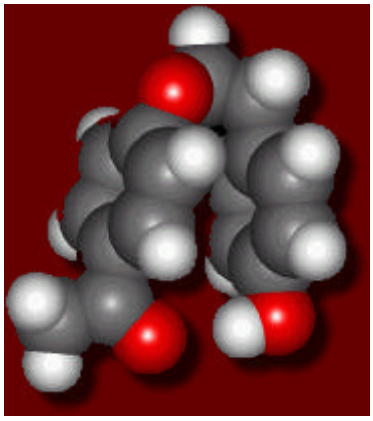


An Examination of the University of Nebrasksa at Omaha's Chemistry Department

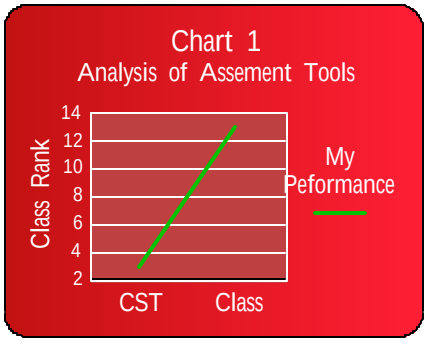
Steven R Green

September 4th 2002

Justifying the Numbers

There is something wrong with the way the chemistry department at UNO offers Organic Chemistry II (OC2). As a student I went into the class wanting a strong thorough understanding of the basic underlying rules and functional groups that chemists understand as organic chemistry. I naturally assumed that if I ascertained this knowledge then those tools of assessment used to evaluate my knowledge of organic chemistry would support my understanding. This turned out to not be the case. Imagine my horror when I realized that no amount of studying would prepare me adequately for the class. I was mad, angered, and frustrated past the point of tears. Despite such frustration, it is not my intent to explain the feelings this class arouses in me, rather I prefer to show you with the numbers I have collected the injustices of this class. I believe that a thorough examination of my number collection will show this class to be fundamentally unfair beyond any emotional conveyance possible.

I will begin with the final scores of the class. This data was obtained through the course web site where Dr. Hagen provided a breakdown of the final grades. For simplicity and ease I have created charts of the relevant material that will be discussed.



The argument is simple: if two evaluative tools report to measure the same thing, then it is reasonable to expect both tools of measurement to be concurrently valid. In the specific case, the two measures are as follows: the evaluative score given to me by the OC2 class derived form unit tests and quizzes and the second measure comes from the comprehensive standardized test (CST) provided by the American Chemical Society. Examine the green line of chart 1. On the CST I was ranked the third (tied) in the class, but in the class grade I was ranked 13th.

Acknowledging the inconsistency places one in the unfortunate position of rejecting one or both of the evaluative measures. One might be tempted then to argue that the class uses other measures besides knowledge mastery as a means to evaluate the student's mastery of the knowledge. Success in this argument implies OC2 was teaching a topic to students who were not evaluated on the material they learned. Fortunately this argument fails because in OC2, evaluative tools such as quizzes and tests constituted roughly 67% of the final evaluative score. The other 33% is derived from what is termed “group work,” which in truth was more quizzes, but there was some type of evaluative features that did not directly relate to OC2 knowledge. For example, group members evaluated each other on variables like preparedness for meetings and ability to clarify subject material, which was then converted into 40 points of our final grade. Class grade was determined from a total of 800 points reducing the effect of 40 points to a minor role in determining a final grade. More importantly, I excelled in this domain so these points could not have brought down the evaluative score I received in class.

This returns us to the problem of determining what evaluative tool failed to measure my knowledge of organic chemistry. I will make the argument that in fact the measure of the CST was a closer reflection of my knowledge of Organic Chemistry then the class evaluation. In so doing, I hope to show that OC2 is in invalid in terms of measuring the knowledge one has of Organic Chemistry.

Organic Chemistry is like a Foreign Language.

Dr. Hagen, the professor of OC2, wrote in the Journal of Chemical Education “Organic Chemistry is a foreign language for students” (Hagen, 2000). He continues the analogy by drawing correlation's between the different processes of Organic Chemistry and of learning a language. Several examples, such as learning a new functional group’s reactions, is much like learning a vocabulary list in a foreign language, or composing a synthesis is like writing a paper in a foreign language. Having taken both classes, I have no doubt that Dr. Hagen’s analogy is true. Since Dr. Hagen and I both think that OC2 is like a foreign

language it should be interesting to compare OC2 to Spanish II (SP2). SP2 was selected because both classes are 5 credits, require a lab, and have prerequisites in order to be enrolled. Thus, not only does Dr. Hagen think the classes to be equivalent, but on an academic level they are given equal weight. Some may argue that the two classes are not equivalent and that this comparison is unfair.

One response to this criticism is to ask the question "what mental process differs between the two? In other words, if these two subjects are so different then how does that difference manifest itself when cognitively learning the material. Furthermore, the data's large magnitude in difference would allow most to justify comparing the two with minor difference lingering in how they are learned. The data shows a gross imbalance and with it makes more clear the assertion that OC2 as an evaluative system is invalid. Please examine table 1.

Table 1	Organic Chemistry	Organic Chemistry II	Spanish 1	Spanish 2
Study Time	216.75	337.00	126.50	121.25
Class Time	44.00	155.00	69.25	64.25
Totals	260.75	492.00	195.75	185.50
Studied per week	13.55	21.06	7.91	7.58
Class per week	2.75	9.69	4.33	4.02
Combined per week	16.00	30.75	12.23	11.59

Table 1 reveals the total amount of hours spent attending class and studying outside of class. The data is broken down into Organic Chemistry, OC2, Spanish I, and SP2. The numbers were simply derived from a daily log I kept and upon request can be provided for. All logged hours were rounded to the nearest quarter hour for convenience and then converted to a 1 point scale. For example, 45 minutes of studying was translated into .75 on the logged sheet. Table 1 also shows how this raw data breaks down into average amount of time spent in class and studying per each subject over a 16 week semester.

One question many might ask is what does an hour of studying constitute for this student? What and how I study varies between subjects, but describing a typical routine should an idea of what I did. For OC2 when a new chapter was started I would read the chapter and record the new reactions into my computer. During this time, I was careful not to do any practice problems until I memorized the reaction enabling me to get the most out of each problem. (This is a rather technical process, but I attempt to solve the problems without assistance from the book. This insures I understand and retain the material for a very long time.) Once I memorized the reactions, I did all assigned problems. Questions that eluding being solved prompted me to seek guidance from my text book, lecture notes, or Dr. Hagen. Once all the problems were completed, and with time allowing, I would do all the problems again.

My study habits were not static and the actual method of studying was adjusted after each test to increase my understanding and retention. The evolution of my studying will be outlined later in the paper in order to give the reader an idea of what an average constitutes.

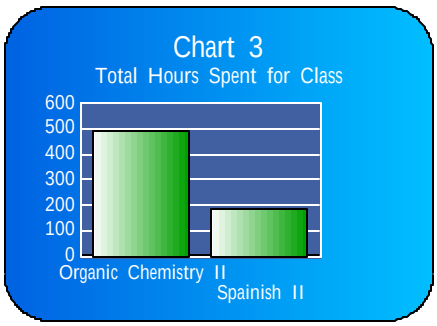


Chart 3 makes even more obvious what should have been made clear in table 1. I devoted nearly 500 hours to OC2, which figures out to be 30 hours per week combining class and study time. Comparing that SP2, to which I devoted only 200 hours, OC2 took roughly two and half times more time then SP2. Keep in mind that these two classes are equivalent according to academic assessment. As mentioned before the magnitude of the difference between the two classes is so great that one does not need agree completely with the assertion that OC2 is a foreign language to realize that one of these classes is not operating properly. Especially

when considering that academic administration gives both of these classes equal weight and yet OC2 demands much more time and effort then SP2. Clearly something is wrong and the question then becomes which class has the problem? I will provide an answer for this in a few paragraphs.

The most shocking thing about this statistical analysis is that I received a B in OC2 and in SP2 I received an A. Technically, I did not receive a B in OC2. The final grade in OC2 relied in part on my performance on the CST and when this is removed from my final grade my class evaluation was only a C. The following is worth mentioning again: I worked two and a half times harder in OC2 over SP2 and received a grade that was 2 letters lower then the SP2 grade. Clearly something is wrong either SP2 is too easy or OC2 is too difficult.

To answer this an examination of the classes in terms of credit hours will be conducted. Remember OC2 and SP2 are considered academic equivalents and it should be reasonable to expect that the ratio of time outside of class to credit hour should be roughly equivalent.

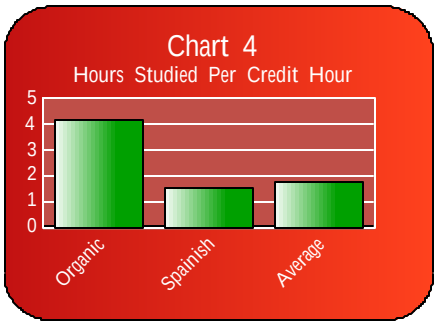


Chart 4 seems to indicate otherwise, by examining the amount of hours spent studying per credit hour. In addition to OC2 and SP2 the ratio of study time to credit hour has been included from an average of all other classes that I have received an A in. This ratio can serve as a rough indicator of what the typical UNO class ratio is required in order to receive an A in a class. The ratio ended up being 1.79. In order to get an A in an average UNO class one needed to do 1.79 hours outside of class for each one hour spent in class.

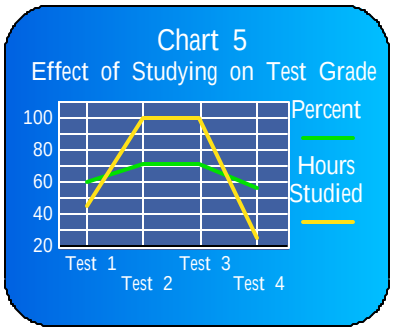
Chart 4 gives the answer to which class is operating poorly. They both fail in that SP2 is too easy, and OC2 is monstrously too difficult. Of course I am using the ratio of SP2 and class average to OC2 which is not a fair assessment as I only received a C in OC2, whereas in the other two categories I received A grades. Thus, in order to get an A in OC2 I would need to spend more then 4.2 hours studying per hour spent in class.

Any good academian would recognize the fact that 4.2 is ridiculously too high especially when you consider the student only received a C in the class. Furthermore, if OC2 is like a foreign language as Dr. Hagen suggests, then some type of explanation should be given as to why the two do not equivocate in terms of time spent studying or going to class. I have an answer to this problem, but before I move on, I want to make one final point concerning credit hour.

If we assume that OC2's 4.2 ratio is the level that the university wants the difficulty of their classes to be then in order to spend 40 hours a week in school, that is to be full time, one should take 7.5 credit hours a semester. This is 4.5 credits less then what is considered full time currently. At this time, the university considers a 12 credit semester to be full time, and so the ratio is at 2.3 so that a student needs to spend 2.3 hours outside of class for every hour in class. OC2 requires about double that amount of time to receive only a C. Clearly something is wrong with OC2 but the question is what?

Doomed for a 72%

Why does OC2 require so much more effort then SP2, or for that matter any class I received an A in? For an answer please examine Chart 5 as it shows the relationship between number of hours studying and percent received on the test. Class time and lab time both in lab and outside of lab has been eliminated to derive this chart. The chart makes plain what little effect studying actually had on the grade received on a test.



For example, on the first test I studied a paltry 45 hours to which I received only a 65%. Realizing that I was not working hard

enough in the class I increased my efforts greatly for the second test to which I received a 71.5% by studying a hundred hours. By increasing my studying efforts by more then 200% I received a 10.5% increase in grade. Despite an astonishing one hundred hours spent on test two I still assumed that my low performance was my fault.

Studying for the second exam I used the method outlined above. After performing poorly on the second test I relied on my experience of previous classes to perform better. Such experience has taught me the most effective way to learn material, so as to master it, is by discovering, by use of textbook, what I have done wrong. Most people do this, but my method differs as a search is conducted for the first time the textbook mentions the idea necessary to solve the problem. Within the chapter that first mentions the problem I work all the problems dealing with that idea. Often times, I would then work through all chapters that has variants on that same idea until I got to the problem I failed to solve properly in the current chapter. This method is incredibly effective in insuring my understanding of the material and yet takes a tremendous amount of time and energy to accomplish. I did this for the second test often times looking in chapters studied during the previous semester to answer question in the current chapter. I performed poorly using this method on the second test and reasoned that the method may be sound, but that I needed to widen the amount of sources I used. Thus, I enlisted the help of an additional textbook, and multiple web sites. This is to say nothing of the amount of material that Dr. Hagen gave us to study. Of course studying this way took another hundred hours and when test 3 came I felt prepared. However when I received the results of the test my efforts were rewarded with a 72%.

To summarize my efforts on test 3, I had spent one hundred hours studying in a slow deliberate fashion using multiple sources, including Hagen's recommendations, to prepare for the exam. For all this effort I received a 72% on the test. Once I got my third test back I was left without any knowledge of how to get a better grade. I employed old techniques and developed new techniques of study only to have all of them fail. I knew of no route that would allow me to get a grade higher then a 72%. When I asked Dr. Hagen, he had no answer for me, even he was not sure how I was to receive a higher grade in his class.

By the time the fourth test came around I was mad, frustrated, and upset. In addition, all the work from my other classes had caught up with me and so I only studied about 25 hours for this test. For this effort I received a 57%. My studying dropped by 75 hours and the resultant grade only dropped 15%. At this point it became rather obvious to me that I had little control over my performance on a test. The price to move a test grade by one percentile point was so much that it made taking the test irrelevant because of the amount of work it required to perform well.

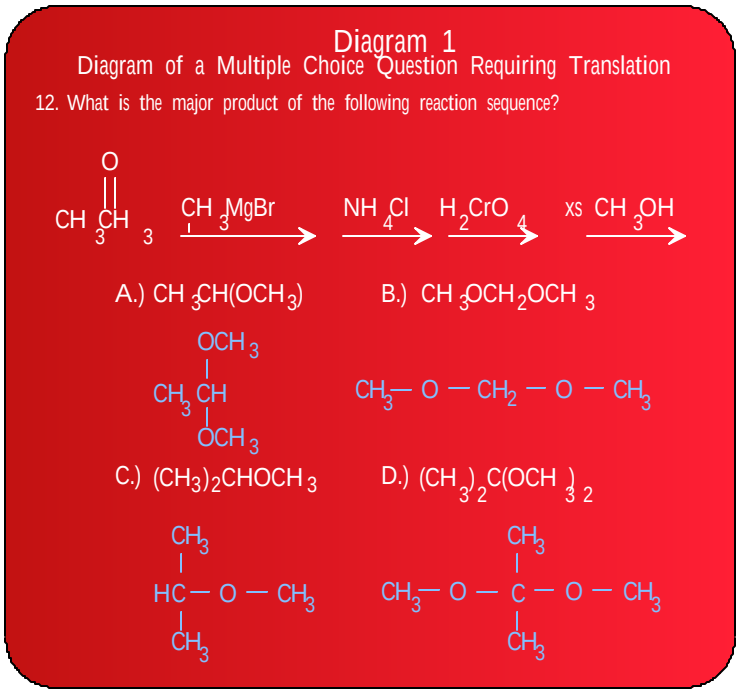
The fact that the hours spent studying had little effect on my performance on the tests indicates that the problem with OC2 was the unit exams. It turns out the claims made earlier that OC2 requires significantly more effort then SP2 were false because the comparison being made in truth could not be made. OC2 has no relationship with hours spent studying while the hours spent in SP2 do have a connection to the grade, or so I assume. Thus, examining OC2 in terms of amount of time spent studying accomplishes nothing, unless of course you evaluate that knowledge that with another measure. Fortunately such data is available as the CST ranked me in the class with the 3rd highest score which must have some truth to it given the amount of time and effort placed into learning the material. Given my effort, and the ranking of the CST one must concede that the evaluative tools in the OC2 class were clearly invalid. Why was the unit test invalid in OC2?

Compound Questions

An issue between Dr. Hagen and I was the amount of time needed to take a unit test. The students are afforded a couple more minutes then a typical 50 minute class. This amount of time proves to be a ridiculously small amount of time for the amount of material an OC2 test covers. A large test coupled with a minimal amount of time strikes at the core of why OC2 as an evaluator is invalid. A more thorough explanation is needed.

A typical OC2 test averaged 19 multiple choice questions and averaged another 12 of what could be called fill in the blank. (Note that this average does not include test four for reasons that will be explained latter.) Fill in the blank means that parts of a reaction are missing and must be filled in properly for credit. The problem could involve a synthesis, mechanism, maybe nomenclature, but most likely a reaction.

Combining the two sets of problems together on the first three tests there were on average 31 problems. Assuming a 50 minute testing period one can then expect to spend about 96 seconds on a problem. This seems like a reasonable amount of time for a test that is mostly made up of multiple choice



questions. Unfortunately this is not the case for one simple and obvious reason: the questions are not written in English but in OC2. On most questions one could expect to spend some time translating. Diagram 1 shows what translating means.

The diagram takes from test 1 question 12. It shows a rather simple multiple choice question in white. However making sense of the question requires translating the abridged, or simplified forms of the molecules and from it forming a more complicated but easier to see molecule as shown in blue. On many questions this was standard procedure. In order to make sense of what was being asked, a laborious and timely procedure of rewriting molecules was needed to solve the problem. This question happens to be middle road in terms of translation complication. There are other levels of translation and one type of multiple choice question that I call compound because of the amount of translation necessary to solve the problem.

In a compound multiple choice question the starting information is heavily coded as well as the multiple choice answers. This type of question gets its name compound because not only must the question be translated, but so does the multiple choice answer before one can actually begin working on finding an answer. Then for each answer a transformation must occur according to each step of each multiple choice answer. In order to answer this one question, one must translate the question, then translate somewhere between 1 and 3 steps for each multiple choice answer, and then take the starting material and carry it through each translated step. In a best case scenario, this one question has 8 steps. As the name compound implies, with each step in the question you multiply for a greater number of transformation steps so that when each multiple choice question has 3 steps one has 26 steps ahead of them. Drawing and understanding this much information takes much more time then 96 seconds, more likely 5 minutes. For clarification please examine diagram 2 (next page) where a sample problem taking from test 3 is shown.

Diagram 2

Diagram of a Comound Multiple Choice Question

16. Which of the following reaction sequence is the best synthesis of m-nitrobenzoic acid from benzene?

The underlined compounds need translation of the higherst degree giving two steps.

A.) $CH_3Cl/AlCl_3$, then $K_2Cr_2O_7/H_2SO_4$/Heat, then HNO_3/H_2SO_4 $(OCH_3)_3$

Answer A gives three reagent systems that must be translated giving 3 steps. Then the starting compound must be takn through each translated reagent system giving another 3 steps. This gives 8 steps already taken in this question and with the addtion of 3 more choices with three reagent systems each we add another 18 steps. Addding this to the first 8 steps and this compoud requires 26 steps to solve.

On average a test contained 2 compound questions, not to mention the various other problems in multiple choice that needed to be translated. As a general rule fill in the blank as a testing method was not as time consuming. In a perfect world, fill in the blank would have only one step, but on average of the first three tests their were three questions with multiple steps averaging three. Thus, in actuality fill in the blank consisted of 19 questions with three questions requiring at least three steps. On test three the final question of the exam required 9 steps to solve.

After solving two compound questions, a student would have 40 minutes to solve 16 multiple choice questions in varying states of translation, 11 fill in the blank, and 3 fill in the blank with at least 3 steps. 50 minutes offers the test taker just enough time to move quickly through the material once. Any hope of going through the test twice was entirely and thoroughly impossible. One had to select the problems they wished to review. This list could not be very long.

In contrast, the CST offered a sufficient amount of time to solve 70 questions. Furthermore, only a small amount of the actual questions required multiple steps and they were never more then two or three steps. If one wanted to, they could take the test once slowly, have enough time to go through all the questions again, and finally if need be, review some of the specific questions several times. This was the method I used when taking the CST.

It seems reasonable then to suggest that class examinations were not true reflections of a student's knowledge base as many mental errors could have had an impact on the test due to the rapid pace needed to finish the test. It is possible to argue that OC2 exams did test my organic chemistry knowledge, but I was not quick enough to respond adequately. With more studying I would have increased my response time giving a more accurate reflection of my knowledge. However, if one responds this way to the dilemma they do nothing more then equivocate organic chemistry knowledge to a multiplication table. A course where one memorizes all possible outcomes of a given reaction in accordance with all possible starting materials. Anyone who has any knowledge of Organic Chemistry knows that the variability is so great that this kind of training is not possible nor desirable. More importantly such a testing scheme requires no independent thinking by the students, a route no university should want to take.

An examination of test four will give support to the argument that the OC2 exams were too difficult. All the statistical analyses conducted on the tests in the last few paragraphs left out test four. This is because test four's format was different as the multiple choice questions had been eliminated. Replacing them was more fill in the blanks giving 27 questions all together. Immediately this is a reduction in the overall amount of question asked, but also the need for multiple translation was eliminated. Obviously this afforded more time for the test taker and I was able to work through all the problems twice without a concern for time. In addition, I had more time to review those question I was uncertain about.

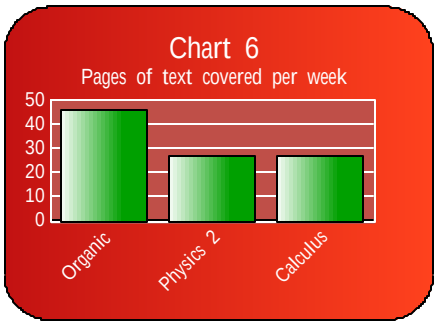
Obviously one then asks: how well did you score on the final test? The expectation would be that I scored incredibly well. Regrettably this is not the case, as I studied for only 25 hours for this test receiving a 57%. However a case can be made statistically for the change in my grade. Since I studied four times less then the two previous test one would except a grade that was four times less and yet my grade only went down about one tenth from the previous test. The explanation is simple, with more time on this test I was able to show what I actually knew from the 25 hours I spent studying. Previous tests had so much busy work in translating that I had to rush through the parts that were testing the concepts of that unit. Clearly OC2's exams were a poor measure of one's knowledge of organic chemistry meaning that the class failed to accurately reflect my knowledge of organic chemistry.

The argument just given began by noting that OC2 and CST failed to yield the same results despite both claiming to measure the same thing, namely my knowledge of organic chemistry. To answer which evaluative tool failed we compared the studying times of OC2 to SP2. We found that OC2 was grossly more demanding then SP2 and still did not result in the same scores. Such inequality in study time between OC2 and SP2 seemed to indicate that OC2 as an evaluative tool was to blame for the lack of validity between the two test. Deeper examination of OC2 showed that no matter how much effort one placed in learning the knowledge, no real effect could be had on the actual score received on the test. This further indicated that OC2 was not measuring my knowledge of organic chemistry, especially when one considers the massive amounts of time spent studying. To argue that I had no knowledge is to say that I spent a hundred hours ignoring all the material despite the methods I employed. Realizing that OC2's test could not be affected by studying caused us to understand how OC2 tests failed. Here we found that OC2 tests asked much too many questions and demanded too much translation for such little time causing the student to hurry through the test, and allowing for simple errors to be made. These errors never showed up on the CST exam because the student had enough time to work through the problem completely and catch such simple errors. We can conclude OC2 as an evaluative tool of my knowledge of organic chemistry is what failed and that my score on the CST was a much more accurate reflection of my knowledge of organic chemistry.

We have an ending to the story then, right? That is to say that finally we can understand why OC2 as a measure failed to accurately reflect one's knowledge of organic chemistry. Sure, we can say that the tests were too difficult only in the sense that there was not enough time to complete them. Despite having a conclusion I must ask one more question: what did I learn from OC2?

What of Organic Chemistry Did I Learn?

There should be no doubt that OC2 tests failed to accurately reflect my knowledge of organic chemistry. Such an assertion leaves a bitter taste in my mouth because it implies that OC2 failed only in its testing format. Surely this is not the case. OC2 failed on just about every level a college course can fail. Unlike most college courses such thorough and complete failure's cause can be traced back to a departmental decision.



To show this effect examine chart 6. In the classes OC2, physics 2, and calculus we are expected to go through a certain amount of chapters during the course. I have simply taken the total amount of pages this is, and divide by 16 weeks. Thus chart 6 shows how many pages one can expect to cover in one week.

I have chosen calculus because of it heavy reliance on practice problems and less reliance on reading text. This point will be made more important later on. Physics 2 was selected as the closest natural science equivalent that I have data to report allowing for further comparison. If we remove the lab credit OC2 is worth three credits, physics is worth 4 credits and calculus is worth 5 credits. If we assume that credit hour should be a rough indicator of amount of effort expected both in and outside of class, we should expect

the work load of calculus to be the highest, physics should be the second highest, and the lowest work load should be OC2.

With all that stated let us take another look at chart 6. At this point, it should not be surprising to find that OC2 has close to double the amount of text coverage when compared to physics and calculus. This of course is backwards to what one would expect. If we suppose that OC2 is in fact the amount of text that UNO administration expect from a 3 credit hour class then physics should cover 60 pages of text a week and calculus should cover 75 pages a week. At a rate of 75 pages a week a student could expect to go through 1200 pages of text over a semester for a 5 credit hour class.

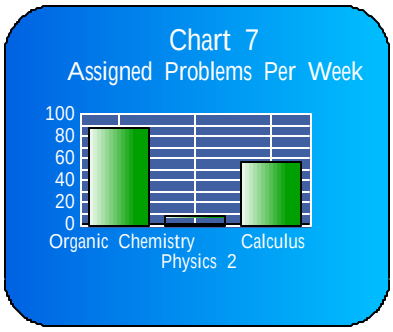


Chart 7 helps make clear the unfair amount of work suggested by OC2. In this chart I have counted all the problems that are suggested by each respective course and then divide by 16. Again we notice that OC2 maintains 88 problems per week, which is more then eight times that of the requirements of physics 2 and a little less then double of calculus. The point of comparing OC2 to calculus is made clear in this statistic. Most would agree that Calculus, as all math classes, is learned primarily through doing actual problems. While at times text can be helpful, in the end, in order to learn math you must do the problems. Thus one should expect that the five credit hour class that teaches primarily by problem solving should have a significantly higher amount of problems then a three credit hour class that can make more use of text. This is not the case.

It should be obvious that something is wrong with OC2 because of the demands it places on the student. For a three credit hour class it demands 45 pages of text to be learned and understood, and 88 problems to be solved. Such demands do not even consider the lab, a two credit hour course that must be taken with the class.

Lab is a nightmare all on its own when considering work load. Each lab required a prelab to be done that culminated in researching the vital statistics of the compound being used in the current experiment. Then the student had to spend four hours twice a week in lab doing the actual experiment and collecting data. In order to do this, we had to translate a poorly written manual that failed to articulate what we were doing, how we are to do it, and why were are doing it. (This is to not say these things were not in the book, it is to say that we could not understand what was being stated in the book.) The manual at times was not explicit what was needed for grade evaluation and so it was not uncommon to lose points because you were unable to find the requirements and not because you were not able to provide for the requirements. Once the lab was completed you had to turn in an index card with critical data for point evaluation. Each lab required a typed conclusion explaining the lab, data, and inconsistency. To be fair the students worked in groups when it came to conclusions and so a student only had to write a conclusion every three to four labs. However, to do this part of the lab took somewhere between three to five hours. As if all this work was not enough we also had lab quizzes and tests which covered the specific nuances of each lab.

Thus, a student taking OC2 could expect on a typical week the following work: reading over 45 pages of text, solving 88 problems, and the memorization of somewhere between ten and thirty reactions. The student spent three hours in lecture and another eight in lab. They would have to spend time reading at least one lab and writing its prelab, doing research for that lab, and writing at least one conclusion. The student had at least one quiz, probably in lecture. A bad week would include all of this and a unit test and additional lab with associated demands.

How does a student adjust to these grossly unrealistic academic demands? The students did not cheat since being caught would end their medical school inspirations immediately. Instead they do what a typical student does, they figure out what the professor wants, and they cater their knowledge to that demand. Thus they make use of old labs, and learn the types of problems of a lecture test by memorizing practice tests. In this way they can minimize the work involved and still perform well enough to not allow their grades to be ruined. The obvious problem with this method is that the student never learns organic

chemistry, instead they learn how to take tests for that professor. Effectively students coped with such demands by allowing knowledge to go in one ear, score well on the test, and then go out the other ear. My concerns for this student are minimal since they are not interested in organic chemistry anyway.

I worry about the student that legitimately wants to learn organic chemistry. For them learning how to take a test from a professor is seen as an abhorrent method of working for the grade. They don't look for shortcuts in learning the knowledge. However, this means in order for them to learn they must go though the work load already described. Such a daunting task results in poor performance in the class for two reasons. The first, of course, is that the poor evaluative measure of the test is unable to measure their knowledge. Second, the pace of the class is such that they are never able to actually learn the material on a level that allows them to feel they have mastered the material.

This is the critical element to the argument. OC2 moves so rapidly that those interested in learning the material only have enough time to stay afloat with the current work being given to them. The student is unable to see organic chemistry on a larger level and acquire a strong, confident understanding of the material. In any course of knowledge there exists an understanding of the material that allows one to see how the entire system goes together. In a sense, one is finally able to see the forest of organic chemistry. Please excuse the term, but I will call this metaunderstanding. To have a metaunderstanding of a topic requires having time to connect concepts from distant parts of the textbook together in one synthetic whole. OC2 prevents the understanding of these crucial relationships because the student is never able to stop doing the busy work to pontificate about the underlying relationships in OC2.

One may argue that OC2 is different in the sense that there is no underlying system of relationships allowing for a metaunderstanding. Thus, it is a waste of time to attempt to learn organic chemistry in this way. Such an argument can be met by the fact that in the beginning of the semester Dr. Hagen introduced us to several lists that according to him drove and explained all organic chemistry reactions. It is fair to say Dr. Hagen had a metaunderstanding of organic chemistry and was attempting to show us it. Arguing that organic chemistry has no metaunderstanding is contradicted by the teacher who attempted to teach us by metaunderstanding

Regrettably, the evidence that OC2's pace hinders my ability to learn organic chemistry is mostly intuitive and less empirical. In the case of physics 2 I have a greater sense of where current relationships come from in previous chapters. I have begun to gain a metaunderstanding that drives the basic questions in physics. I have acquired this knowledge without even finishing the course as I am currently taking it this semester. More compelling is my experience with calculus. Despite being worth more credit, and having to work less, I was able to distill underlying patterns and an overall flow to calculus' system of knowledge. Upon completion of the course I had acquired a metaunderstanding of calculus. Both calculus and physics 2, as the numbers show, did not keep me so busy that I was prevented from connecting distance concepts to gain a metaunderstanding.

When I compare such personal experience to organic chemistry I feel cheated. I have no metaunderstanding of organic chemistry. I do not see the detailed relationships between the molecules that result in a variety of products formed from reactants. Instead, when I look at things related to organic chemistry I feel intimidated by them, which makes me embarrassed that I put such effort into a class but still do not understand how it works. I have not gained a metaunderstanding despite putting more effort into this class than any other class I have taken. Perhaps the ultimate insult to the evaluative tools argument is the fact that such tests were unable to detect whether a student has gained a metaunderstanding of the material. More insulting is to the student legitimately trying to learn organic chemistry. They have chosen to make an honest effort at gaining a metaunderstanding only to find that they have only learned as much as those who only tried to skate by.

An Issue of Standardized Tests

We have almost finished the journey. We have only one question left to ask: Why does organic chemistry move so rapidly that a legitimate student is never able to gain a metaunderstanding of the subject? I believe an answer to this question will solve all of the problems with OC2.

In the second course of general chemistry I noticed that the class was moving at a very rapid pace. I do not claim that it moved as rapidly as OC2, but relative to the kind of student I was, it moved very quickly. Inevitably the class as a whole fell behind the professor in material and we demanded that he slow down. After hearing our pleas for a while he did slow the class down. I viewed this as an indication of the commitment of the chemistry department to teaching knowledge and not just covering material. However, my perceptions quickly changed when I realized that, to make up for lost time by slowing down, the professor would not cover material that we would be responsible for on the exam.

This prompted me to wonder why a professor would be willing to ignore our obvious needs for attention on certain topics so that he could cover even more material. It seemed counterintuitive to respond to students problems leaning the material by giving them more material. My curiosity in this regard was answered at the end of that semester. The class' final exam was the comprehensive chemistry test provided by the American Chemical Society and it did not take a genius to figure out why it was so important to cover material rapidly.

If we had not covered all the material the chemistry department would have two problems. First and foremost, we would not perform as well on this standardized test, making the department look bad. I believe the department derives a lot of pride from being able to capture such impressive scores from its student on this test. The irony of course being that I showed the CST for organic chemistry was unable to test for metaunderstanding, only a superficial understanding, making the meaning of such score irrelevant. The second reason is that the department would have to find ways to justify to us, the students, why we were tested on material we did not cover in class.

This same explanation can be applied to OC2 since the final exam in this class was a comprehensive exam created by the American Chemical Society. Thus, the pace of the class had to be fast to insure that all the questions on the CST were covered in class. Since the amount of material was massive both in size and complexity, the work load of the class was also massive. In the cases of both physics and calculus there was no standardized test that needed to be taken. So ultimately, the professor had the final say over the test and anything not covered in class. To a certain extent this holds true even for the first semester of general chemistry and organic chemistry because those finals were written by the professors since they were not responsible to the comprehensive exams. However, control of the final exam at the end of the second semester was out of the hands of the professor so they could only control what was covered in lecture.

To summarize, OC2's work load was found to be significantly higher then other similar classes since it covered more material per week then the other classes. The motivation for such rapid coverage was to insure that all topics tested on a comprehensive test have also been covered in class. The motivations for the department to insure that its students take a comprehensive exam, is not clear to me other then the simple pride one can take from knowing your students score better then the national average.

However the chemistry department's demand that its courses be centered around comprehensive exams comes at a Draconian cost. First, the professor losses control of the class because he is no longer responsible to the students knowledge but to the material. This causes the professor to be unfairly demonized for something he can not control and restricts his ability to be an effective teacher by being forced to sacrifice explanation for new material. Second, the amount of material of the class makes the work loads of the class so large that students could never possibly keep up with all the work the class demands. Third, those students interested in learning organic chemistry must in fact complete the disproportionate amount of work only to find they do not have time to acquire a metaunderstanding of organic chemistry. Fourth, students that are not interested in learning organic chemistry are in fact encouraged not to learn the material because they score at the same level as those making actual attempts at learning the material. Fifth, no student walks away from organic chemistry with a metaunderstanding of the topic, and sixth, many students do walk away from organic chemistry with firm hatred towards it.

I look at these costs and I cannot see what kind of gains the comprehensive exams affords the department that justify the problems it creates. A policy for standardized testing leads to the implication that covering material takes precedence over the students understanding of the material. For a university this is the wrong way to conduct a course and my suggestion is that the department remove standardized tests to insure that their priority be with the students understanding of the material.

Hagen, J., P. (2000). "Cooperative learning in organic II. Increased retention on a commuter campus." Journal of Chemical Education, 77, 1441-1444