentially you have to put on a show. It's difficult with some of the material that can be rather boring. Relating [the material] to real world examples, showing highlights from my own research group, which is something I try to do quite a bit, I think [helps] to maintain [student] interest a little bit.

Changes to Attitude

Teacher A

For me, [my attitude has] evolved over the years. I think when I first started, I was more of the "get the information out there, and that's it." There wasn't as much interaction. Now, there are good days and bad days in lecture. There are some days when I can get a lot of interaction, there are other days when you can hear the crickets and you can see the tumbleweeds blowing through the audience, Fridays and Mondays being key among those. Wednesday is when we have our best interaction, it seems. People don't want to be back on Monday, and they want to be gone already on Friday.

You get better year-by-year. Several years ago, I wasn't where I think I am now in terms of being able to interact with the class. That comes with just comfort with the material, as well. The first couple of times you teach, you're staying very close to your notes and to [the] podium and all that sort of stuff. Then you get a better idea of when and where you can take a walk, essentially. If you know you have a long explanation for a concept, you can walk around a bit and talk to people and use examples and things like that. So if you can get away from the monotone droning of the podium speaker, then you're okay. And then you can throw in some clickers. People like to participate, whether they admit it or not, they like to chime in.

Teacher B

Some of [my attitudes haven't changed]. I think [my philosophy has] pretty much stayed the same. It's so important that we learn how to think, that we learn how to learn, and that I help students to learn how to learn. Organic happens to be a very good tool to do that. So that really hasn't changed.

In some respects it has changed a little bit because I used to be very much an idealist. What I mean by that is, I thought that everyone had an enthusiasm for learning. I'm not sure that's the case. When I entered the university, I had enough credits to skip an entire year, so I could have started in essentially my second year. I had earned those in high school. I didn't use any of them. Some of those courses that I took that were core courses, I enjoyed learning how to think in those disciplines. I actually enjoyed the learning process. It's still exciting to me. I enjoy the learning process and I enjoy learning how to see things from a perspective that I hadn't previously considered. Frankly, I thought that that was a common desire of university students.

I think I've changed a little bit in that regard because I've seen that a lot of students over the years have said, "Don't make me think, just give me the grade I need to get into med school." That's a little discouraging because when they're just about to give me that injection to put me under, I want to make sure that the person who is going to be standing over me with a scalpel knows how to think. What if they run into a problem? I want to make sure they know how to think their way through it. It's important that we learn how to do this. It has been a little bit disheartening over the years to realize that there are more than I would hope of students that approach their university education as just a hoop to jump through. From my perspective, there's nothing further from the truth. This is not a hoop and we're not trained seals.

That has been a little disheartening when I thought that everyone really was excited about the university and then I came to realize that['s not the truth]. Some people see it as just a burden or just a hoop to jump through or something they have to slug through until they can get on to what's really important in life. Then you'll have students that don't engage, they sit up at the top and yap and just don't invest themselves, for whatever reason, I don't know. The you'll have students like the one I was describing that came in and this really pushed her hard and she worked her tail off and ended up doing very well. She went on and on about how it was the most rewarding experience of her life. That's a good thing. So there are a lot of students out there that recognize that this has value other than just a grade on a transcript.

Teacher C

I think [my attitude] changes every year. Organic strongly influences that. In the beginning, when I was a new assistant professor, I taught mostly graduate level courses and undergraduate courses that had numbers of twenty-five or less, and I think I can do that very well. In the beginning I wasn't that great of a teacher. I think that teaching is something that takes time and experience to become an effective communicator of the material. Still [I received] good reviews and everything, but I just personally, the way that I prepared and handled the material, I wasn't comfortable yet.

I'm very comfortable when the students are very interactive, I love it. Organic tends to break me down every time. While the lecture may be fun for me to give, the class typically in the large lecture [is] not very interactive. A majority of the students focus not really on the material, but just what's gonna be on the test. "What do I need to know for this test? Not why does this happen or what is this good for?" While I understand that they're there to get good grades that can be very frustrating when you are trying to show the importance of this material.

Also, in organic, because the difficulty of the class, [I] have to deal a lot outside of class with students who ultimately have not prepared, have not studied, have not done what they need to do to make an effective grade, and they have dug a hole. They have made an F on the first two exams, and wonder what to do. A lot of times, these students say, "Oh, [I'm] a senior and I can't graduate. This is the third time [I've] take[n] the course." The first day of class, I basically give you the formula to passing this class. Most of them haven't even looked at the notes. That part is very frustrating. It takes me a few weeks to get my gusto back [after teaching the course] because that part is the worst part.

I think I will definitely continue growing as a teacher as I get more experience, as I learn more, as our tools get newer. I think staying current with the latest multimedia [is important]. Most people tell you that organic chemistry has been the same since 1960. I mean there is no new chemistry there. Organic is a very thriving area of research, both for conventional pharmaceutical design, but also for things like new solar cell technologies or electronic components, something that I do a lot of research on in my own group. I think that continuing to stay current is a way that I can grow as a teacher, as a communicator. That's the most important thing and to maintain that level of interest from the student. The first year that I taught this class, something like 40% of people dropped [or made] Ds and Fs. I still got good reviews from the students because I think that they can understand the difficulties [and] can appreciate staying current. I think that's the worst thing you can do as a professor, is to not change your notes for years. Many people do not change [their] technology, don't stay current. I think that for me, to continue to grow, I have to continue to stay up to date both in multimedia [and] in current literature.

Other Topics Discussed

<u>Teacher A</u>

He elaborated with a story when he was asked if he had ever had any teacher training.

The irony of college [is the professors have no teacher training]. I have friends who teach [high school] in Atlanta. They go through their certification process, through the Education Department. They do their student teaching and lesson plans. You get to the university level and there is no formalized structure that says, “Let’s teach you how to teach.” That is where a lot of the issues arise with some disciplines. We’ve got a lot of people that are fantastic researchers, but do not necessarily make the best teachers and vice versa.

There has to be an understanding and an admission that you’re going to have to break things down. Otherwise, it’s, “What’s the point? They could just read the book and get the exact same information.” There has to be a belief that the fact that we’re teaching, that we’re up there in front of them, makes a difference. Otherwise, why do we do what we do? Right now, online courses are starting to become the rage. Of course, traditional teachers are going to back at that because it undercuts what we do and the very fabric of education. To assume that everybody can be an autodidact and teach themselves everything is naive. There are very few classes that I’ve gone into and said, “Oh, if I just had the book I’d be able to figure all this stuff out myself.” How much more difficult would it have been? How much less effective would it have been?

I look at a lot of these online courses and it makes me very, very nervous. One, because you have no proctoring. If someone takes a test in an online course, you have no idea if it’s that person taking the test [or taking it] without their book taking the test. Also, if someone reads through the printed materials on the online course and doesn't understand what point that [it] is [trying to] get across, who do you go talk to? Who do you have to clarify any of this stuff? There's nobody. It's kind of like doing your taxes with Turbo Tax. When you come to a point that you don't understand, you don't have an accountant across the desk from you to explain it.

I believe strongly that the teaching element has to be there. Online courses are going to be what they're going to be. They're going to exist. Usually, what they're doing from a marketing standpoint is they're trying to tell people that they're wasting money paying for large universities and that it can be done this way. They're going to play to their strengths and they're not going to mention the weaknesses. They're not going to mention the accreditation issues. They're not going to mention, you know, the fact that a lot of these online degrees and courses are not well received out in the real world.

I feel very strongly that we need to be there. I'm the only person that can break it down, and hopefully find a way for the student to understand it, find some analogy, some comparison that the student is going to say, "Oh! It's like that." Then it makes sense. One of the things we ask our students to do a lot from a synthesis and mechanism standpoint is, "Create your own. Bring it in to me. We [can] take a look at it and see what you've created." Creating a question oftentimes is just as good as solving a question. It gives you some insight into how it's put together, how everything is constructed. Pull the curtain back and see how things work. You don't get that interactive from an online environment. We don't get as interactive in the large class environment as I would like. I'd love to have a class of 30. I'd love to call everybody out by name: "You, you, you. Answer that question."

This teacher used the term "we" rather than "I" in most of his responses, which prompted me to ask: Who is we?

I do that and I don't know why. I think of it in terms of the [teaching assistants] and I or my fellow teachers. Really when we teach, we teach as a group sometimes if there's three of us teaching the same class. The TA's [are] the ones [teaching everything] in the lab. I coordinate [and] I give probably two lectures a semester for the labs. By in large it's the TA's that are doing all the teaching. Because of the nature of the way that we teach and the number of people involved in the teaching process I always use the collective to describe all of us together. Everything I say about lecture of course is my personal philosophy. Some of it is born out of discussions that we've had together, [my] colleagues and I saying what is the most effective way to do this, that, or the other, but I tend to use we just to force of habit I guess.

Teacher B

Teacher B had several students that would talk while he was lecturing which prompted me to ask: How do you decide when you're going to say something to them when they're talking during lecture?

I watch them for a while, and I kind of have to size it up and see if they're just disturbing each other, and then I'll say, "Alright, I'll let this go for a little bit longer." When I see that it's affecting other students that are trying to listen, that's where I have to draw the line. I'll have students come to me and they'll say, "Thank you for saying that, because I was having trouble hearing the lecture." They don't feel comfortable turning around and telling the students to be quiet. [Although] some of them do. Some of the students are oblivious to the fact that there are other people in there trying to learn and they don't want to hear about your weekend or your boyfriend or whatever, you know? They're trying to be engaged. So I owe it to those students to tell the students that are being disruptive, “You can stay in and engage, or you can leave. It’s your choice.”

I will admit I take it more personally than I should. When I come out of lecture and I feel like it’s been a bad lecture, I’m down for the rest of the day, or for several hours, thinking, “Geez, I could have done that better.” When I’m working that hard on trying to make sure I’m giving them every opportunity to learn, I expect them to reciprocate. To me, it’s a matter of just decency and respect. We respect each other. When there are students that aren’t willing to do that, I feel like they can go outside. I’m working too hard here. I’ve never actually told someone to leave the lecture. It has sufficed to say, “To remain in the lecture, you have to be quiet,” or, “You can go outside and talk about whatever you want to.”

On a couple of occasions I’ve had some students [where] that will shut them down, and about 15 minutes later I notice them doing the same thing. In that case, it doesn’t help. Every once in awhile when I react that way, the impression it gives to the class, those that are coming to engage, is that, “He’s serious. He’s trying very hard.” It conveys to them that I am invested in their education, and I’m serious about it. I want them to learn. I want them to succeed.

If I do it too much, it becomes a sideshow. [The students would] see, “Okay, who’s going to win this one: these students that are still misbehaving or [Teacher B]? What’s he going to do next?” Then it becomes a distraction. For students that have continued this behavior, I don’t deal with it in the lecture anymore. I’ll give them a shot in lecture, and that’s also a reminder to everybody that you can stay focused for 50 minutes. For those that don’t, I’ll do it outside of class. I’ll grab them, I know who they are, or I’ll find out who they are invite them to come in and deal with it individually. Then it’s not a spectacle. I don’t want it to be a spectacle [or] a power play. It’s not something about me demanding respect from students. It’s simply establishing the healthiest learning environment I can, which means that we can't have disruptions and distractions.

We work together. We're not adversaries. We're on the same team. They come into this class thinking we're adversaries, because they hear all sorts of horror stories about organic. Some of them have been fed the nonsense that all we're trying to do is weed them out, which is the most ridiculous thing I could ever imagine. It's the last thing I want to do. What I want to do is make sure they're prepared for what's coming down the pike. I know what's coming down the pike; they don't. I know where they need to be performing when they get out of here, so when they get into pharmacy, medical, or graduate school, they have the skills to where they're up to the task. If I haven't given them every opportunity to get there, I have failed in my job.

This teacher did not use any notes he used while teaching during class so I asked him: I noticed that you just use the textbook. You don't have any written notes? Do you just kind of like make them up as you go along through lecture, or do you actually have some sort of lesson plan?

I've done this for so many years. I know what I need to know. I know how to develop these things. Another reason why I don't actually have templates that I fill in [is] because I like it to stay loose enough to where I can be responsive to the class. I've just done it enough to where I know how to develop certain things. Every topic in organic chemistry I can teach the whole year without a note. It's just because I've done it enough. I know what they need to know about this to be ready for this, and this to be ready for that. When I pulse them like I do, and sometimes with a clicker, I kind of find out where they are and I get some insight into, "Oh, they didn't understand this very well," then it allows me to amend this a little bit, or weave this into the next, or use an example that fortifies this while helping them move forward. I like that kind of flexibility.

I don't have a lesson plan. I know exactly what I want to teach them today when I go down there, and I know what concepts we need to talk about. I know how to develop it, but I have a lot of flexibility in how I'm going to go about it. I try to be as responsive as I can with the class. That's why I'm always asking them, "Are you with me? Do you have any questions? Is this clear to you? Now watch this carefully, this is something you need to make sure you're comfortable with." Your more courageous ones will very often be asking the questions that those that are a little bit more timid are asking to themselves, so we ferret out a lot of those questions and we take care of them. *Teacher B used the term "toe hold" on a number of occasions in his lectures so I asked him to define what it meant.*

It means a place to get started from. It's like when you're looking to scale something, like to scale a wall, you look for a toe hold where you can get your toe in, so that you can have a place to launch from.

<u>Teacher C</u>

Teacher C mentioned having very poor attendance and posting his completed notes online after his lectures. This prompted me to ask: "What is your reason for, if the attendance is so low, putting your notes online?"

The reason that I do that is because I don't want to punish the students that are there regularly. One of my study habits that I try to drill to the students [is] that once you finish the class, you need to go back and either re-write your notes or re-copy. A lot of times if they don't get the last three arrows of the mechanism, or if they've drawn [a structure] incorrectly, why punish the people who are trying really hard? I think that putting the notes there allows them access, and that's what I'm doing it for. The people who don't come to class, there are few of them that can do okay in the test, but I think that that's not my problem. My job is to do the best that I can with the people who want to learn, the people who are willing to do that, and I think putting the notes [online] helps them.

Observations

Teacher A

Teacher A starts the class off by greeting the students then going straight into teaching the material. He has his templates printed out and filled in, sitting next to the computer. He refers to them as he teaches and writes in the on screen outline (Smart Board). While he is writing, he keeps constant eye contact with the students. He stays up front as he lectures, but does not constantly stand at the computer. He walks back and forth periodically, but not up the stairs. At one point during lecture he nicely gets on to students for having a computer out.

As he teaches he uses little to no hand motions. One he does use was very simple: to explain the peak widening he moved his hands apart from one another. Some of the compounds are preprinted on the slide so he just points to them using the laser pointer. He does not write down all facts that he mentions. He provides the students with practice problems to work in class. He emphasizes learning how to work the problems rather than memorizing. NMR spectra problems are printed on the screen and not drawn.

During his class he asks the students many questions, but sometimes does not give them enough time to answer. He answers for them or waits for them to answer; he is not consistent with it.

Teacher B

Before class, he conversed casually with the students. When it was time for class to start, he waited patiently for students to stop talking. He only has the required textbook with him when he arrives to class. The screen is just a blank white screen that he writes on (an electronic chalkboard.) He occasionally glances at the textbook as he teaches but appears to make it up as he goes along. As he lectures he does not write down factual information, just example molecules and problems.

As this teacher explains concepts he uses a lot of hand gestures periodically through lecture, such as making a chopping hand motion for molecules cleaving apart. As he lectures he walks up and down the isles between the students when he does not have to write on the Smart Board. He uses the laser pointer to point at things on the screen because it is out of reach. On a couple of occasions he walks up to individual students and talks to them and asks them questions, requiring them to answer or guess if they do not know. When he asks the whole class questions, he waits for more than one student to provide an answer before moving on. He asks students a lot of questions throughout lecture. For some of the reactions, as he is explaining them, he explains them in a storytelling manner.

At one point during the lecture he runs to the corner of the room and grabs a fifteen-foot stick. He brings it over to the students and begins pointing it at them and waving it through the crowd. He then proceeds to use the stick instead of the laser pointer.

On several occasions, he calls out a pair of students talking during class. He also asks students to put down their phones.

Teacher C

Teacher C starts the class by saying "Let's get started," then goes right into it without waiting for the students to stop talking. At the beginning of class Teacher C provides a couple of problems for the students. These are questions they had before they came to class and now he works them out, explaining what he does as he goes along. He stays at the bottom of the classroom while he lectures, but he does not stand at the computer the whole time. Occasionally he will walk from side to side. He uses the laser pointer when he needs to point to something on the screen.

For his lecture he uses pre-made PowerPoint slides and writes on them as he goes along. He has all of his slides printed out, and the printed out, sitting next to the computer. The printed version already has what he wants to write in on the screen written in. He references the printed out copies very frequently as he goes through his PowerPoints. He does not read from his slides and he tells the students some facts that are not printed on the slide, but does not write them down. He glances down at the board a lot while talking, rarely looking up.

He gives the students practice examples to try on their own. For the examples, the solutions are not pre printed. He goes through the process of drawing, writing, or working it for them. He does not talk very much as he is working the problem out on the board. After he is finished, he goes back and explains what he did.

Occasionally he asks students questions that are from concepts they learned previously. When he asks the question, ones that are not clicker questions, he does not give them any time to answer. He answers for them almost immediately.

During one of the classes he asks the students a question out loud, and to respond using their clickers. After the students respond, the results are shown on screen in graph format. He talks with the students and jokes with them some during class.

CHAPTER 5

DISCUSSION, IMPLICATIONS, AND CONCLUSIONS

What philosophies, if any, do chemistry professors have that influence their teaching of chemistry?

Teacher A specifically defined his philosophy as "one of inclusion, questions, and interaction, as opposed to just lecture." He also added that it is "an applications-based philosophy." He felt applications-based meant that the students are to learn factual information, and then afterwards do example after example with that information. He provided me with an example: "We don't just show you a picture of a hammer, a screw, a nail, and a piece of wood, and then on the test show you those same pictures and say, 'Identify,' where it's just regurgitating fact. Instead, we tell you what each of these is used for and then on the test we say, 'Now use them. Now build a birdhouse. Now build a doghouse.'" Applying what the student knows means to have the necessary pieces and be able to assemble them.

Part of his definition of what he believed his philosophy to be was "one of questions." This is evident as he speaks. On numerous occasions he used the word questions. He emphasized how important questions were in class and how much he encouraged them. He went into detail about how many students feel they cannot ask questions in class "because they're afraid of feeling foolish." He strives to diminish this mentality because questions help him understand where the class is at in terms of understanding the material. He mentions interaction once, tying it into how he feels about questions in the classroom. To him, the questions create interactions between the teacher and the student. It is important to him because he does not want “a whole section of the class left in the dark,” meaning they do not understand what he is teaching, because they are too timid. The silent students are the ones he would prefer to get questions from. He feels this helps him in determining “what’s working and what’s not” in the way that he teaches.

He also feels very strongly about doing many examples with the students. This goes along with his definition of an “applications-based philosophy.” He explains students will memorize a set of fixed rules, and then try to apply them on the test without ever doing an example. Those rules can be difficult to follow, so the student may not do well on the test. He tries to foster an “environment in class” that involves providing the students with examples after examples. He feels that doing examples sparks student interest and they began to ask questions. With lecture he does not get that, “If I’m just lecturing on the base material, I don’t get that many raised hands, but when we start doing examples, then all of a sudden the hands come up and people start to get more interested.” Once again, he has enforced that he believes strongly about questions in the classroom, because he tied it into the application portion of his philosophy.

Teacher A’s philosophy could be identified as well when discussing his reasons for teaching. He brought up the topic of interaction in the classroom several times. He was required to be a teaching assistant for the chemistry labs throughout graduate school, and while many of his fellow classmates despised it, he “actually enjoyed the interaction.” He explains three times that it was the interaction that caused him to enjoy teaching. He said it “really took hold” when he had to substitute in the lecture while the professor was away. He taught a small class of thirty, and was able to get a lot of student interaction.

It is important to Teacher A that there needs to be a “teaching element” in the learning process. What he means is, there needs to be a teacher present who can convey the material to the students. The students need to be able to interact with the teacher and ask questions to gain the skills they need. He uses online classes as an example where this is not present. In his opinion, students cannot get what they need out of the class if they are taking an exclusive online class. If there is no "understanding and admission that" the teacher is there "to break things down," then "otherwise, it's, 'What's the point? They could just read the book and get the exact same information.'"

This portion of his philosophy can also be seen in the way he responds to the difficult and easy concepts to teach interview question. As he goes into detail and provides examples on the misconceptions students having when teaching the harder concepts, he makes a point to stand up and teach some alkyne chemistry to me, then teach me what the student was doing wrong. His enthusiasm was very evident.

When explaining how his attitude toward teaching has evolved through the years he brings up interaction again. He felt when he was a new teacher he did not have as much interaction as he would have liked because he was not as comfortable with the material. Now, "There are some days when I can get a lot of interaction, there are other days when you can hear the crickets and you can see the tumbleweeds blowing through the audience." It is clear he values the interaction between student and teacher.

Teacher B was the oldest of the three, and had been teaching the longest, twenty years. Teacher B struggled with coming up with what his philosophy was at first by taking almost three minutes to answer. He also joked and commented how hard a question it was. He started off his answer by discussing that a teaching philosophy is something that is requested on applications. His answer started out kind of generic by giving a common theme he found in many teaching philosophies he had read, "the purpose of teaching is to be able to effectively convey knowledge so that students can understand a framework to be able to continue to learn on their own." However, as he began to talk, his answer became less generic, and his philosophy could more easily be determined. Eventually he defined his philosophy as "trying to help them to learn how to learn, to learn how to analyze things, to do more than simply memorize." This was very evident in his responses. He used the words "analyze," "think," and "memorize" frequently.

Having students be fully engaged during lecture was a main concern for him. On numerous occasions he stressed how important it was to have their attention. His first example involved teachers posting lecture notes online. He felt that to do that would be to "do students a disservice." When they are posted the students do not always come to class, and when they do they are not what he calls "engaged." To him, being engaged means the students are attending lecture, focused on what he is saying, and they are asking questions when they need to. In his opinion, to posts notes means to teach "students that they don't need to learn how to analyze, they don't necessarily need to learn how to think, they only need to learn how to memorize." His says students have had plenty of practice memorizing, now in college "they need to be analyzing."

According to Teacher B, "memorizing only gets them part of the way through mastering the material. They have to learn how to analyze." He defines analysis as a method of "puzzle solving." He uses an example of a patient diagnosis: "They have to learn how to take this piece of data and this piece of data and this piece and put them together and make a coherent diagnosis, which is what many of them are going to be doing anyway when they take this class and they head on into medical school. They've got to be able to look at the various seemingly disparate facts that they're presented with by a patient and come up with a coherent diagnosis."

He thinks students being able to think and analyze are the most important skills they can take away from organic chemistry. He believes organic is there for the student, not to memorize a ton of information, but to be able to think through how a reaction takes place or how a mechanism works etc. “At some point, they have to learn them[the skills], because memorization doesn’t get them all the way to being the professionals that they’re aspiring to be. So I’m trying to teach them how to learn and to find real satisfaction in learning.”

In Teacher B’s reasons for teaching he goes into great detail about students having to “learn how to study, how to figure out, and how to learn in a completely different way.” He provides examples where he feels he has taught students to do just that, and they have come back to tell them how much they appreciate it or how they passed their pre-entrance exams because of him. “To me, that says we’re doing our jobs.”

Overall, he felt his philosophy has not changed through the years. He feels organic is a good tool to teach students how to learn and think. However, he does say when he first started teaching he “used to be very much an idealist.” He thought all students who attended college had “an enthusiasm for learning.” He always had it, so he felt other students felt the same way. He realizes now that that is not the case because he has seen so many students over the years say “Don’t make me think, just give me the grade I need to get into med school.” His philosophy on teaching students to think is very clear here. He states, “When they’re just about to give me that injection to put me under, I want to make sure that the person who is going to be standing over me with a scalpel knows how to think.” He finds students feel college is “just a hoop to jump through.” He makes a point to mention many students “don’t engage,” another part of his philosophy.

Teacher B uses comparisons several times when responding. When explaining about a difficult topic, he compares electrons to breadcrumbs. “We trace these logic steps actually by following the electrons, because the electrons are breadcrumbs. You follow those [then] you know where things are going.” For analysis, he compares it to a path in the woods, “You have to get into the woods to be able to see where the path is taking you sometimes. You can’t see the other side.”

His philosophy on how he feels he should be teaching the students to think, and how to analyze is evident when he defines the difficult topics to teach. Concepts that just require students to memorize are the easiest to teach to him. He gives the most difficult topics to teach as the ones where the students have to put reactions “together into a logical sequence, starting from [the beginning] and then going through several steps to get to [a] product.” He believes if the students have a “toehold”, “a place to get started from,” then they can work the problems. He strives to help students be able to identify a “toehold.”

A major comparison he makes is comparing organic chemistry to a language. This comparison reveals his philosophy. He feels there are certain vocabulary words students must memorize in organic, like memorizing what the word for door is in French or Spanish. The hard part is the usage. Students have a hard time mastering the usage in a language such a Spanish, and they have a hard time mastering it in organic. “Being able to take these things and formulate them into something you can actually use is where the mastery comes in, the mastery of the language.” He wants the students to be a point where they are “conversant, not just having memorized vocabulary words.”

Teacher C was the youngest of the professors, and he had only been teaching for five years. His philosophy was harder to distinguish because his answers were short and generic. He feels being able “to become an effective communicator of the material takes time and experience.” He said he had not thought about a teaching philosophy since he had applied for positions six years ago. Teacher C felt a different teaching philosophy is required depending on “the students, the context of the class, and the context of the material.” He says there is not “one formula that works.”

When he talks about a philosophy, it is more in terms of a job he has to do, not so much how he feels about teaching. He states his overall philosophy “is to really challenge and push the students in every class. I think that is my job. I’m here to make the student better, this university better, and to increase our standards always.”

For organic chemistry, he feels “examples [and] relating the material to the real world helps” the students. However, he states that he has a hard time doing that because of the amount of material he has to cover in the course. He feels getting through all the material will help the students perform well on their pre-entrance exams for whatever field they want to go into. He mentions it as being his job again: “It is my job to do whatever I can to get the material across to the student.” The most important thing to him is “being able to be flexible,” because teaching the students “requires different motivations.”

He uses the term “interactive.” He likes when the students are interactive, but feels large classes are not so interactive. He says his students mostly focus on what is going to be on the test rather than asking questions like “Why does this happen or what is this good for?”

Part of his philosophy involves staying current with the newest technologies. It helps him communicate to the students better, and he feels that is important is maintaining student interest. “It allows us to communicate more effectively…[and] to cover more material.”

Teacher C's philosophy is slightly more evident when he talks about the most difficult or easy topics to teach. He mentions the term "memorization," a few times. He feels student study habits are "based on memorizing this reagent and less to do with, 'Why does that reagent do that or why does this happen or what is the mechanism of this reaction? Why do we use this solvent?'" Even though he recognizes there are concepts you can memorize, such as nomenclature, he wants students to stop memorizing the information and think about why something is occurring or how to approach a problem.

How do teaching philosophies lead to different teaching methods in different levels of college chemistry?

Since the classes are so large, all of the professors have to mainly give lectures. Since it is lecture, the topic of note taking came up with all three of them. Teacher A provides his students with note templates before they come to class. In class, they can use these templates to fill in as he writes notes on the Smart Board, an electronic chalkboard that projects the image or writing on a larger screen. This method brings up the part of his philosophy he has talked about frequently already: questions. He also uses a term he did not use when defining his philosophy, "engaged." He wants students to ask questions in class, and to do that they need to be engaged. He feels that if he does not give them portions of his notes beforehand, they will be furiously writing. They won't have time to pay attention to what he is saying, be able to think about it, and come up with questions.

He brings up examples again. He feels giving the student templates allow him to go over more examples, those are what he does not have filled in. "In organic, practicing the structures, practicing three-dimensional drawing is essential, so we can't have that stuff already filled in."

Teacher A posts his completed notes once lecture is over. He does this for students who have a legitimate reason for missing class. He does acknowledge however, that the bad side to posting notes is a lot of students choose not to come to class for various reasons. "Some students are going to use that resource poorly, but that's a battle you can't really fight." He does give the students a participation score to encourage them to come to class. He also posts the completed notes because some students miss portions, and he encourages them to go back re-write and organized their notes.

On the subject of homework, he does not use a graded one because the class is so large. Instead he assigns it to be a "purely a self-assessment tool." Another reason he chooses not to use graded homework is because he feels graded homework does not actually reflect that the student understands the material. "We know that students work together. We know that some students have other people do their homework for them." Requiring un-graded homework should "realistically give them an unbiased assessment of where they stand." Teacher A creates homework problems to try and "mimic the test." Un-graded homework is one method of doing this because they cannot have their friends in the test with them.

He provides the students with the solutions to the problems as well. He explains a downside to this is many students will approach doing the homework by only looking at the answer key before attempting the question. In his opinion, this is not preparing them for the test. "Generating the right answers when you've got a big blank page staring at you is very different entirely." He stresses practicing problems, or examples, just like when he stated the importance of examples when asked about his teaching philosophy.

A problem he discovered was students were constantly only studying previous exams rather than working examples. He discovered this by providing exams to students that had similar questions from previous exams with subtle changes. He did not do this to be "underhanded," but to find out if his students were actually practicing the examples he provided them. When they were identical, he knew that students were just memorizing old exams. "That's regurgitation of our own, work." He feels this is not "conceptual understanding." He gives the students numerous examples because he wants them to "look at the problem, not try to remember an answer from a previous solution."

He elaborates more on the examples he uses in lecture, and in doing so reveals another part of his teaching philosophy. He provides an example of equilibrium reactions that can proceed forward or backward. When the students are presented with questions that involve the reverse reaction, they act like they have never seen them before, when in fact they have. Teacher A tries to present them with examples in class that deter them from this "tunnel vision." He wants them to be able to think critically. He states, "If we can't break this cycle of memorize old exams and regurgitate answers, then we've done everybody a disservice." He feels critical thinking is what the students need to learn from organic chemistry.

He explains anyone who is going to go into a medical field is going to "need the critical thinking skill." Over and over again he stresses how much he uses examples in his lectures and the importance of them. "We try to make those examples as complex as we can so that thought process has to kick in. 'Why is this one different from this one? Don't they look similar? But wait a minute, this one is not just a ketone, it's a conjugated ketone, so that reacts a slightly different way.'"

Another method he uses that reinforces his philosophy of questions and examples is the clicker technology. Clicker are electronic remotes the students buy where they can answer the teachers question by inputting it in, and sending it to the teacher's computer wirelessly. The teacher can then instantly see how the entire class performed. "Do they really understand the concept or is it something that they're just answering to answer?" He also uses the clickers to decide how to proceed with the second part of the class. "Alright, how do I approach this? Did everybody do very well? Did they seem to understand the concept? Or were they having a lot of difficulty and it is obvious that there is real issue here?"

Again, he uses the clickers to help mimic the test situation as discussed above. He gives the students examples to work that "look like they would react one way, but there's one little caveat, one little thing that we've learned that tells us that it's going to react another way." He feels doing this will boost their confidence levels. He wants the students to go into the test feeling like they can manage it because they have seen numerous examples.

One interesting thing he mentioned is he tries to teach through metaphor. "Giving examples, giving comparisons, using sports metaphors or just general life metaphors, to try to explain some of these chemical processes can be fun." This is evident in the interview alone. When he tries to explain the point he is trying to make he often uses a comparison. For example, when he discusses how he feels about online classes he compares it to using the online tax tool Turbo Tax. "It's kind of like doing your taxes with Turbo Tax. When you come to a point that you don't understand, you don't have an accountant across the desk to explain it."

In terms of motivational methods, he finds it hard in a class that is just "basic science." He use to do demonstrations, but does not anymore because the college will not allow them. Instead he tries to "inject humor." He also says using "real world examples" get people to "perk up." His goal is to keep the lecture from becoming "monotonous."

When Teacher B lectures, he writes all of his notes on the Smart Board, except when there is a visual that is to complex to do so. He thinks this gives them time to write everything down and hear what he is emphasizing. He makes sure to pause frequently so they are not scrambling to write down everything furiously; he wants them to have time to think.

Teacher B believes very strongly about not posting his lecture notes online. He wants students "to be as invested in this class as I am." He feels notes posted online give the students the option not to come to class. As for using a template, he is not against that because not everything is provided for the student. However, he does not use a template because it does not allow him to stay loose with the material. He wants to be able to be "responsive to the class." It also allows him to "pulse" the students, such as ask questions to find out what they understand, and amend what he teaches based on how well the students are doing. He likes to have a lot of "flexibility" when it comes to lecturing. He ties it to his philosophy by stating the "students can tend to be less engaged." He wants to "amend and learn from the way I'm trying something." In his opinion PowerPoint is not effective for organic chemistry "because there is too much analysis involved."

The only exception he makes, is any complex visual he uses such as an NMR spectra. He uses a comparison to explain this: "A cardiologist would look at an EKG and then, by the shape, would be able to determine maybe where there might be some malfunction of the heart muscle. Or if there's either a pre-ventricular contraction or a pre-atrial contraction, they can see that on a trace. So that's analogous to what I'm talking about here. Rather than drawing out an EKG, which is a little bit pointless for students to do that, they'll have several examples of it. It will be available to them, but I'll show them how to look at these things and how to analyze them, what they're looking for, to be able to understand, or what they can extract from it." Once again, you can see he does this to stress students learning how to analyze and think so they can function in the real world.

He explains students that come to lecture and chat are not coming "engaged." To him these are the students that are not doing well. "The students that do well are making the connection between what they just wrote down, which is what I had written down on the Smart Board, and what we're talking about, and then they can also make little annotations in their notes about, 'I have to remember this,' or 'This is why this is important.'" He tells these students to be quiet because he feels he owes it to the students who are behaving and trying to be engaged. He wants a "healthy learning environment so he can have students engaged and asking questions when he lectures.

He stresses over and over again that the students need to be engaged. He feels this gets them asking questions during class. He wants them to ask questions because he wants them to understand the material and learn the skills he is trying to teach them.

When Teacher B goes to lecture he does not bring any written notes with him, just the textbook. Even still, he barely glances at that while he teaches. He does not use lesson plans either. He explained he does this because he has taught the course for so long that he knows exactly what he wants to teach them each day.

For student motivation, Teacher B explains it in terms of keeping the students "engaged." When he notices students are not paying attention or they do not understand what he is talking about, he adds an "element of spontaneity to the lecture." For example, during an observation, the students did not understand how to look at a molecule, so he ran down the stairs and bounced up onto the lab desk to illustrate his point. Students were so taken aback by what he did; they were taking pictures and applauding. He feels adding this spontaneity not only engages them, but also gives them something "to anchor some learning objective to."

Another method Teacher B uses, is he makes sure he is constantly walking around the lecture hall and interacting with the students when he is not having to draw on the Smart Board. He thinks this helps keep the students attention. It is a way to connect to the students in the very back of the room who would otherwise be lost or playing games on their computers. He relates this back to posting notes online. "Do you think they'd be doing that as casually and as frequently if they realized if they don't get these notes this time when the professor is delivering them in class, they're out of luck, because they're not going to appear later online?" His philosophy surfaces again because he believes students who are coming to "multitask" are there only half engaged.

Sometimes, on tests, he puts questions on there that are from the homework problems to determine if they are practicing the skills he is trying to teach them, not just memorizing.

Teacher C reflects his philosophy by staying current with the latest technologies. He uses PowerPoint on the sympodium (the Smart Board), and allows his students to take notes with their iPads, an electronic device where you can write manual notes with a stylus in an electronic notebook. The sympodium allow him "to draw the molecules, push arrows in different colors, and it allows the student to sort of see mechanisms, [and] see how to approach synthesis problems."

For notes, he posts his completed notes online. He does this even though he makes a point to say how he has poor attendance, which correlates to bad grades. His reasoning is he does not "want to punish the students that are there regularly." He says he moves at such a fast pace because of the volume of material, that it is easy for the student to miss something. He encourages the students to re-write their notes after lecture, and having the notes online allows them to do that in case they missed something or had a viable reason to be absent. He feels it is “not my problem” when students that do not come to lecture. He brings up his job again, “My job is to do the best that I can with the people who want to learn, the people who are willing to do that, and I think putting the notes [online] helps them.

To gauge if the students understand a concept, he uses the clicker device to ask questions and get immediate responses. He says it allows him to decide right then if he needs to spend more time on a topic.

Teacher C’s motivational method is “to put on a show.” He does this by “relating [the material] to real world examples [and] showing highlights from my own research group.” He also says, if he can illustrate a concept with a demonstration, he will pull up a YouTube video to do so.

The tests for the course are the same for all the teachers. Teacher C explains that if he and another teacher are teaching the same course, then they meet and match up their notes to make sure they are teaching the same thing. They then take fifty percent of material from each professor and create a uniform test given to all the students who are enrolled in organic chemistry that semester.

Teacher B explains that the tests are written exams rather than multiple choice. He feels multiple choice exams do not show what the student has learned. They could have been guessing, or they may have known part of the answer, but multiple choice is “all or nothing.” Written exams help him decide if he has taught a topic well, or if he needs to rethink how to go about it.

How is the teaching philosophy reflected in the teaching?

Teacher A’s philosophy involved wanting to constantly interact with the students, making sure they asked questions during lectures, and providing them with numerous example problems for practice. All portions of his philosophy can clearly be identified in his teaching. Instead of just lecturing to the students, such as just telling them the information or how to work the problems, he is constantly addressing them with questions of his own. "Why would we want to have regular chloroform? What is regular chloroform?...$CHCl_3$ So what would that do?" In some instances he waits for the students to answer, and other times he almost immediately answers for them. This is probably because of his statement “If you have everybody asking a question every five seconds, then obviously you can’t get through the volume of information. We have to find some balance between a good number of questions. We don’t want to have *no* questions, because that means that everybody just stares at me numbly and furiously writes down what we try to give them.” He does not always give them time to answer because he has a certain amount of material he needs to cover. The students asked questions on a regular basis as well, which fits into his interaction and questions part of his philosophy.

He also stated that he likes to “inject humor” to keep the students attention. This is evident at one point in the lecture when he asks the students a question about a problem, "Let's take a look at a sample...how many different types of hydrogen types do we have? I hear two, anybody for anything different? What do we think? Three, ok, so I hear three, so I hear two, *twelve*? {laughs} Is outside of what we really expect to see here..." It was clear that the student who answered “twelve” was joking with him because there were only four hydrogens on the screen.

It can be seen in both his lecture, and in his lecture notes, that he provides the students with numerous examples to work. His notes are templates like he stated in the interview. When they work them in class, again he is asking questions, "Where is B? What type of carbon is B located on?...Where is C? Is this C here? {points to a hydrogen} What do you think? What do we think this compound...let's try and draw this compound...what’s something that we could do?" Asking these questions are a way to keep his students engaged and gauging if they understand what he is talking about.

Teacher B’s philosophy involved wanting the students to learn how to think and analyze rather than memorize. He wants them to be engaged during lecture so they can do this. All of these points are evident as he teaches.

He focuses on trying to keep the students engaged during class, so he is constantly having to tell students to be quiet or put down their phones. "You guys, wake up! Put down your phones, stop your texting, stop your yapping, and plug in!" He also has to say something to the whole class at one point, "I'm not gonna talk over ya, so if you wanna end now, I'll just pack up and leave, you’re choice. Ahh see it can become quiet." This is consistent when he says in his interview, “When I’m working that hard on trying to make sure I’m giving them every opportunity to learn, I expect them to reciprocate.”

Another way he tried to keep them engaged, was asking them questions regularly, "Are ya'll with me? What did we call something that has the same group on the carbon? Do you remember? Are you with me? What do you call this again right here? {points to molecule} Do you understand the difference between... How come you're not talking today?” The students do ask him questions throughout the lecture.

Trying to teach the students to think and analyze is evident in how he asks questions when they are working an example, "What is that? Ozone. What does ozone do?" {allows students to answer him} It cleaves doesn't it? Ozone will cleave carbon-carbon triple bonds as well."

His lectures notes match what he said in the interview. He does not use PowerPoint, or any templates. He writes in different colors to make it easier for students to see what changed on the molecule, or how the mechanism is occurring. As he writes down his lecture notes, he keeps the colors consistent throughout. When he writes, he does not write too much, so the students can pay attention to what he is saying. He also matches what he said in his interview, that he is not constantly standing up front. Throughout the entire lecture he is walking up and down the stairs through the whole classroom, so he can interact with all the students, not just the ones up front.

Another way it shows he is trying to get the students to think and understand how a mechanism occurs, was teaching the mechanism as if the molecules had personalities, “Imagine I've got a pair of electrons on the end of this {points to molecule}, and that pair of electrons is looking for, follow me, is looking for somethin’ to plug in to! The carbon says I'm already making four bonds, I've gotta give something up. The iodide says 'No problem! I'm use to having an extra pair of electrons. I'm a iodide. I like being an iodide right? I'm a good leaving group, is what we say, and so this will attack." He also keeps the students attention by using silly voices as he talks through this.

His “storytelling” method carried over into an “element of spontaneity” that happened during observations. He was trying to make a point about electron density when he ran and grabbed a fifteen-foot stick from the corner of the room and waved it through the class, "Those electrons now that used to be shared in a bond between the carbon and hydrogen are now owned exclusively by that carbon. They are sitting in an orbital only being held by the nucleus of that carbon. You got it? And so the more they can snuggle up to that nucleus of that carbon, the more stable they are. {grabs the stick and points} There it is do you see it? It's an acytelyde right there do you see it? And it's very directional isn't it? Can you visualize it now?"

He even stresses to the students that this class is not about memorization, it is about analyzing, "This is not a flash card. This isn't something you memorize the answer to. This is something that you walk through. So let's walk through how you're seeing it. What are the differences? You've added another carbon. I've got three carbons on the starting material, I've got four carbons on the product. AH HA!" He puts a lot of emotion into everything he says.

It was hard to see Teacher C's philosophy in class. It was clear he was still not as comfortable with the material, since he has only been teaching five years. He had all of his notes written down that he wanted to write on the board. When he was talking, it gave the feel he was saying it to reinforce it for himself, rather than the students, because he would not make eye contact with the students while he was talking and writing, "hydrogen atoms can deprotonate a compound to generate the nucleophile, in this case. Nucleophile can attack electrophile to provide alkylation, carbon carbon double bond forming reaction..."

When he goes through an example, he explains what he is doing as he goes through the reaction, pausing between steps to draw, "So if we look at the first one, this guy here, first step in the enolization is protecting the carbonyl, so we use H_3O+. Protonation of the carbonyl yields the oxonium. Next step in the acid catalyzed case is elimination. The conjugate base is water in this reaction so water is...remember the acid is the catalyst so it's going to be regenerated in the long run, conjugate base instead of attacking as a nucleophile, eliminates to give enol structure...."

There were times where he would point out differences in reactions, trying to get them to think rather than memorize. However, he would not always go back and explain how the mechanism worked, "The workup is identical to the last one so were gonna use aqueous acid and heat. The net result is we undergo a hydrolysis reaction...Note that if we use acetyl acetic ester we get a methyl ketone..."

On rare occasions he asked the students questions, "To which side do you think the equilibrium lies? Why?" Mostly he just explained how the problem worked without their input, "So the reaction doesn't stop. What happens it, base can deprotonate another proton from this, form another enolate that can attack another electrophile, another equivalent, another molecule of bromine, another electrophile."

A part of his philosophy that was evident was his use of examples. He did provide the students with many problems, including ones to take home, which he went over at the beginning of class. In his lecture notes, these numerous examples can also be seen. However, many of the molecules are preprinted on the slides rather than drawn in. This is probably because of the volume of information he is trying to get through, “We have sort of this regimented amount of material to teach and the class is very fast paced.”

The students did not ask many questions during his lecture so it was not very interactive. He did provide the students with a clicker question during one lecture to see where they stood with the material, which can be seen in his lecture notes. He did go over how it worked in the same manner he goes over other examples.

The tests were the same for all the teachers that taught the course. As all three teachers stated, the tests are written, and not multiple choice. This allows them to see what the students really know. Teacher C stated that nomenclature was one of the easier topic to teach because it just involved memorizing the rules. He said, “It’s always there on the exam basically as a gimme to the student." This can been seen when looking at the first page of the exam. The first page is all nomenclature.

Many of the questions on the test are mechanisms that require the student to think through, such as question two and three. This is consistent with both Teacher A and B's philosophy. They want the student to demonstrate that they can analyze a problem. "They have to learn how to puzzle solve," according to Teacher B. The questions are consistent with the way Teacher A describes them, "We don't just show you a picture of a hammer, a screw, a nail, and a piece of wood, and then on the test show you those same pictures and say, 'Identify,' where it's just regurgitating fact. Instead, we tell you what each of these is used for and then on the test we say, 'Now use them. Now build a birdhouse. Now build a doghouse.' We give you the pieces that are necessary, and then the assembly is up to the student." A couple of the questions on the exam are from the homework problems, just as Teacher B stated they were to see if the students were practicing.

Is the professor's teaching philosophy the same when lecturing and in the laboratory?

The lab was only discussed with two of the three professors. Both of the professors provided similar explanations. This is because the teachers' work together to develop the labs, but Teacher A is the professor in the department that is responsible for coordinating the labs. He focuses on developing them rather than performing "classical research," as many other teachers do. Any student who takes organic chemistry, no matter which professor they have for lecture, will take his lab. Also, it is not actually Teacher A who teaches the lab, but the teaching assistants.

Teacher B said that he tries to use the same philosophy in the lab, but it is difficult. He describes the labs as being very "cookbooky." This means that the lab experiment is basically a recipe the students have to follow to get the reaction to work. The reason for using "cookbooky" experiments is because the students need results. Teacher B gives a metaphor that compares the experiments with "baking a cake." "You want to be able to see them get the cake at the end. The problem with that is baking the cake is a pretty simple process. You've got the cake mix, some water, and a few eggs; you mix them up, plop them in here, heat it to a certain temperature, and boom, you've got it." This makes the labs more of a recipe, rather than something the students can explore and adventure into, because "with adventure, you fail."

According to Teacher A, the reason the labs are made to get results is because "We're training people to be bench scientists to a certain degree: getting [them] use to taking notes, recording observations, [and] keeping a notebook." He believes it also teaches them to pay attention to what they are doing. If the students do not pay attention, such as the example he provides, combining reagents together in one step versus two, then their reaction will fail.

Teacher A explains the lab as the "first opportunity to do practical application" of the reactions they discuss in lecture. To him, the lab is there to focus the students on "observation" and "critical thinking." This is consistent with his definition of his philosophy, saying that it is "applications-based."

Teacher B states they are in the process of revising the labs to add in ones that are a little "more adventurous, but still have a very high likelihood of success." According to Teacher A, after doing "the same reactions in the lab for many many years," they want to try something new.

How do teaching philosophies and methods vary between different professors in organic chemistry?

There are several similarities between the three teacher's philosophies because as Teacher A explained, "Everything I say about lecture of course is my personal philosophy.

Some of it is born out of discussions that we've had together, [my] colleagues and I, saying what is the most effective way to do this, that, or the other." Teacher A and B both felt strongly about providing many examples for the students to work so that they can learn how to analyze. Teacher C also felt this way. The goal for all of them was to get the students out of the habit of memorizing and into the habit of thinking through a problem.

Teacher A and C were similar in the fact that they liked it when the class was interactive. However, the interaction was only evident in Teacher A's lecture. Teacher C had barely any interaction and asked only a few questions. Teacher A was constantly asking the students question on how to work problems, which in turn caused them to ask questions in return. Teacher B was very interactive with the students as well, even though he did not define this as part of his philosophy.

The biggest part of Teacher A's philosophy was questions. He felt it was very important in getting the students to engage and understand the material. Teacher B was very focused on engaging the students. He was the only teacher of the three that did not provide online notes, nor teach using PowerPoint or a template. He felt this was important in getting the students to attend class and to pay attention when he is teaching because the notes will not be available at a later date. The other two professors, however, felt it was important the students had access to the completed lecture notes in case they missed something during class or were absent.

All three teachers used the clickers to gauge how well their students understood the topic. Depending on how many students answered right or wrong, guided each teacher how to proceed with the lecture. Using the clickers also fit into every teacher's emphasis on providing examples. It also fit in with Teacher A's philosophy of questions.

All three teachers showed evidence of both pragmatism and constructivism. According to Antz (1976), pragmatism is a philosophy where students learn by doing, rather than memorizing facts. Teacher A states, “We don’t just show you a picture of a hammer, a screw, a nail, and a piece of wood, and then on the test show you those same pictures and say, ‘Identify,’ where it’s just regurgitating fact. Instead, we tell you what each of these is used for and then on the test we say, ‘Now use them. Now build a birdhouse. Now build a doghouse.’ We give you the pieces that are necessary, and then the assembly is up to the student.” Teacher B states, “What we’re trying to do with these students is get them to the point where they’re actually conversant, not just having memorized vocabulary words.” Teacher C also has a similar view, “That concept is difficult for the students because so much of their study habits, is based on blind reactions, or memorizing this reagent and less to do with, ‘Why does that reagent do that or why does this happen or what is the mechanism of this reaction? Why do we use this solvent?’” These quotes all show that the teachers are focused on getting the students to learn how to think and use what they learn to function and ask questions, not just memorize. It also highlights constructivism, where the main idea is knowledge is constructed (Wheatley, 1991).

According to Raij (2012), another belief of pragmatism is the teachers believe learning takes place within the student, and they only learn if they want to; they cannot be forced. This is observed when Teacher B states, “Our lecture is to sometimes 375 students [and] it is a real effort to try to get them all engaged. And you don’t. Sometimes you can’t do it.” More evidence of pragmatism can be seen in Teacher C when he says, “In terms of teaching philosophy, I don’t think there’s one formula that works.” Antz (1976) says pragmatists believe any philosophy to work to be true, and this is clearly evident in Teacher C’s statement.

Conclusions

All three professors felt they had an underlying philosophy they used in their teaching. They all showed evidence of pragmatism and constructivism. They were very focused on teaching the students how to think and apply their knowledge, versus just memorizing facts. Teacher A and B's philosophy's were the easiest to understand. Teacher C's philosophy was a little more difficult to distinguish due to his short responses.

Teacher A specifically stated his philosophy involved interaction and questions. He felt it was very important to interact with the class during lecture. To him, it makes the material more interesting to learn, and the students pay better attention. He can gauge where his students are as well if they are asking questions. He encourages a lot of questions in his lectures, both given and received. He was also insistent on providing the students with examples so they can learn how to analyze, rather than just memorize. This fits into his philosophy of asking questions. His philosophy was very evident as he lectured. He spoke with students, asking them questions about the material on a regular basis, and getting them in return. His notes reflected many examples he worked through with the students.

Teacher B asked questions frequently in his class, as well, as a method to engage his students. He was very focused on engaging them. Almost every topic discussed, brought him back to talking about methods or reasons they should be engaged. He felt the students had to be engaged to be able to learn the skills he was trying to teach them. He was the only teacher not to post his lecture notes or use a template as a way to encourage attendance and engage the students. He also was the only one to walk around the entire classroom to keep their attention.

Another major part of Teacher B's philosophy was to teach the students how to think. He stated that they have already had plenty of practice of memorizing in their previous education.

Organic chemistry was the first class many of students are exposed to learning how to think and analyze. He believes that teaching them how to think is the most important, because they will be able to use it in the real world when they graduate and find a job.

Teacher C's philosophy was hard to determine. He did feel it was important that the students have plenty of practice problems to work. This was evident in his lecture notes. He also felt the students needed to stop memorizing and start thinking. The problems he gave the students during class and on the tests reflected this as well. He was very concerned with staying current with new technology, because it is a way to cover the large amount of material.

The teachers described the laboratory experiments as "cookbooky," because they are more like following a recipe, rather than letting the student adventure out. This is the main problem Erduran et al. (1998) discussed as happening in organic chemistry labs, which may be a result of objectivist education. The reason the teachers did "cookbook" labs was because they need to have labs that give results. The students need to learn essential lab skills, and the only way to do that was through these types of labs.

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APPENDIX - A

Interview Questions

1. How do you view philosophy and is it important in teaching chemistry?

    a. If so, how do you approach teaching with you philosophy?

    b. Why do you teach? Organic chemistry?

    c. How do your research interests shape your teaching?

2. Do you use the same philosophy with the lab portion of the class?

    a. How do you decide what experiments students should do in the lab?

3. How do you decide which concepts are the most important?

    a. What topics do you find the most difficult to teach? Easiest? Why?

    b. How do you decide how you are going to teach each topic?

4. What methods do you use to teach? i.e. chalkboard, PowerPoint, etc. Why?

    a. What kind of assignments/assessments do you use? Why?

    b. How can you tell if your students are learning?

    c. How do you respond to different learning styles?

    d. How do you motivate students?

5. How has your attitude toward teaching and learning changed over time?

    a. How will you continue growing as a teacher?

Demographic:

1. Years of teaching experience: _______________

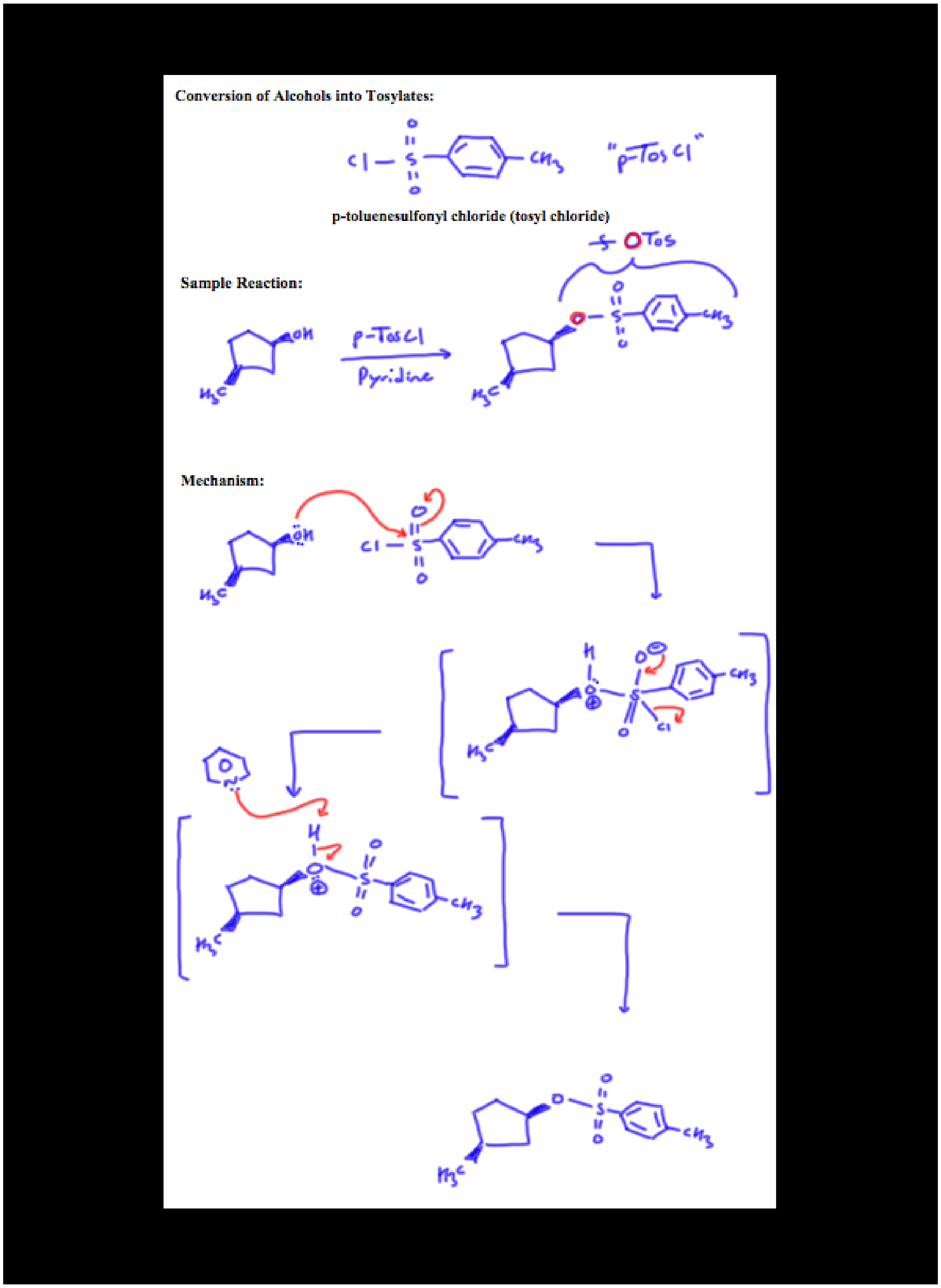
    At the college level _______________

Teaching organic chemistry ______________

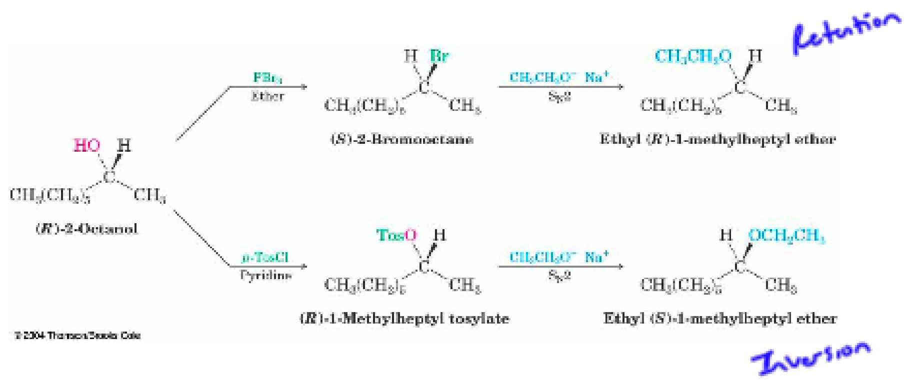
2. Any teacher training? Yes No

APPENDIX - B

Teacher A Lecture Notes



Important Stereochemical Considerations of These Reactions

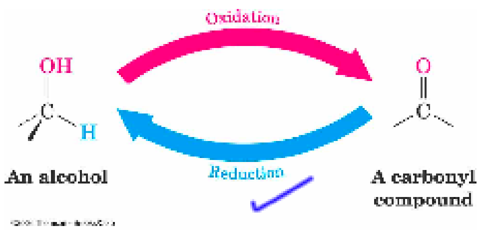


☆ **Formation and use of an alkyl halide intermediate results in retention of configuration**

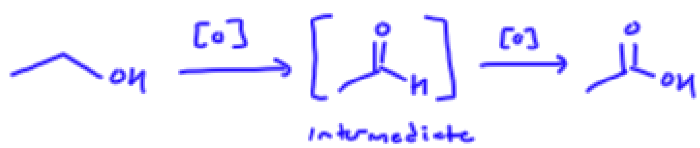
☆ **Use of a p-TosCl intermediate results in the inversion product**

☆ **We now have a way to exert stereochemical control!**

Oxidation of Alcohols



Primary



Secondary

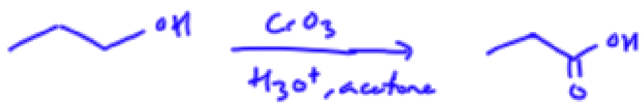
Tertiary

Typical Oxidizing Reagents:

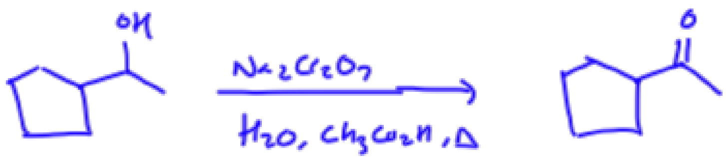
Potassium Permanganate:

$KMnO_4$, H_3O^+

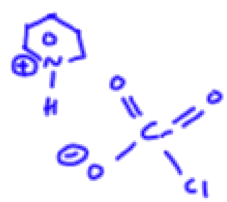
Chromium Trioxide: CrO_3



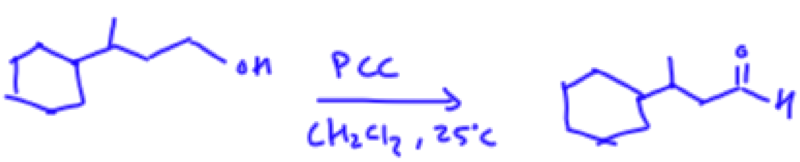
Sodium Dichromate: $Na_2Cr_2O_7$



Pyridinium Chlorochromate: PCC $C_5H_6NCrO_3Cl$



☆ **Oxidizes 1° OH to an aldehyde and stops**

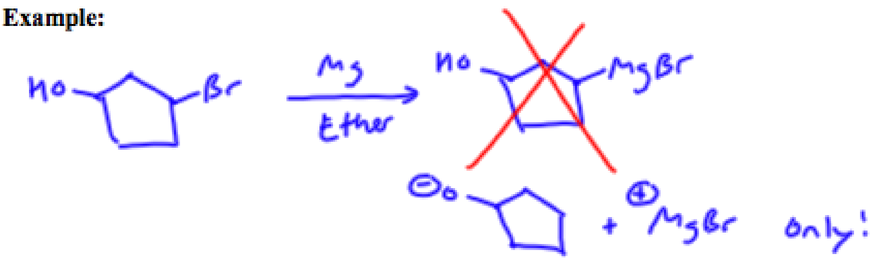


*- Can also use "Dess-Martin"

Protection of Alcohols:

☆ **Sometimes the reaction conditions necessary for the conversion of specific functional groups are incompatible with other groups present in the molecule**

Example:



3 General Steps of Protection Group Chemistry:

1.) **Introduction of a protecting group to block interference (reactivity)**

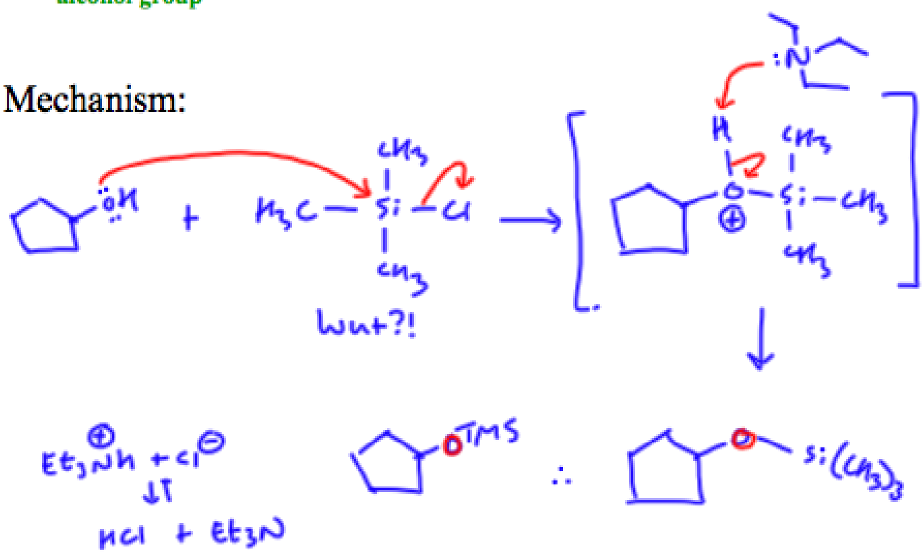
2.) **Primary reaction execution (protecting group must be stable in these reaction conditions)**

3.) **Removal of the protecting group**

Common Alcohol Protecting Group: TMS

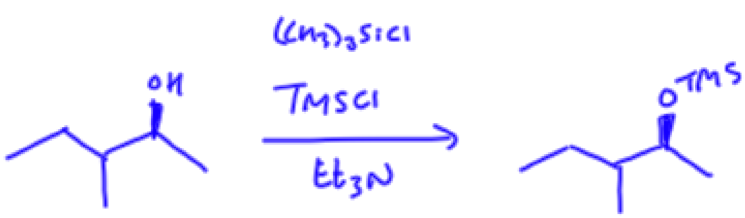
☆ **Use Chlorotrimethyl silane (w/ Et_3N) to form a trimethyl silyl ether with the alcohol group**

Mechanism:



C–C ≈ 154pm   C–Si ≈ 195pm [accessible for SN2]

Example Reaction:

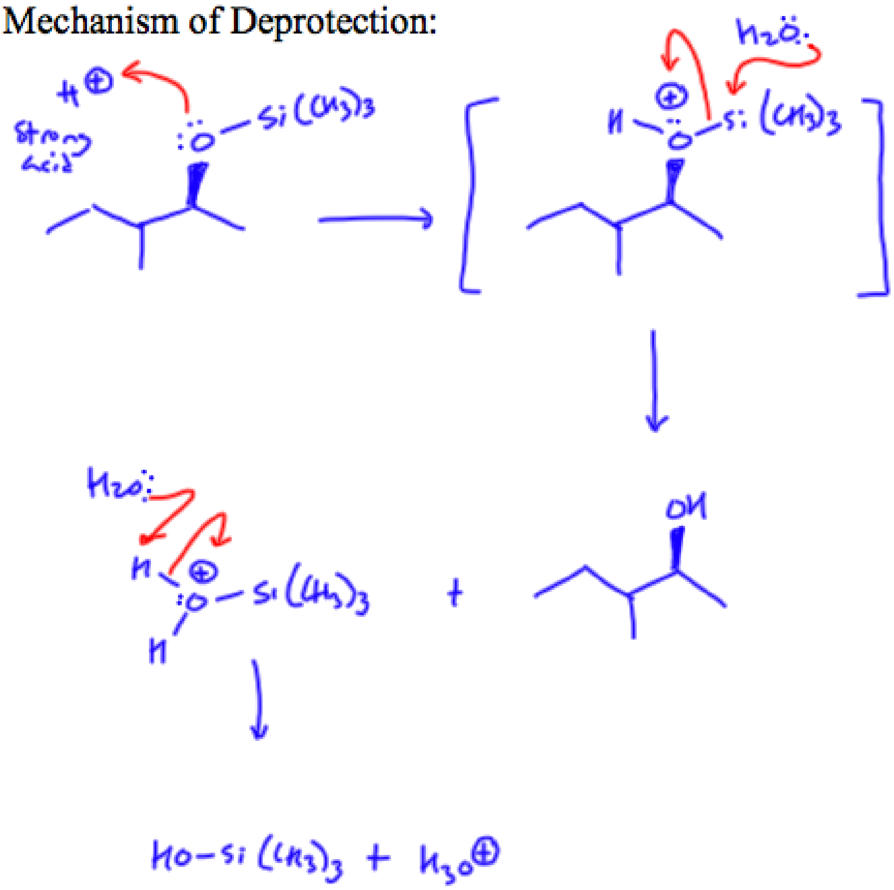


TMS Reactivity:

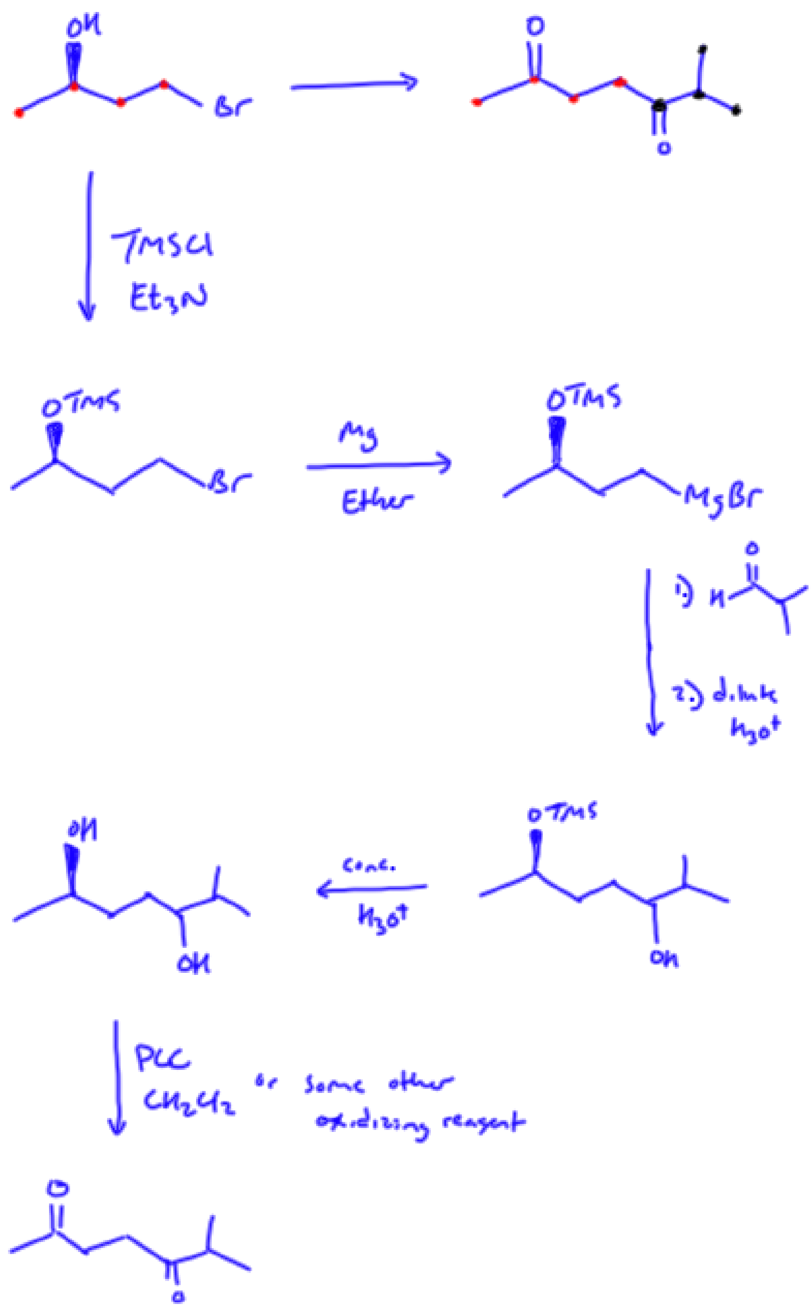
☆ **TMS ethers are relatively unreactive due to the fact that they have no acidic hydrogens:**

- **No Oxidation**
- **No Reduction**
- **No grignard reactions or deprotonations**

Mechanism of Deprotection:

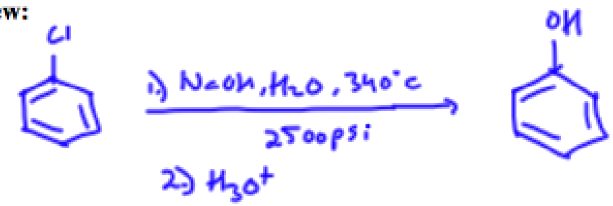


Sample Synthesis Problem:

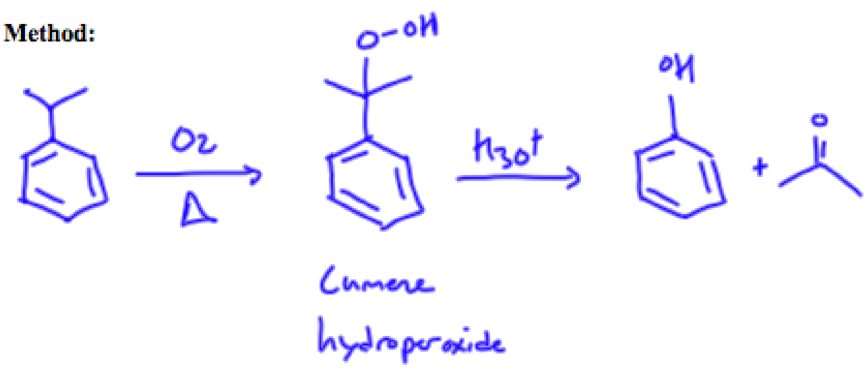


Preparation of Phenol:

Review:

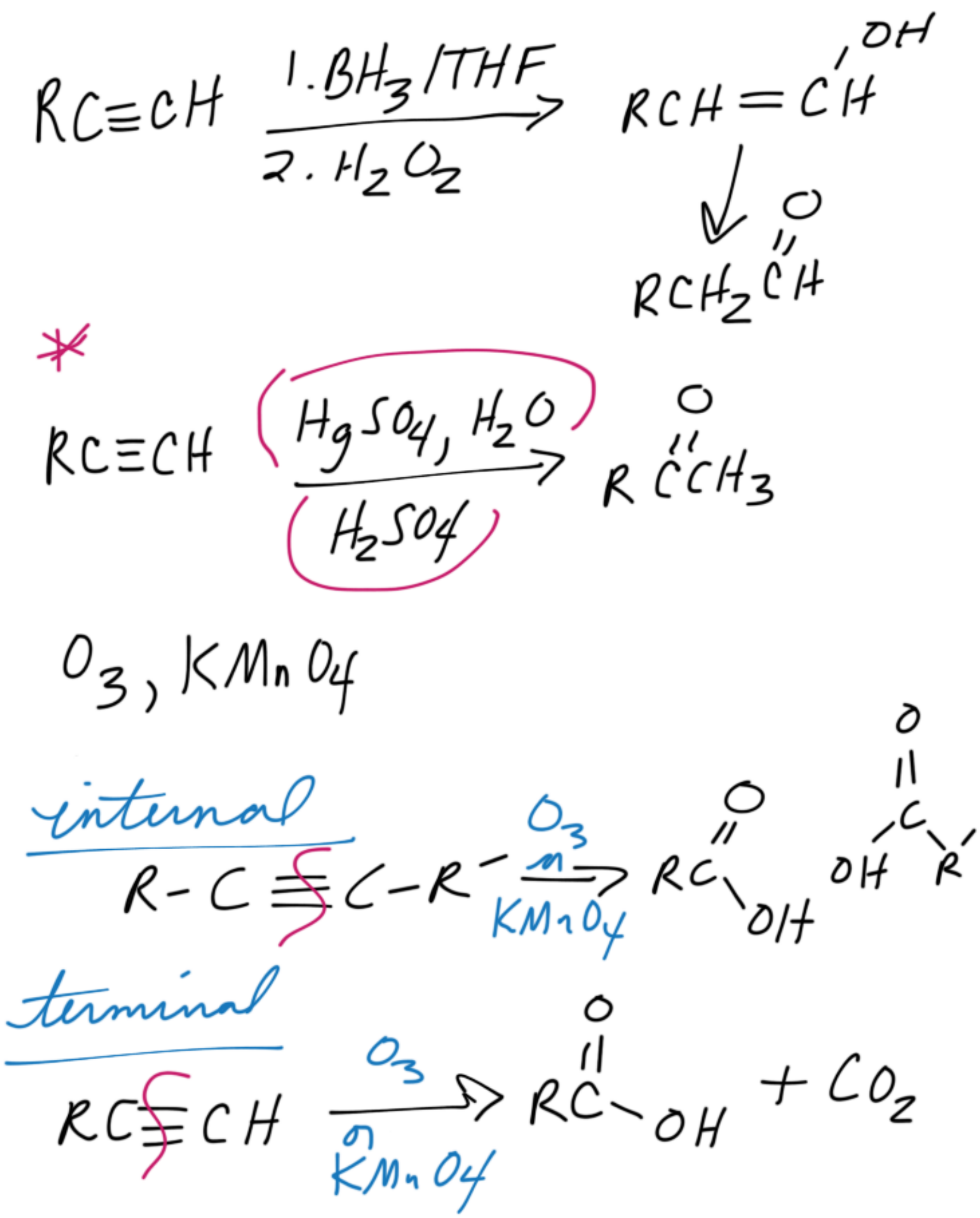


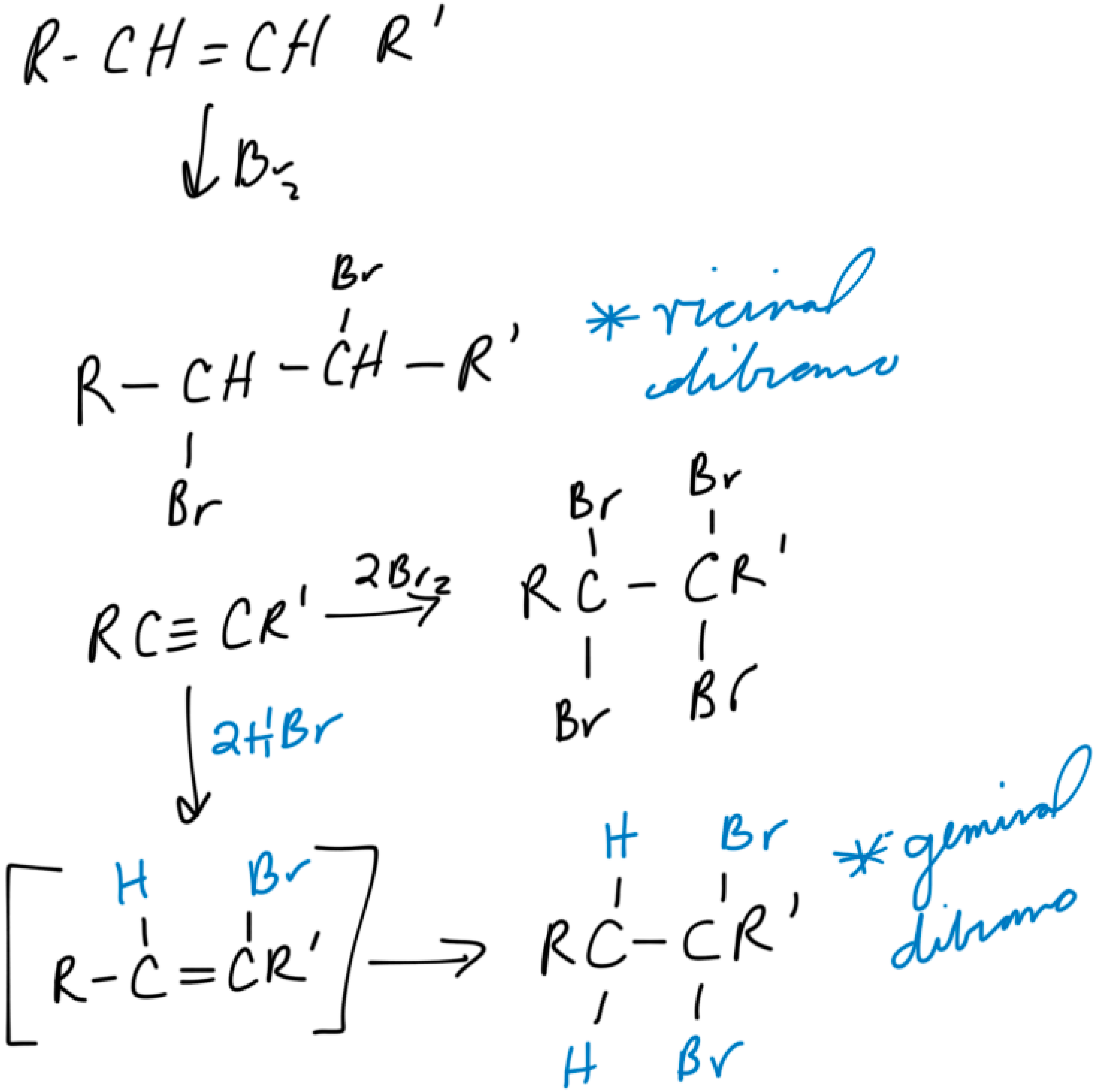
New Method:

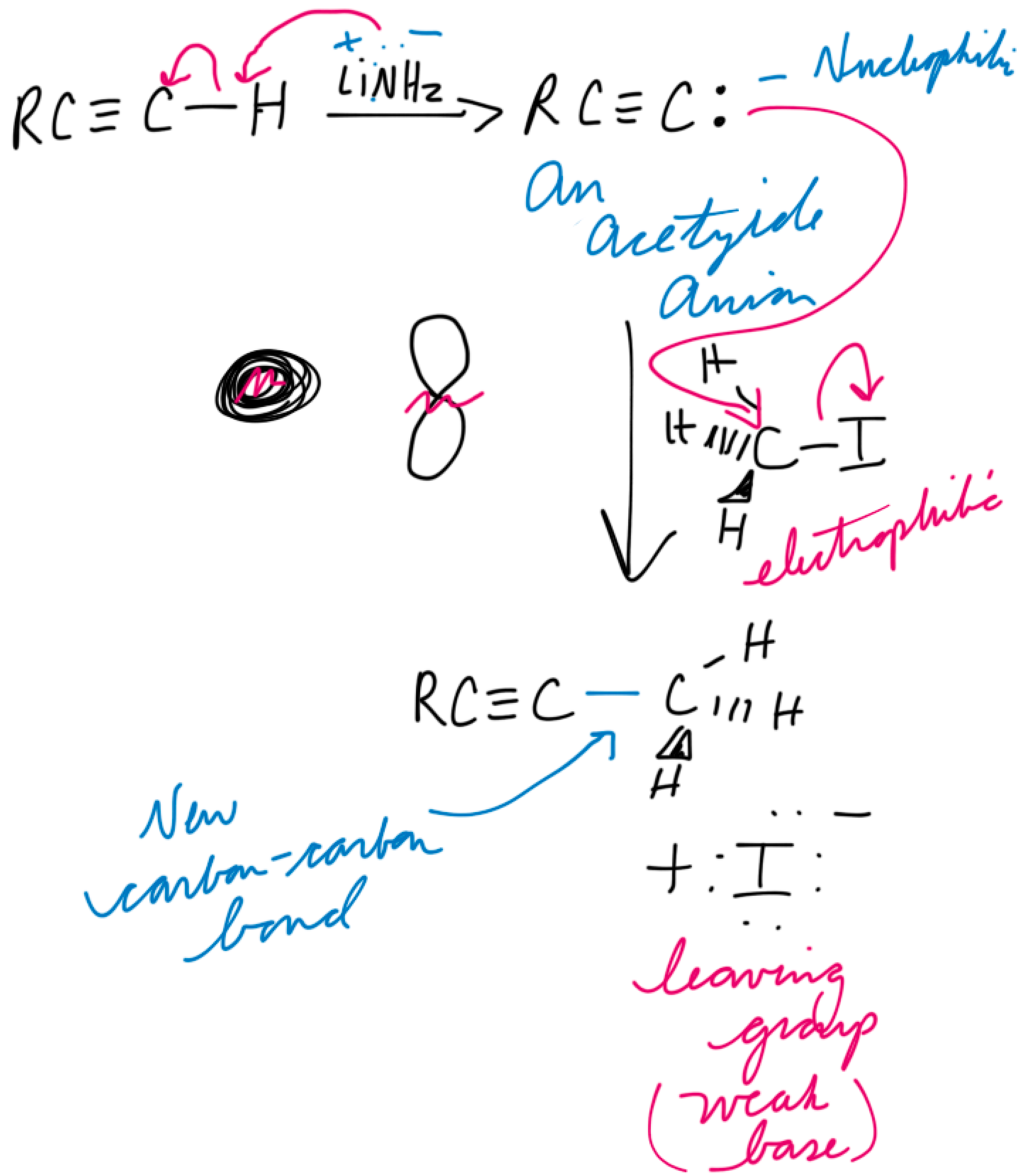


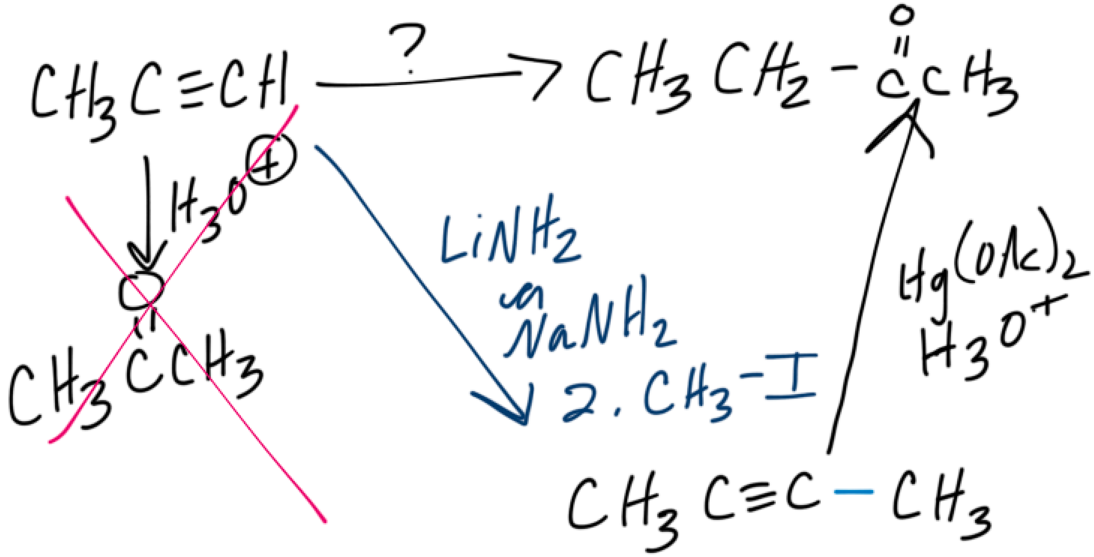
APPENDIX - C

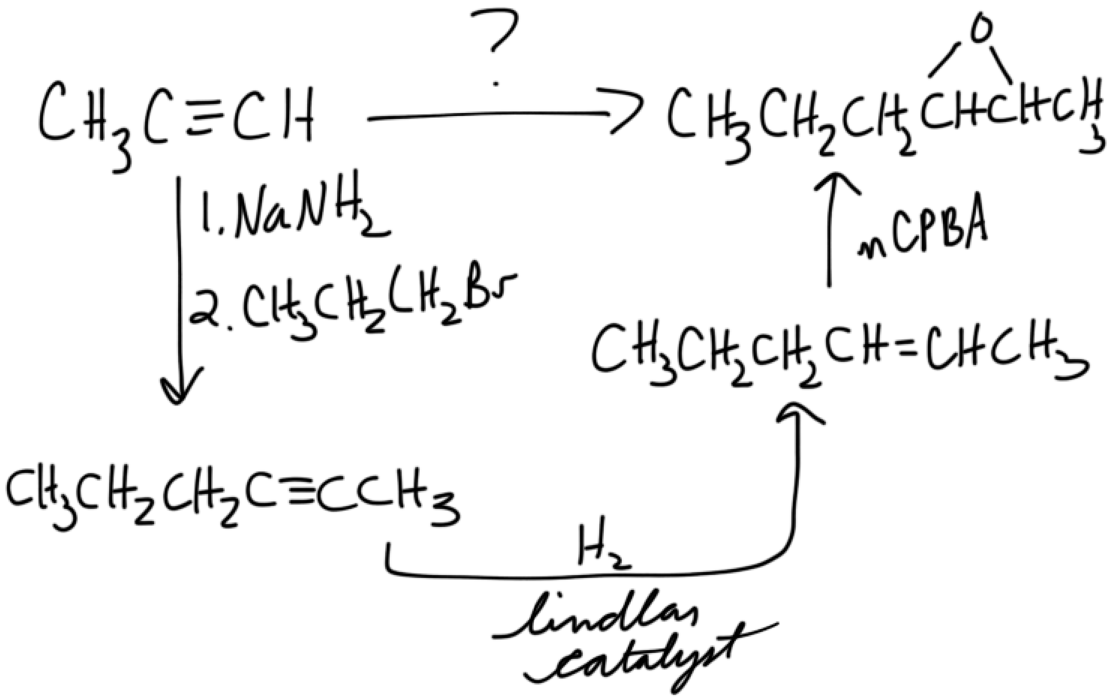
Teacher B Lecture Notes

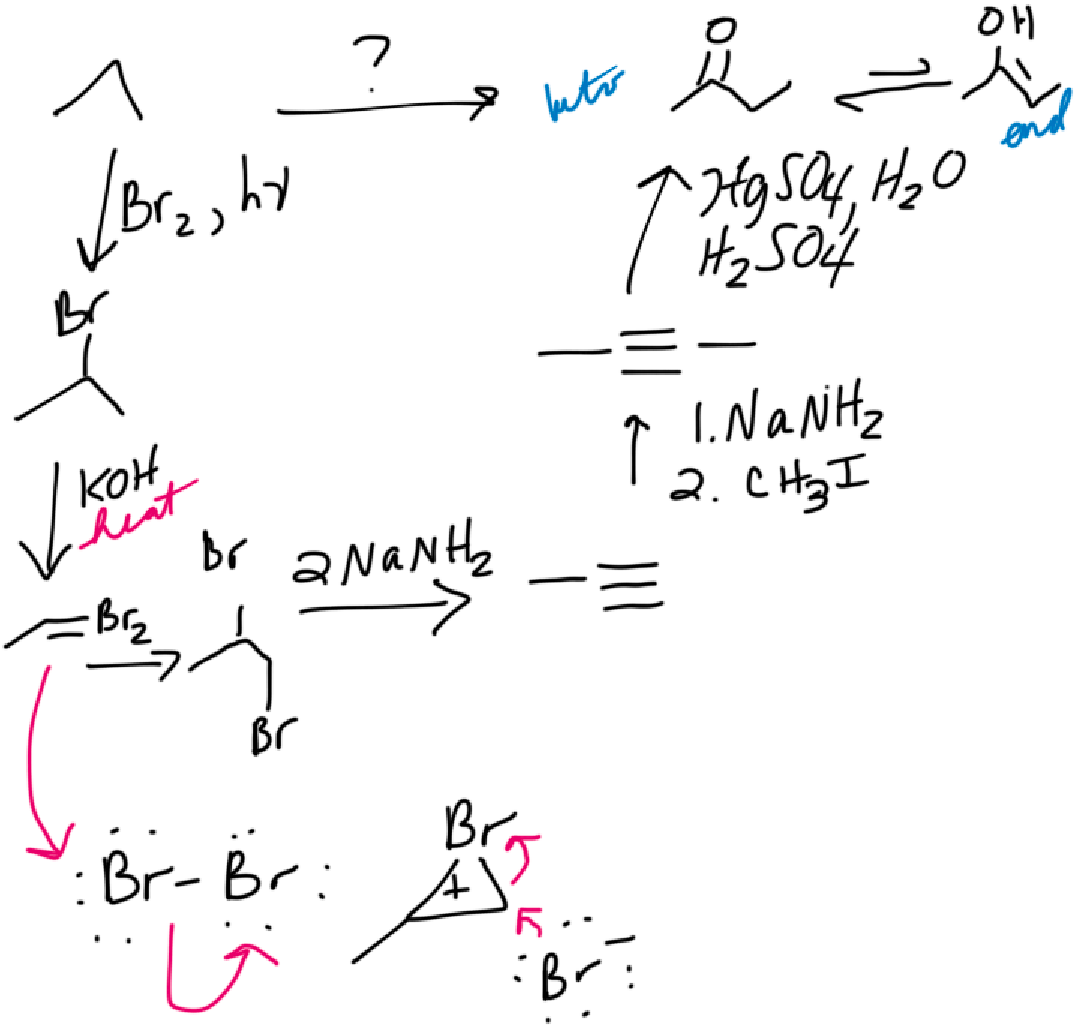


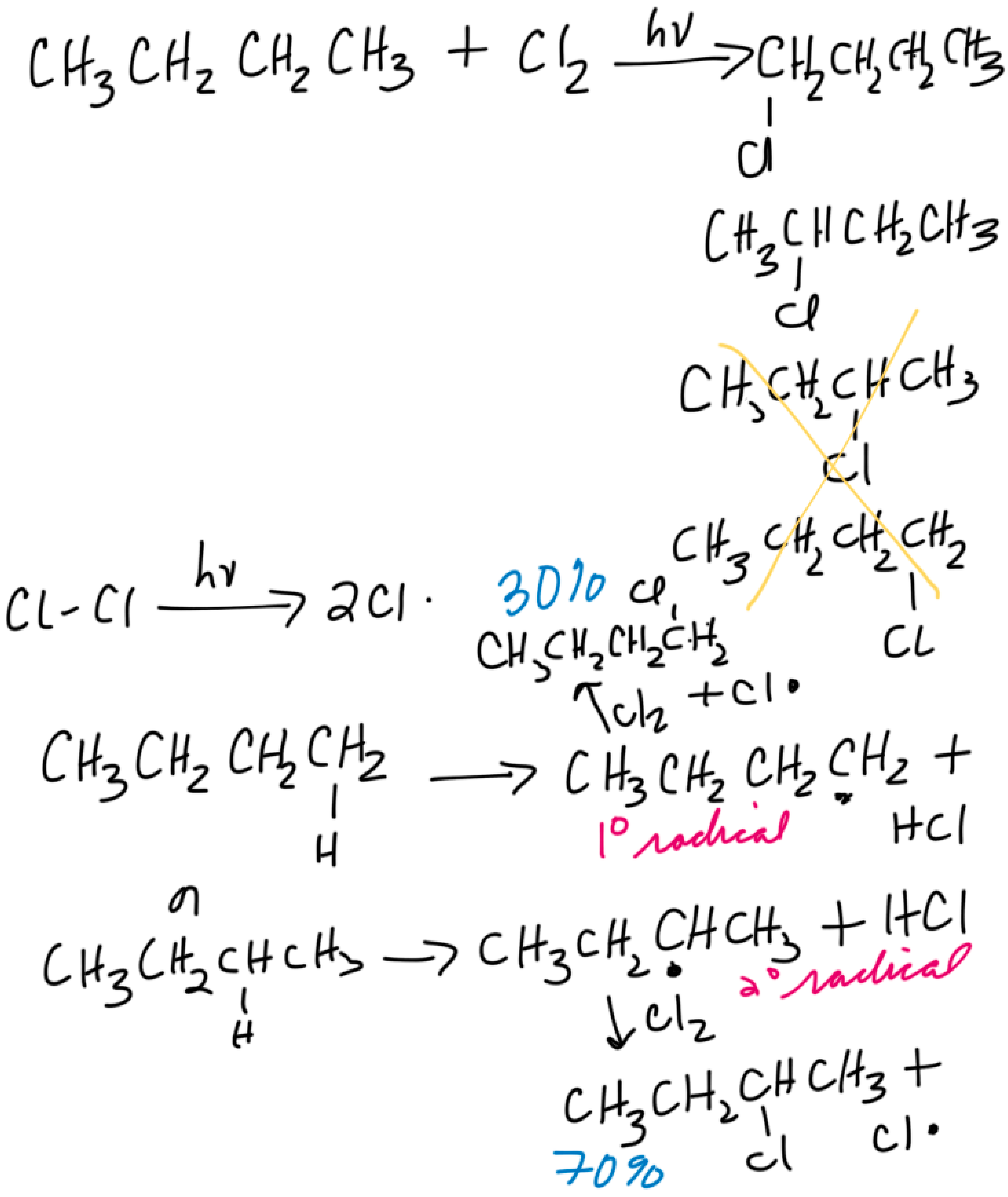

Br2
* vicinal dibromo
2Br2
2HBr
* geminal dibromo

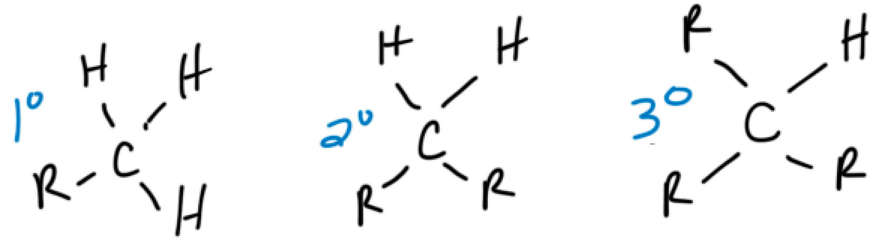

RC≡C—H
LiNH2
RC≡C:
Nucleophilic
An acetylide anion
H
H
C—I
H
electrophilic
RC≡C—C
H
H
H
New carbon-carbon bond
+ :I:
leaving group (weak base)


CH3C≡CH
?
CH3CH2-C(=O)CH3
H3O+
CH3C(=O)CH3
LiNH2
or
NaNH2
2. CH3-I
Hg(OAc)2
H3O+
CH3C≡C-CH3


CH3C≡CH
?
CH3CH2CH2CHCHCH3
O
1. NaNH2
2. CH3CH2CH2Br
mCPBA
CH3CH2CH2CH=CHCH3
CH3CH2CH2C≡CCH3
H2
lindlar
catalyst


?
keto
end
Br_2, hν
Br
KOH
heat
Br_2
Br
Br
2NaNH₂
1. $NaNH_2$
2. CH_3I
$HgSO_4$, H_2O
H_2SO_4
OH
Br–Br
Br
+
Br⁻


hv
Cl-Cl → 2Cl·
30%
1° radical
HCl
2° radical
+ HCl
Cl₂ + Cl·
70%
Cl·

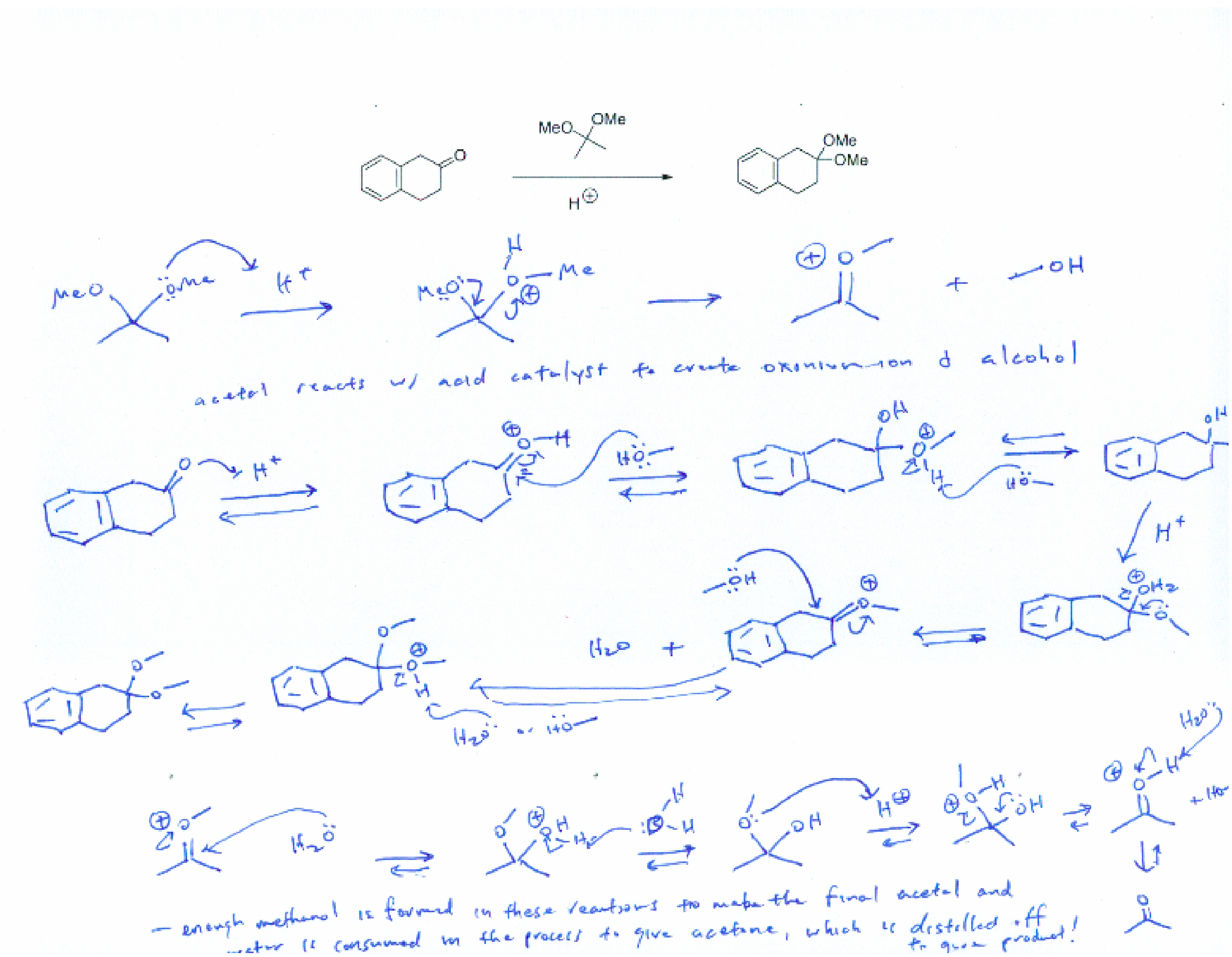


1.0 3.5 5.0

for chlorination

APPENDIX - D

Teacher C Before Class Practice Problem

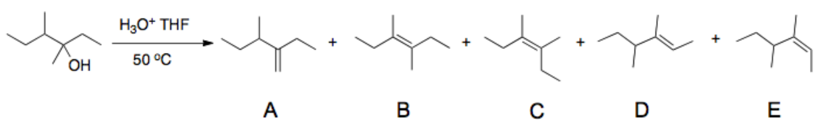


APPENDIX - E

Teacher C Lecture Notes

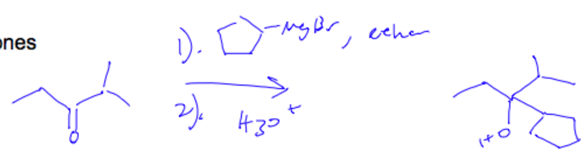
clicker question of the day:

what is a major product of the following reaction?

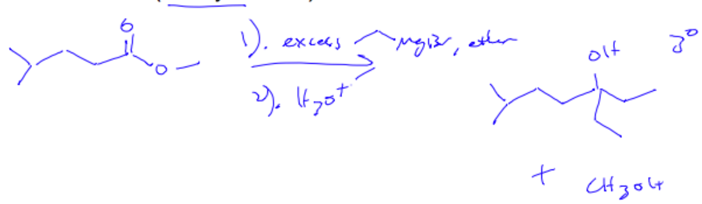


Example reactions continued: Reductive coupling reactions

Ketones

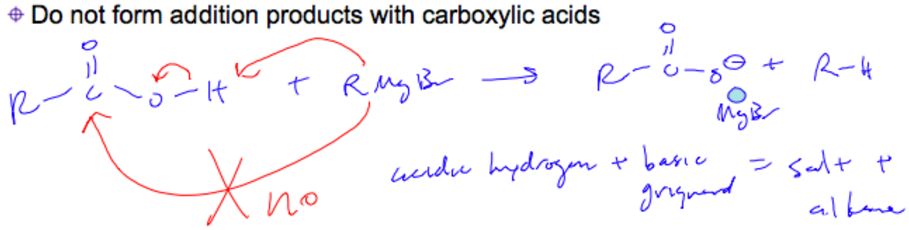


Esters: Disubstitution (tertiary alcohols)



Grignard reagent limitations:

- Do not form addition products with carboxylic acids



acidic hydrogen + basic grignard = salt + alkane

- Grignard reagents cannot be formed with compounds that have the following functional groups present in their structure:

where FG = —OH, —NH, —SH, —CO_2H } The Grignard reagent is protonated by these groups.

FG = —C(=O)H, —C(=O)R, —C(=O)NR_2, —C≡N, —NO_2, —SO_2R } The Grignard reagent adds to these groups.

Alcohol reactions: new rxn $POCl_3$

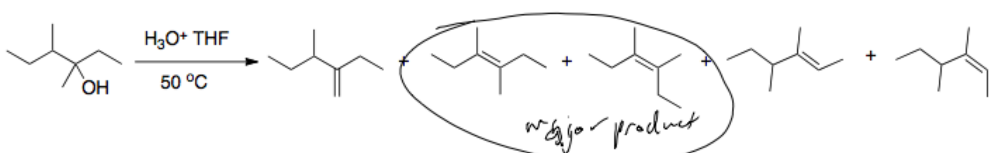
1. Acid catalyzed dehydration to yield alkenes (Review chapter 7)

E1 Tertiary alcohols: H_3O^+, THF, 50 °C (dilute acid)

E1 Secondary alcohols: H_3O^+ (75% H_2SO_4), 100 °C } Harsh conditions

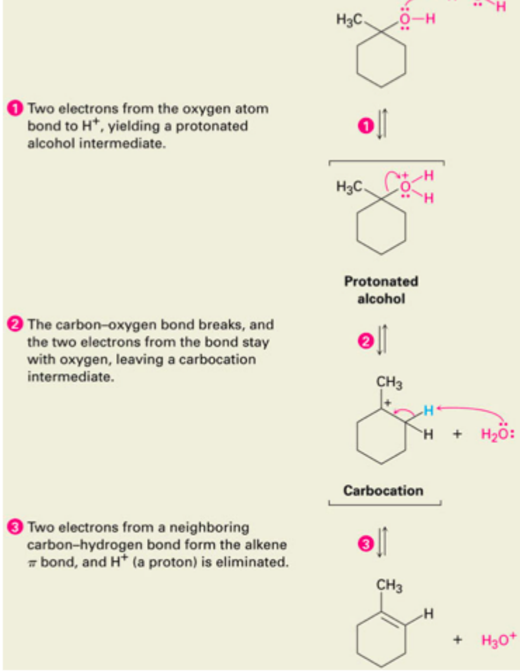
E2 Primary alcohols: H_3O^+ (95% H_2SO_4), 165 °C

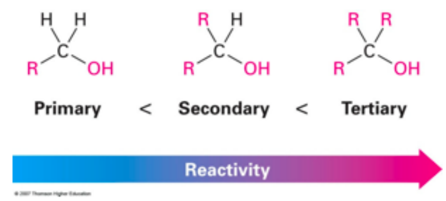
Obey Zaitsev's Rule: H_2SO_4, no good nucleophile is present, no competing S_N1 rxn possible



If different isomeric alkenes are possible, the most substituted alkene will be favored

E1 Review:





Remember for E2

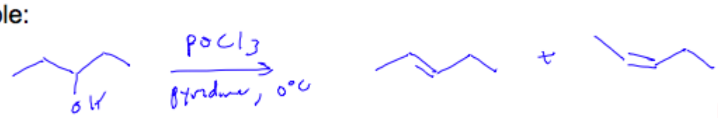
1). protonation

2). concerted bond breaking and bond forming rxn.

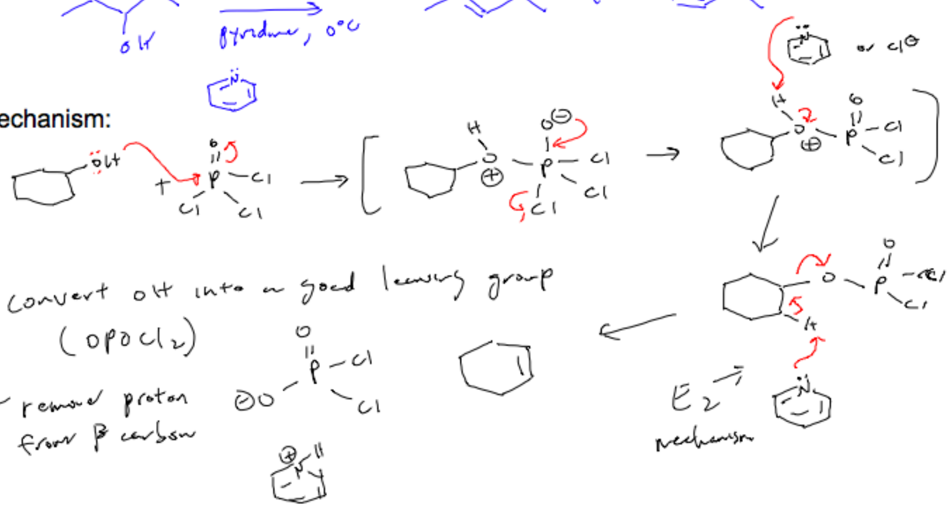
Dehydration using phosphorous oxychloride: $POCl_3$

Allows for the dehydration of alcohols at much lower temperatures (milder conditions)

Example:



Mechanism:



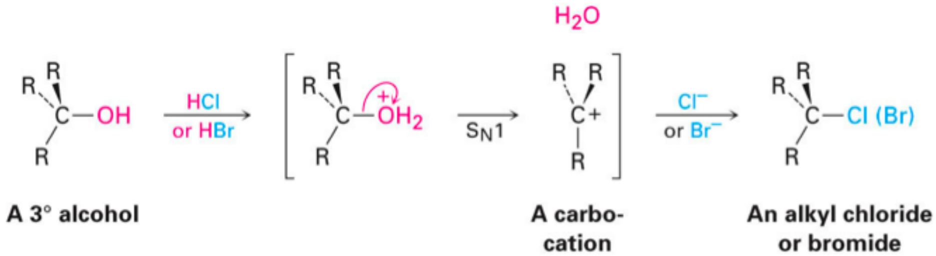
- convert OH into a good leaving group ($OPOCl_2$)

- remove proton from β carbon

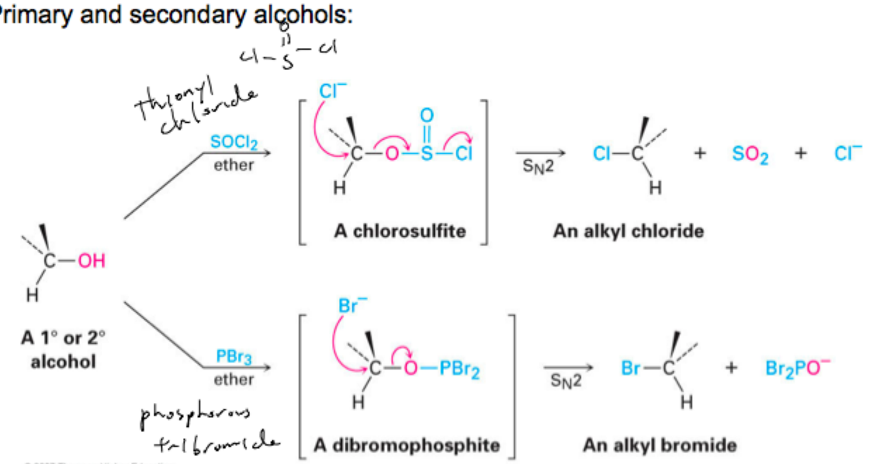
E2 mechanism

Conversion of alcohols into alkyl halides

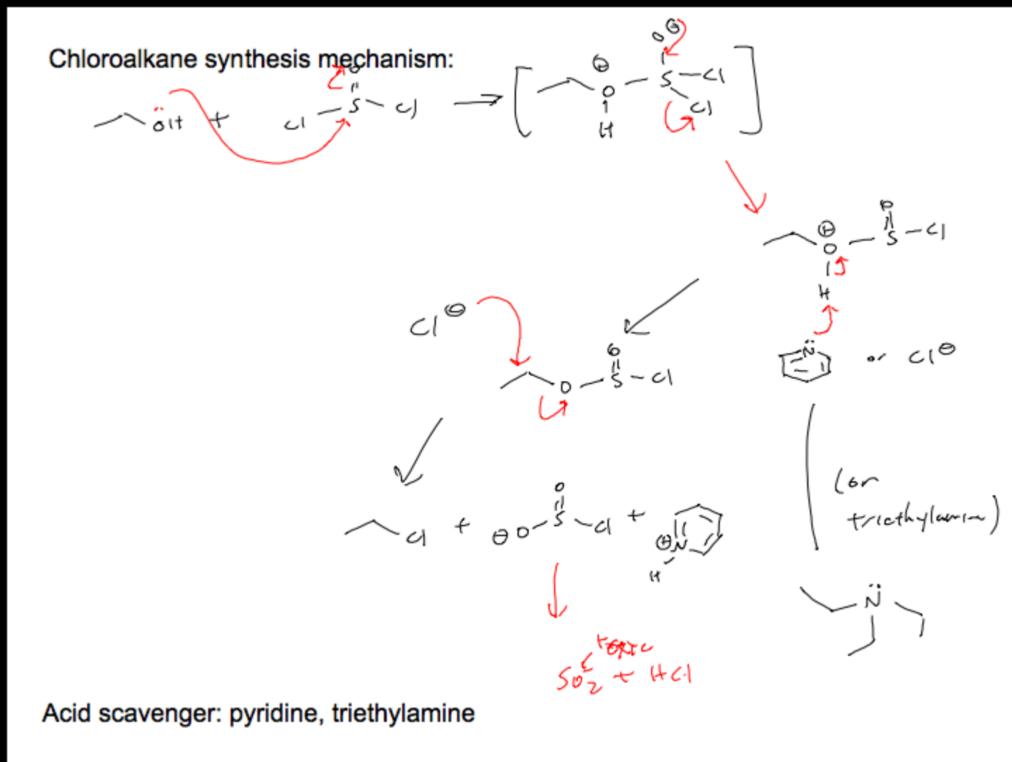
Tertiary alcohols (review): readily occurs w/ HCl & HBr at 0°C

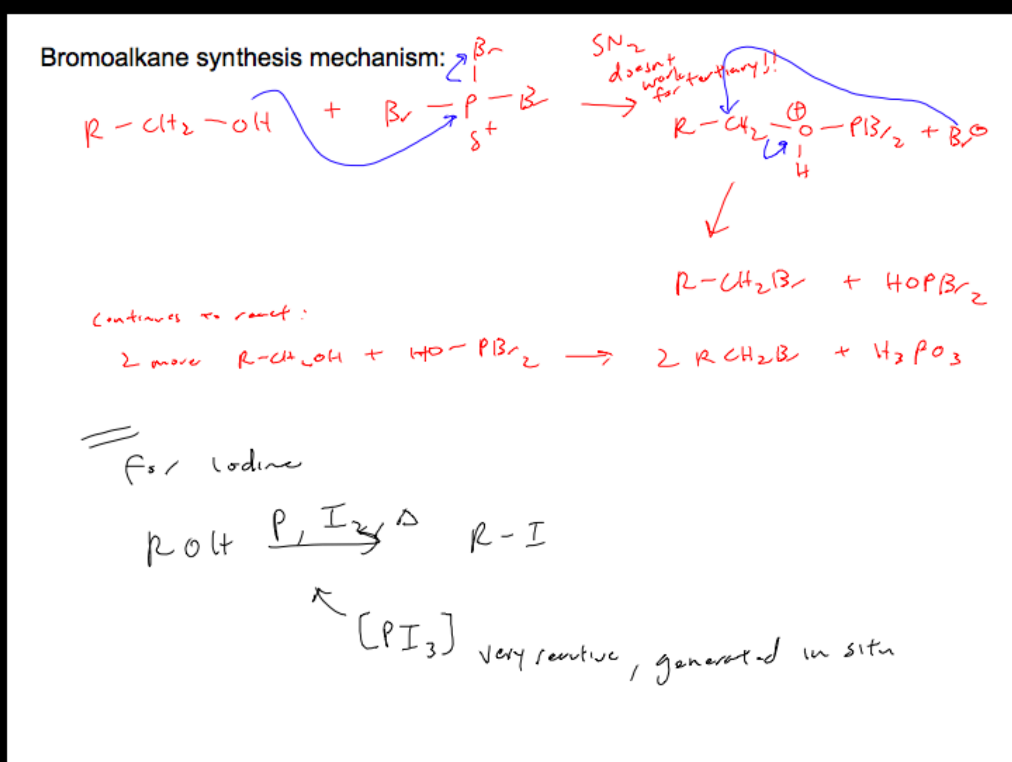


Primary and secondary alcohols:



does not work for tertiary alcohols (S_N2 mechanism)

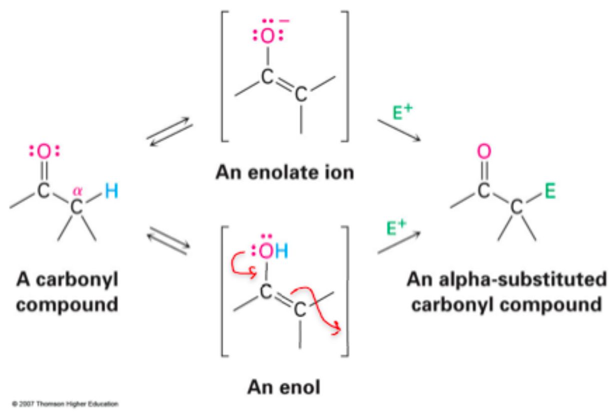

Chloroalkane synthesis mechanism:
(or triethylamine)
Acid scavenger: pyridine, triethylamine


Bromoalkane synthesis mechanism:
SN2 doesn't work for tertiary!!
continues to react:
For Iodine
[PI3] very reactive, generated in situ

Chapter 22: Carbonyl alpha-substitution reactions

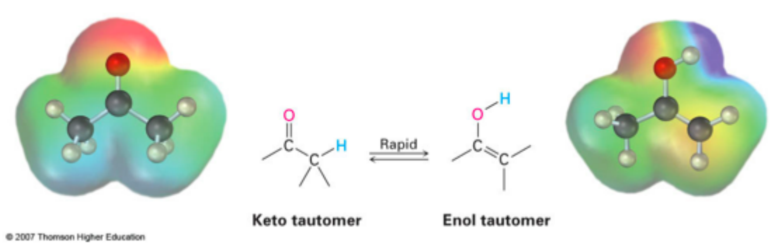
General Overview

The carbon adjacent to the carbonyl is designated as the α-carbon
Electrophilic substitution occurs at the α-position via one of two possible intermediates:



Keto-enol tautomerism

A carbonyl compound with a hydrogen on its α-carbon rapidly equilibrates with its enol tautomer



Difference between Tautomers and Resonance Forms:
•Tautomers are structural isomers
•Resonance forms are representations of contributors to a single structure

Difference between Tautomers and conventional structural isomers
•Tautomers interconvert rapidly while ordinary isomers do not.

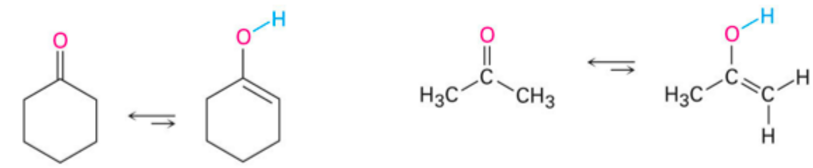
Position of the equilibrium lies toward the keto form in most cases:

Reasoning:

C-H single bonds and O-H single bonds are comparable in strength

BUT: C=O is stronger than C=C

Tautomerization can be catalyzed by both acid and base

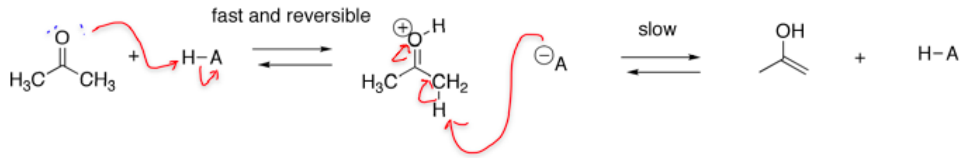


99.999 9%	0.000 1%	99.999 999 9%	0.000 000 1%

Cyclohexanone **Acetone**

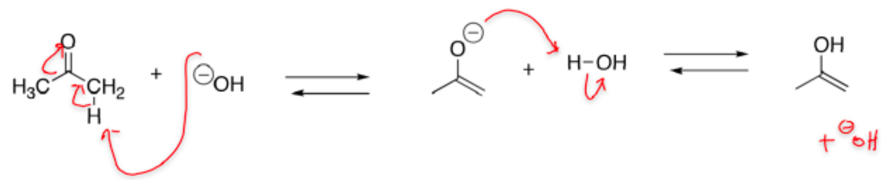
Note: *Equilibrium can lie towards enol form!*

Acid Catalysis of Enolization



1. proton addition
2. elimination

Base Catalysis of Enolization

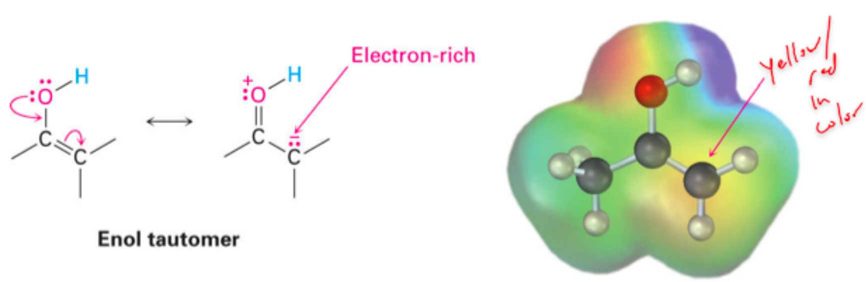


1. proton removal (elimination)
2. protonation to reform base and enol

General Reactivity of Enols

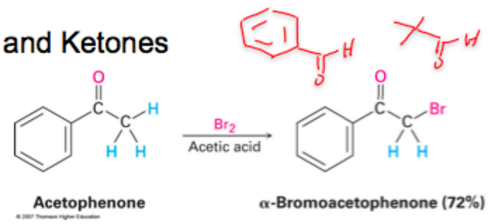
Enols behave as *nucleophiles*

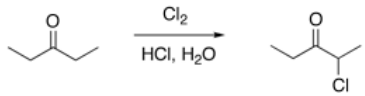
More electron rich than alkenes due to the electron donating OH group



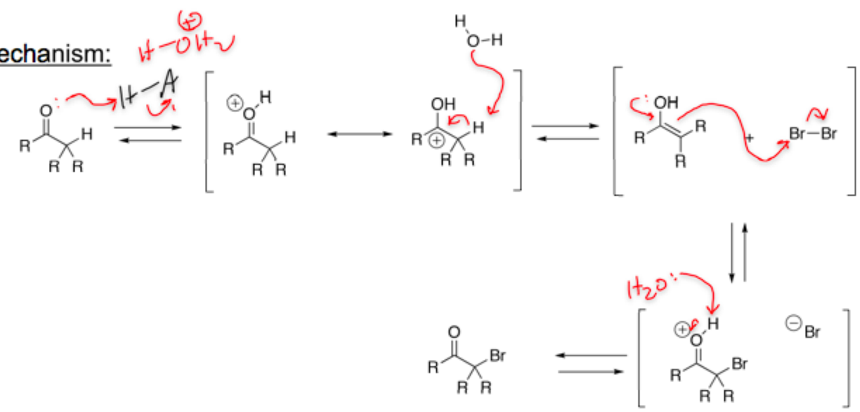
Alpha Halogenation of Aldehydes and Ketones

Cl_2, Br_2, or I_2 in acidic conditions





Mechanism:

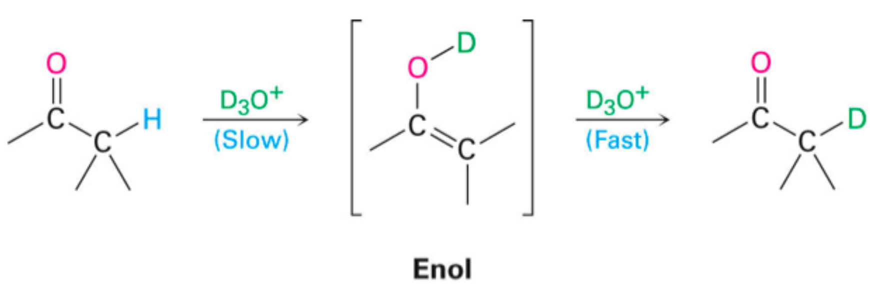


Evidence of the Rate Limiting Enol Formation Mechanism

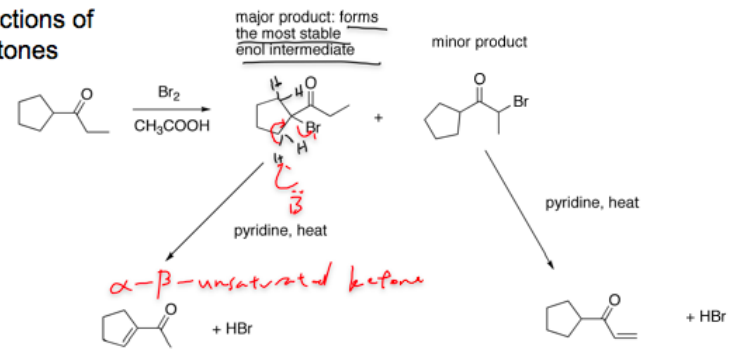
•Rate of halogenation is independent of halogen concentration and identity (Cl, Br, I react at the same rate)

•in D_3O^+, the α-H's are replaced by deuterium at the same rate as halogenation

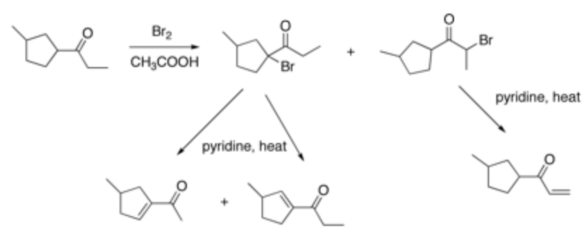
•Why? Formation is the enol is the RDS (no remember)



Elimination Reactions of Alpha-Bromoketones



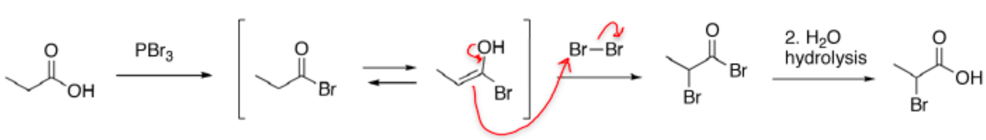
Be careful for product mixtures:

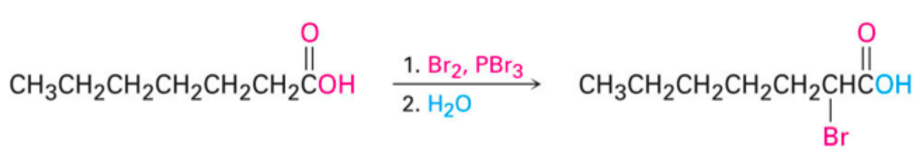


Alpha Bromination of Carboxylic Acids

carboxylic acids, esters, amides do not enolize in solution

Hell-Volhard-Zelinskii Reaction: carboxylic acids brominated with Br_2/PBr_3 mixture





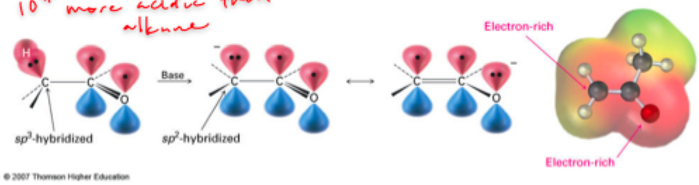
Heptanoic acid **2-Bromoheptanoic acid (90%)**

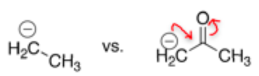
Why is the alpha hydrogen acidic?

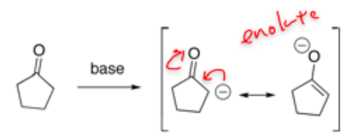
acetone: pKa = 19.3 (weak acid)
ethane: pKa ≈ 60
acetic acid: pKa ≈ 4.8

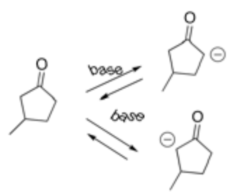
10^{40} more acidic than alkane

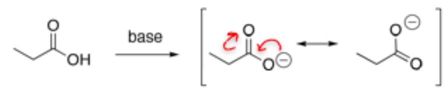
The conjugate base of a ketone/aldehyde is an enolate (resonance stabilized anion)











APPENDIX - F

Sample Exam

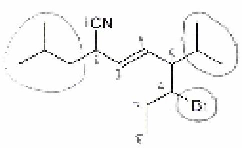
Name ____
Last, First 810#

CHEMISTRY 2212
EXAM 3
April 4, 2012

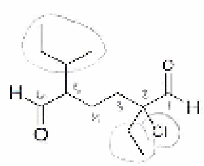
SCORE

Be sure to read each question carefully. Partial credit will be assigned where appropriate. To receive full credit you must answer the question completely. **Relax and good luck!!**

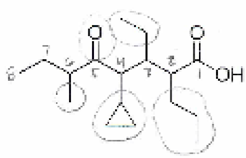
1. **(6 pts) Provide the appropriate IUPAC or common name for the following compounds:**



oct-3-enenitrile
or
E-6-Bromo-2-isobutyl-5-isopropyl-3-octenenitrile
or
E-6-Bromo-5-(1-methylethyl)-2-(2-methylpropyl)-3-octenenitrile



-1,6-hexanedial
or
5-sec-butyl-2-chloro-2-ethyl hexane dial
or
2-chloro-2-ethyl-5-(1-methylpropyl) hexane dial



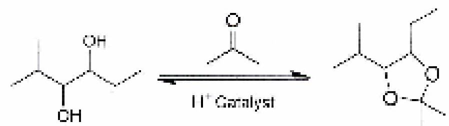
4-cyclopropyl-3-ethyl-6-methyl-5-oxo-2-propyl octanoic acid

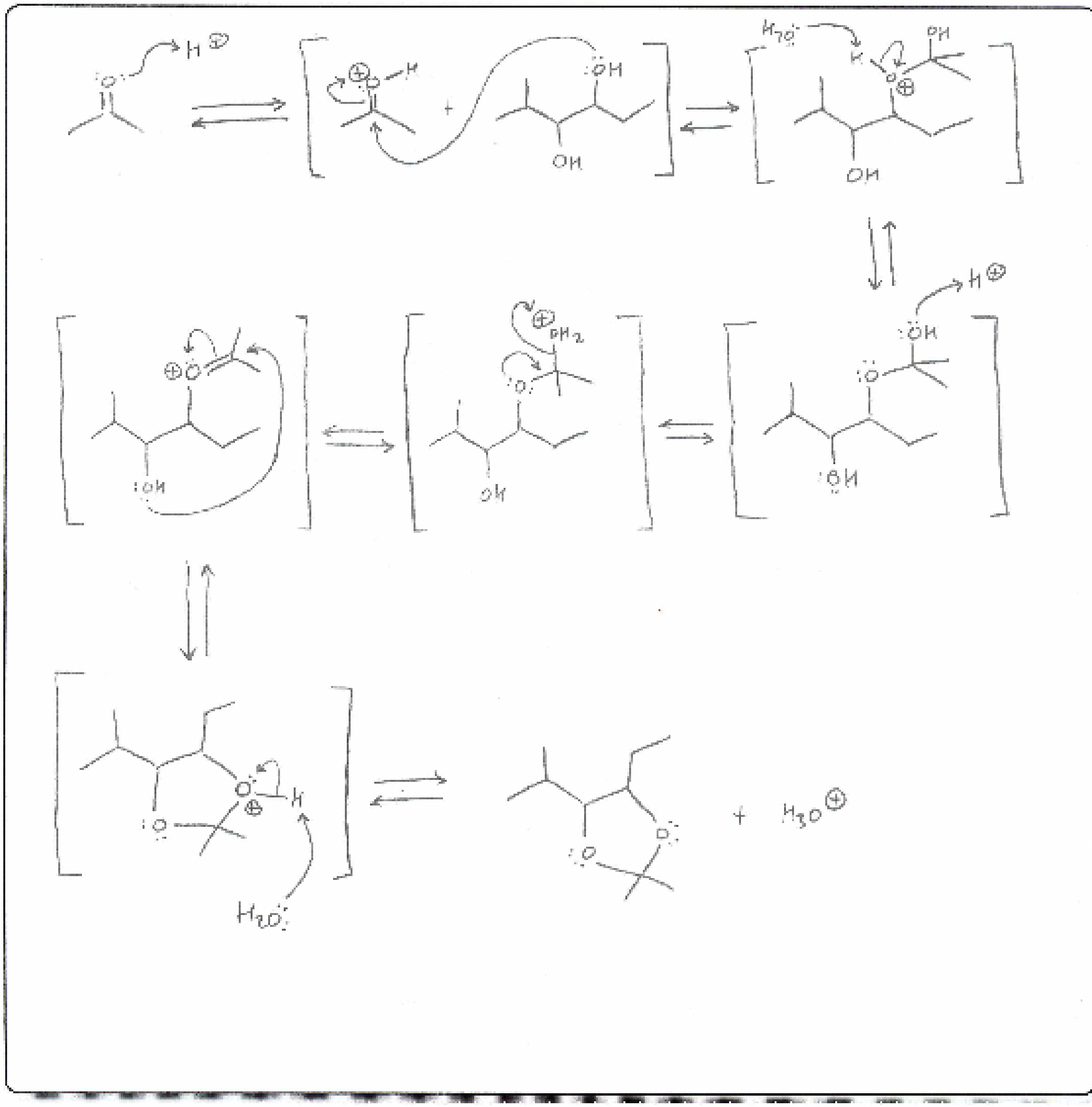
1. ________
2. ________
3. ________
4. ________
5. ________
6. ________
7. ________
8. ________
9. ________
10. ________

Total: ______

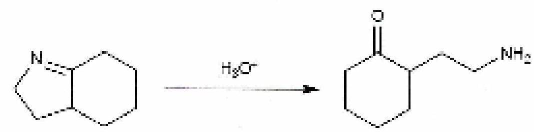
1

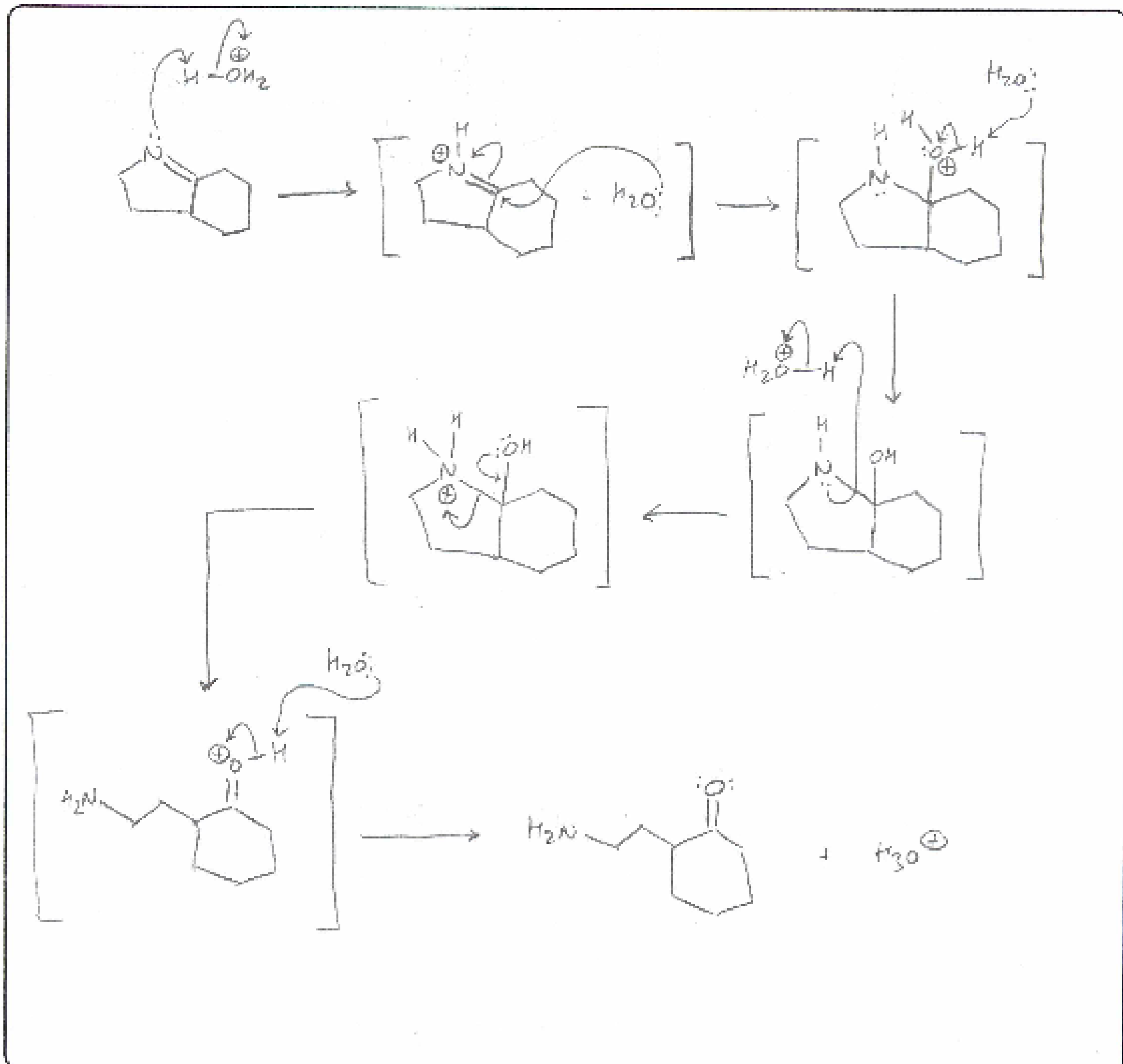
2. (16 pts) Provide a complete, detailed and stepwise mechanism for the following reaction. In order to receive full credit <u>you must show all electron movement and provide all of the possible intermediates for this reaction:</u>



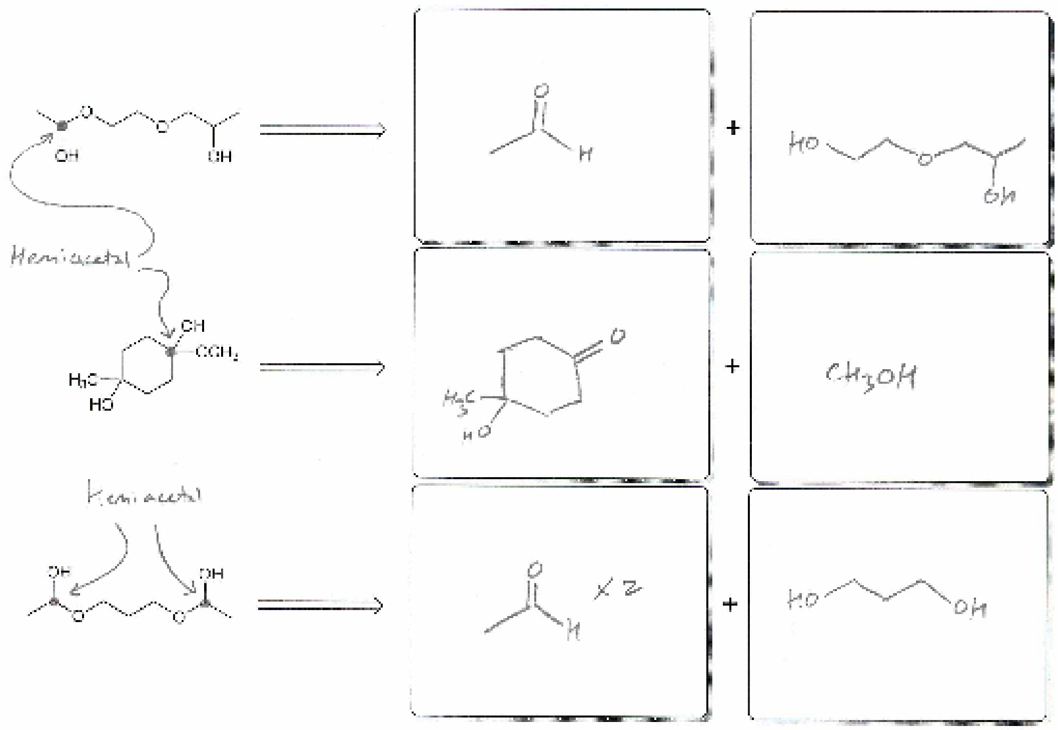


3. **(14 pts) Provide a complete, detailed and stepwise mechanism for the following reaction. In order to receive full credit __you must show all electron movement and provide all of the possible intermediates for this reaction__:**

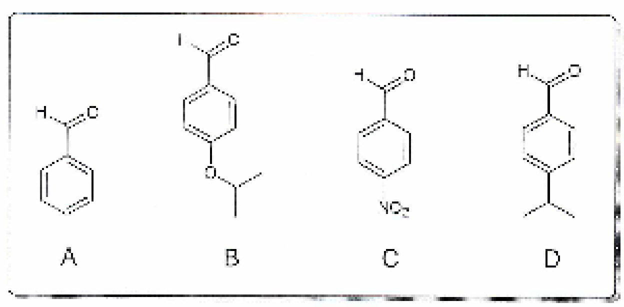




4. **(6 pts) Each of the following compounds is a hemiacetal, formed from an alcohol and a carbonyl compound. For each of the compounds below, provide the structure of the starting materials used to form the specific hemiacetal indicated:**

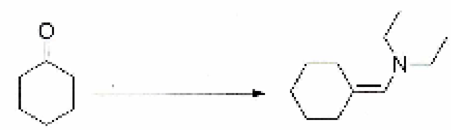


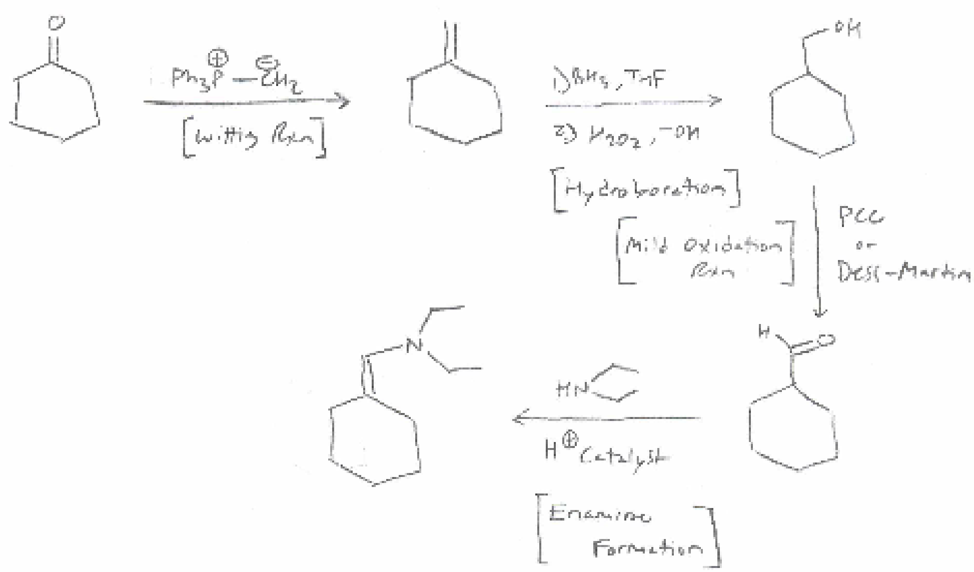
5. **(4 pts) Rank the following compounds in order of their <u>decreasing</u> reactivity towards nucleophilic addition. Place the <u>letters corresponding to each compound</u> into the boxes provided below to indicate your ranking:**



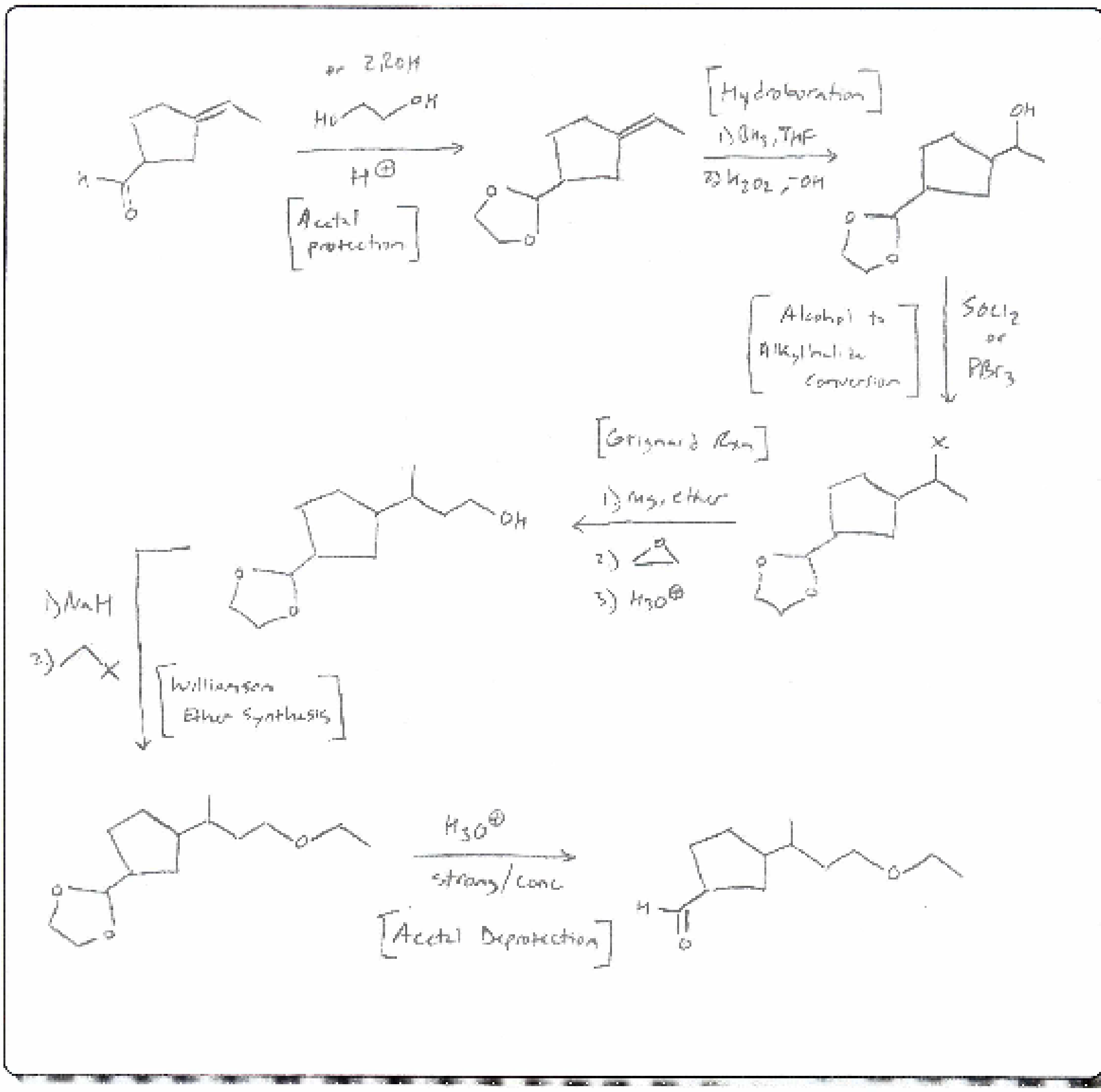
C > A > D > B

6. (10 pts) Provide a series of steps to accomplish the following synthetic transformation. You must provide all appropriate reagents and intermediates for your synthesis. <u>No reaction mechanisms (arrows) are necessary to answer this question</u>. [Hint: If you are having difficulty, try working backwards from the product to the starting materials.]

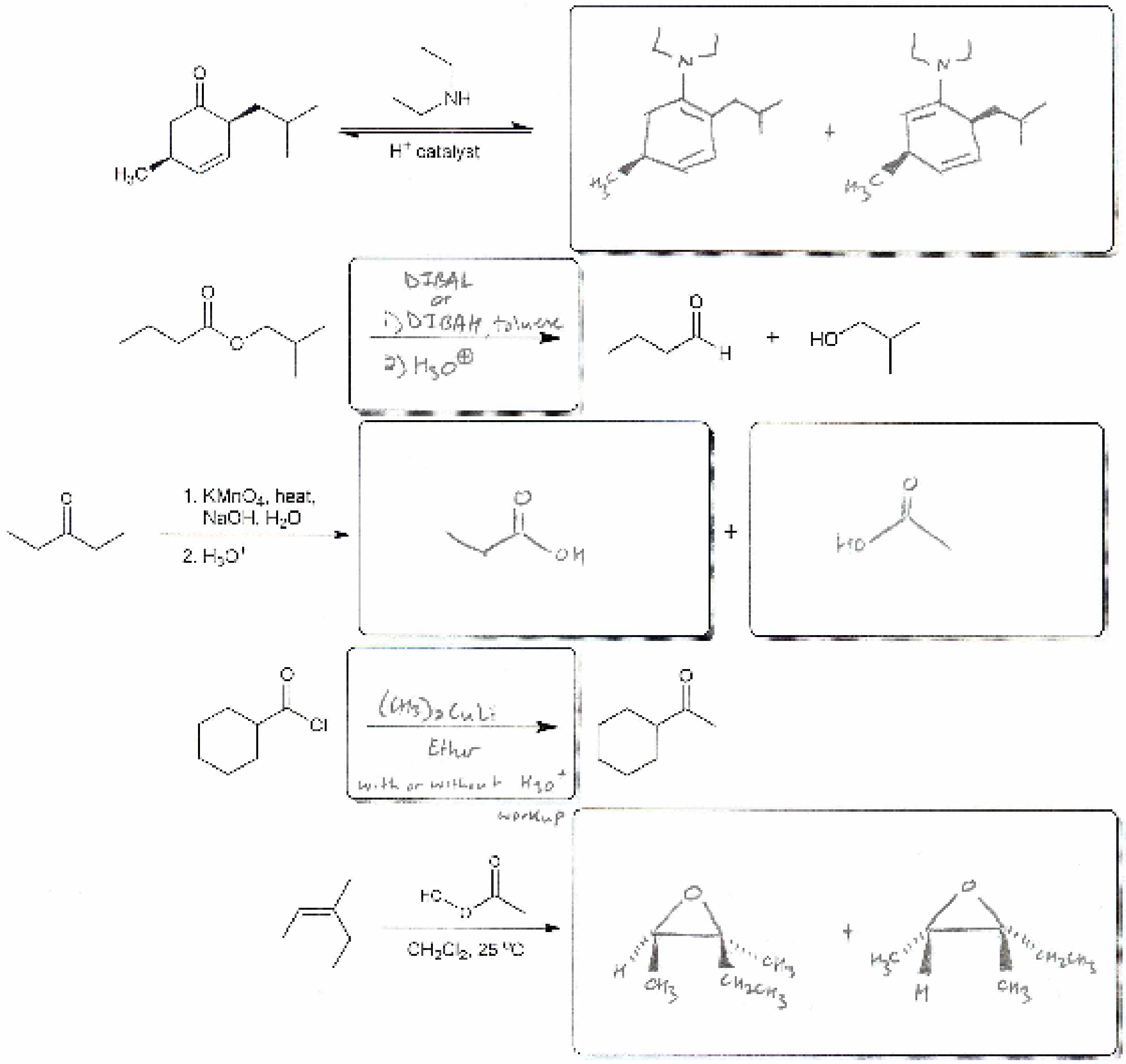




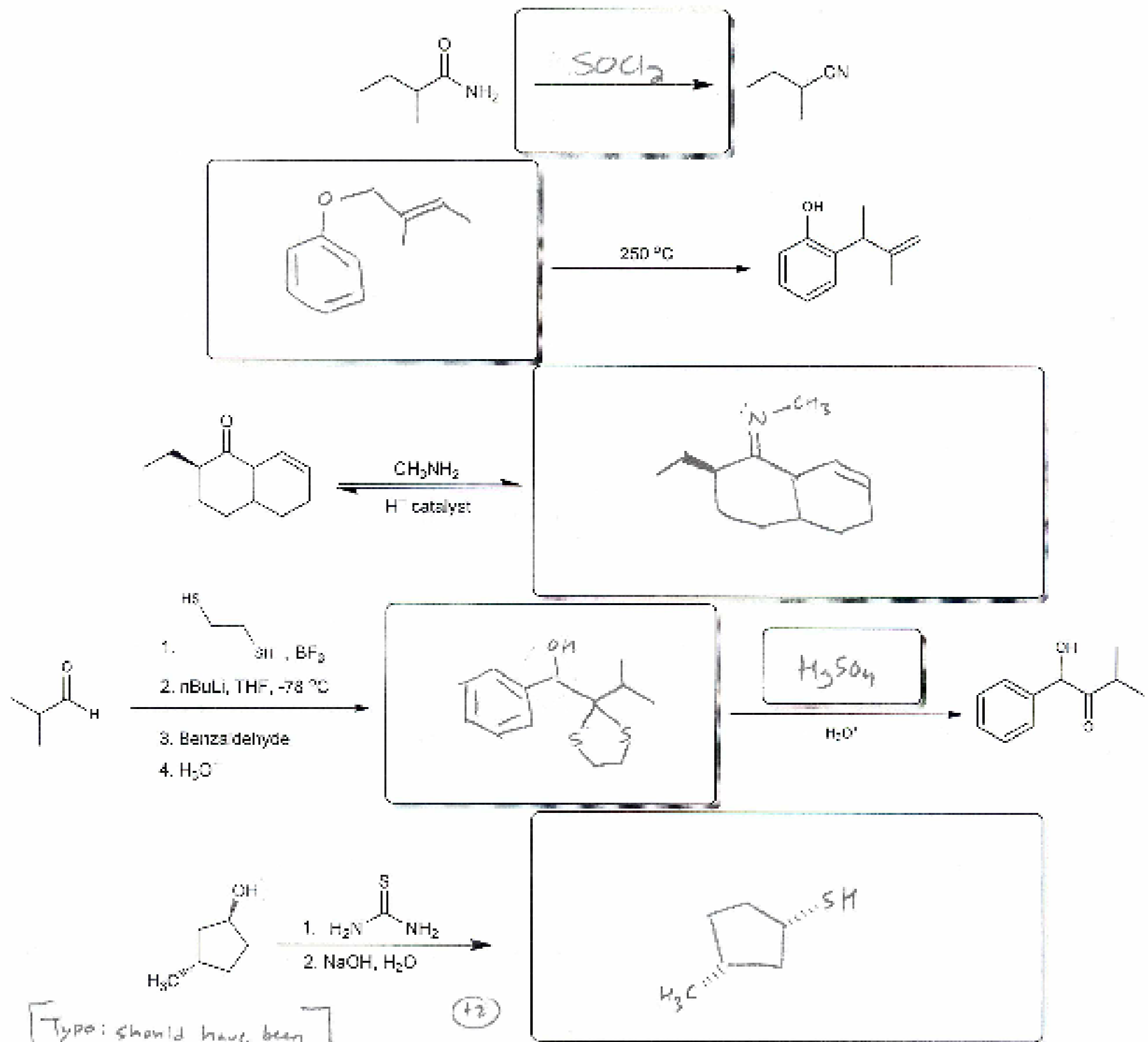
7. **(11 pts) Provide a series of steps to accomplish the following synthetic transformation. You must provide all appropriate reagents and intermediates for your synthesis. *Any and all carbon containing reagents used may only have two carbons or less.* No reaction mechanisms (arrows) are necessary to answer this question. [Hint: If you are having difficulty, try working backwards from the product to the starting materials.]**



8. (12 pts) Complete the following reaction schemes by providing the appropriate starting material(s), reagent(s), or all possible product(s). Be sure to indicate proper regiochemistry and stereochemistry where necessary:



9. **(11 pts) Complete the following reaction schemes by providing the appropriate starting material(s), reagent(s), or all possible product(s). Be sure to indicate proper regiochemistry and stereochemistry where necessary:**



Type: should have been an alkyl halide rather than an alcohol

10. (10 pts) Complete the following reaction schemes by providing the appropriate starting material(s), reagent(s), or all possible product(s). Be sure to indicate proper regiochemistry and stereochemistry where necessary: