Proposed course modifications:

The course that I targeted for modification was CHM 120 (Chemistry and Art). The course is designed to fulfill Area II general education requirements (Natural Sciences) by demonstrating the connection between the chemical properties of artists’ materials and their color; it meets for two 50-minute lectures and one 170-minute lab period per week. When I first taught the course in the fall of 2007, the laboratory portion consisted of 10 experiments derived from material provided from an NSF-sponsored workshop I had attended; these experiments required one or two lab periods to complete and demonstrated the chemical and physical properties of various artistic materials. To bolster them, I also had students pursue a longer term project probing the light-induced fading of paint. The purpose of this project was to give the students an experience that employed the scientific method in a more authentic fashion than the weekly experiments provided.

In my proposed modification to the course for 2008, I sought to replace the weekly experiments with five longer-term projects requiring three or four lab periods to complete; inclusive to each project would be short preliminary exercises, derived from the weekly experiments, that would provide a segue into the project. The topics of these projects are 1) light-induced fading of paint derived from lake pigments, 2) the effect of different mordants on the color of dyes and lake pigments, 3) the correlation of the chemical composition of Egyptian paste and the final color of the fired object, 4) the surface appearance of copper metal produced by patination baths of differing chemical composition, and 5) modification of the monochrome color imparted to kalliotype photographs by different developing agents. Each project would introduce students to digital data collection and require them to write a report based on the accepted format for scientific publications. Assessment of this approach would rely on a written survey of the student’s perception of the nature of science combined with oral interviews with select students after the course was complete.

Results:

Work prior to the summer of 2008 had established working procedures for the projects involving Egyptian paste and the patination of copper. Throughout the summer, I generated the basic procedure for producing several different lake pigments, while working with two chemistry students on a procedure for the development of kalliotype photographs. As the fall semester progressed through its first several weeks, my students required far more time than I had anticipated working through the first set of preliminary exercises and to synthesize the lake pigments needed for the first two projects; simultaneously, it was becoming clear that the kalliotype project lacked the reproducibility to be an effective demonstration of the scientific method. This prompted me to modify the lab schedule and only require the first three projects listed previously; portions of the last two projects were folded into existing experiments from the 2007 lab schedule and performed during the last four lab periods of the semester. The instructions for these three projects and sample reports from the same student are provided in Appendices 2, 3 and 4.
The written survey was developed based on an article by Lederman, Abd-El-Khalick, Bell and Schwartz (Journal of Research in Science Teaching, 39(6) 2002 497-521); it consisted of six questions and was given to the students at mid semester. The complete responses to each question are provided in Appendix 1, but I will summarize them below:

1) What, in your view, is science? What makes science (or scientific disciplines such as chemistry) different from other disciplines of inquiry, such as religion or philosophy?

Most responses identified that the difference between science and religion or philosophy was that science required some type of proven fact or evidence to validate an opinion, while the others did not.

2) How are science and art similar? How are they different?

The common thread in these responses identified that both science and art are executed according to some preconceived scheme or plan, but the origin of that scheme is more intellectual in the case of science and more emotional in the case of art.

3) Is there a difference between scientific knowledge and opinion? Give an example to illustrate your answer.

As with question #1, most responses identified the necessity of evidence to establish something as scientific knowledge.

4) How is scientific knowledge developed?

A connection between opinion and scientific knowledge was acknowledged, with scientific knowledge starting as opinion, then either validated or refuted by evidence.

5) What is an experiment? Does the development of scientific knowledge require experiments? Explain your answer to this question by giving an example to illustrate it.

Most responses defined an experiment as the trial that provides the evidence needed to validate or refute an opinion and thus generate scientific knowledge.

6) Science textbooks often represent the atom as a central nucleus composed of positively-charges particles (protons) and neutral particles (neutrons) with negatively-charged particles (electrons) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine what an atom looks like?

These responses were the most varied. They ran the gamut from expressing that the structure of the atom is based completely on unsubstantiated opinion to great misconceptions of the basis for the evidence of the structure described.

Based on individual student responses, Dr. Provi Mayo will issue invitations to select students to participate in an oral interview designed to determine the reasoning behind the answers given to
the written questions. These interviews will be conducted during the 2009 spring semester and the results will be submitted as an addendum to this report.

Conclusions:

The most successful outcome of this proposal to me is reflected in the three sample project reports included in the Appendices. I chose to include the reports from this student because they demonstrate an increasing understanding of the nature of science and its attendant methods. This student, in particular, was very diligent in seeking help from me on a one-to-one basis to address her misconceptions, especially after getting back her graded report for the first project. The improvement in her last two project reports is commendable and I believe shows that this approach (long-term projects) is effective at improving a student’s comprehension and appreciation of what goes into doing science.

She also points out the greatest shortcoming in the proposal: overestimating the skills and motivation of the target student audience. This student was a nontraditional senior and had a well-developed set of study skills. She was an exception in my 2008 group, in which eight of the 14 students were freshman. When I taught CHM 120 for the first time in 2007, only two of the 15 students in that group were freshman. Their motivation and skill levels were the basis for the expectations that guided me in proposing the modification. Unfortunately, the extent of the modifications, I believe, proved to be beyond the capacity of the 2008 group. Given that CHM 120 is supposed to be a 100-level general education course, I think an effective compromise for future offerings of the course will maintain the three established long-term projects, mixed with several of the weekly experiments performed during the 2007 version of the course.

A second lesson learned from the 2008 offering of CHM 120 is the need for tighter coordination between the lecture and lab portions of the course, with an inclusion of more material focused on the nature of science. Early in the semester, I devoted one lecture specifically to the nature of science, but delays in completing the first lab exercises caused a gap in time between this lecture and the first of the long-term projects. Without the availability of a textbook specifically designed for such a course, ordering, prioritizing and coordinating lecture topics and lab experiments/projects will remain a challenge, as I seek more information on how other science-based general education courses accomplish this.

One outcome of this work has proved to be wholly unexpected. As mentioned previously, I have been working with two chemistry students on developing kallitype photographs. Although their efforts were unsuccessful at producing a reliable method that CHM 120 students could use as a long-term project, one of the chemistry students is hoping to expand her results into an Honor’s project and present them at a national conference later this year. Additionally, I have two more chemistry students engaged in research projects probing the chemistry of lake pigments derived from natural dyes; I am hopeful that one of these projects will be the basis of an experiment I will incorporate in the quantitative analysis course (CHM 224). I am teaching in the spring semester of 2009. This project has opened up an entirely new area of research to me and I hope to attend an advanced workshop in chemistry and art at Villanova University this summer and, eventually, pursue my next sabbatical leave in the conservation department at a major museum.
Appendix 1: CHM 120 Questionnaire Responses

1) What, in your view, is science? What makes science (or scientific disciplines such as chemistry) different from other disciplines of inquiry, such as religion or philosophy?

Student #1: Science is based upon fact. It is about proving or disproving an idea with statistics and logic. Religion and philosophy also hold onto logic but it is in an attempt to prove an opinion, which is always debatable.

Student #2: Science explains how the environment works, how technology works and we use the information to form theories of how things work.

Student #3: Science is empirical data. It is a way to understand the world around you. I think it can be a part of philosophy and religion, though. It can be a way to prove something in either area if a quest was started by a desire to get at the truth, not prove a point by only accepting data that could benefit yourself. Science and religion are different in that there is an element of faith in religion. Science is closer to a fact/false relationship.

Student #4: Science is experimenting with different things in different ways to see what happens or what was suppose to happen.

Student #5: Science is a quantifiable way to view many aspects of the world. Science proves things in the form of testing hypothesis and creating theories. It is different from many other disciplines because of the fact it tries to place a numerical value to many aspects of research.

Student #6: I view science as a very broad subject. Things like chemical reactions and what makes up the earth I view as science. Religion and philosophy are different from science because there is no scientific proof for them. Scientists may believe the big bang theory but those of us with a brain know that it is nonsense.

Student #7: Science is the understanding of the unknown through proven facts. In science there needs to be a sound answer that explains the lifelong question: why? Religion doesn’t always require proof and can be understood with faith, which science has no part in. Much like religion, philosophy doesn’t need a definite answer, but rather thrives on asking open-ended questions that sometimes have no answer.

Student #8: They are all pretty similar but science tells me how things work and religion shows us what to believe in.

Student #9: Science is the ongoing study of the world around us. While religion and philosophy are primarily discussion or thought based, science tests theories for things that might be proven. Rather then simply rhetoric, science pushes to find answers thru testing of hypotheses.

Student #10: In my view science is more about numbers. It focuses on how matter changes and becomes what it is. There are many disciplines in the field of science but all of them pertain to...
some numerical order. Chemistry is different from religion and philosophy because chemistry is very detailed and set with numbers and facts. Religion and philosophy are more subjected to different points of view and not so much on proven facts. With religion and philosophy, there can be many different answers and with chemistry, there are actual proven facts that are the answer and there is little room for interpretation.

Student #11: Science is the field of discovery and exploration. What makes chemistry different: using the earth’s elements to advance man’s knowledge: medicine, art, etc.

2) How are science and art similar? How are they different?

Student #1: Science is all throughout art, starting with reaction of color to light continuing to chemically producing various colors. However when it comes to being a scientist or an artist the occupations vary greatly.

Student #2: Science and art are similar in that they both can be something that is unknown. Science is used in art: making paint, making products to use, such as paper. They are different in that science doesn’t always go right - it isn’t up to the eye of the beholder whereas art is.

Student #3: Art is a creative use of scientific understanding. It allows a process (pigments to paint/mud to ceramics) to become an enjoyment. You can use one to discover another. But art has more room for change. You can do something that makes little sense. People call it unique. Science seems to only be worth something if it makes sense every time you perform it.

Science #4: Science and art are similar by both using different chemicals and experiments. They are different by art being a visual difference, where as science is several things. There is visual, reaction of chemicals and what happened along with what was suppose to happen.

Student #5: Science and art are similar yet very different. Chemicals and chemical reactions are used to create the basic products (paints, etc.) of art. The chemical measurements and equations obviously are chemistry related, but the uses of those products are more typically related to art. Without science there would be no chemical aspect to art, but without art there would be no reason to create these chemically combined materials.

Student #6: They are similar because to make pigments and paints for art you must use chemistry to make them. They are different because these paints and pigments are not used for chemical purposes.

Student #7: In science, you need a starting point or somewhere where you want to begin; maybe thought up in your head, this is a hypothesis. Much like science, art requires one to plan out what will be done, a hypothesis so to speak. Eventually, based on the hypothesis, you finish with a final product in both cases that reflects what the intentions of the original plan were. In art, however, an explanation is not always necessary. Where science needs proof, art welcomes creativity.
Student #8: They are similar in the way that you have to be creative for both to find new discoveries and they are different in the way that art is more fun.

Student #9: Both seem to involve a lot of trial and error but, both scientists and artists tend to push on thru failure to achieve the desired results. Science differs from art in that it isn’t necessarily a personal expression. Art, to me, tends to be a form of an expression of our emotions.

Student #10: Science and art are somewhat similar. They both use chemistry and both build hypothesis and then search to find the answers or create the answers. They are different because art, like religion and philosophy is up to interpretation and anyone can have an opinion on it. Science is more of definite answers.

Student #11: They are similar in the way natural elements such as: rocks, trees, plants, flowers, animal skins and other body parts are used to obtain glues, dyes, etc.

3) Is there a difference between scientific knowledge and opinion? Give an example to illustrate your answer.

Student #1: The difference between scientific knowledge and opinion is that one is proven fact and the other is subjective. The Big Bang theory is a scientific opinion because there may be some proof to back up this theory it is not quite a fact.

Student #2: Scientific knowledge is something that has been proven. Scientific opinion hasn’t yet the information to be proven. Knowledge is usually first an opinion. It could be your opinion that when you mix two chemicals together that they will explode. It is scientific knowledge when you mix them together and they do explode.

Student #3: Yes. Scientific knowledge is the man who knows why astronauts survive when they fall back to earth from space. He has seen it done, he has done the math, has manipulated gravity to suit this venture, and has worked w/ others to make it a success. Opinion is the guy who says he can land the 10 foot ski jump yet has calculated nothing, cannot manipulate gravity and is driven by testosterone, not safety to completion of the task.

Student #4: I believe there is a difference. Anyone can have an opinion but if you have no idea of scientific knowledge, your opinion does not mean anything.

Student #5: Scientific knowledge is fact, thing that have been proven to be true. Scientific opinion is the particular view of the scientist. An example of scientific knowledge is the chemical name for table salt is sodium chloride (NaCl). An example of scientific opinion is the chemicals combine to make Prussian blue are pretty.

Student #6: Yes, usually scientific knowledge can somewhat be backed by scientific clues and an opinion is not backed by anything. For example: scientific researchers think they can back the big bang theory while most people think that religion is not backed by anything. It is just an opinion of faith.
Student #7: Before Columbus came to America, people had (what they thought to be) knowledge that the earth is flat. Through scientific knowledge, we know that the earth is indeed round and that early conceptions of the shape of the earth were only opinions not backed up by hard evidence.

Student #8: Scientific knowledge is based on facts and figures while opinion is just someone’s biased view. For example someone could have the opinion that he or she weighs more than someone else but someone with scientific knowledge would weigh both subjects on a scale to find the real answer.

Student #9: Yes. I could assume (take the opinion) that if I dropped an apple it would hit someone in the head. However, I will not have scientific knowledge until I have proven that fact.

Student #10: Yes there is a difference between scientific knowledge and opinions. Scientific knowledge is based on proven facts, and opinions relate to the feelings one has. Take religion for example, many scientists have been studying the facts of whether Jesus actually lived or not. While that kind of evidence isn’t that important to believers, the believers have a “gut feeling” that it’s true and believe that the Bible is enough evidence for them.

Student #11: Scientific knowledge is obtained by experimentation. An opinion is based on what a person feels or thinks. There is no empirical evidence to support an opinion whereas scientific knowledge is based on evidence w/ a control group. Tests show alcohol is a depressant but Mary says it elevates her mood so she is happy and less inhibited.

4) How is scientific knowledge developed?

Student #1: Scientific knowledge is developed by taking an idea and doing enough and gathering enough proof to confirm that it is a fact.

Student #2: Scientific knowledge is developed with tests. First you have an opinion and you test your opinion. If the outcome proved your opinion you are correct and it is knowledge. If it is wrong it is still knowledge it just has a different outcome than what you thought.

Student #3: It is developed by studying what others have done (successes and failures). In doing so you can form your own hypothesis to alter the results and begin a study. It is not a belief or opinion but rather an idea you set out to prove and once you take the action to do so, you gain knowledge.

Student #4: Scientific knowledge is developed through doing experiments and study.

Student #5: Scientific knowledge is developed over time by much hypothesis testing. Every time a hypothesis is proven wrong the theory in turn will be adjusted. Over time, a final theory will be made (after years of testing hypothesis.)
Student #6: It is developed by starting off with a question or hypothesis then developing a research plan to see if it is capable of being explained.

Student #7: We come to scientific knowledge the the scientific method. This method emphasizes the importance of planning out a hypothesis and not resting until you can probe it or disprove it. Through experimentation that we can apply to the practical world we can better come to the final conclusion that something proven to be true is no longer an opinion or theory, but rather the truth.

Student #8: Through thought (you must have an idea first) then you try your theory out over and over and then you know if your theory was correct.

Student #9: Through ongoing testing of hypotheses.

Student #10: It starts with a hypothesis, then from that creates ways to find out how to scientifically prove whether the hypothesis is true or not. It’s basically trial and error with scientific data to back it up.

Student #11: By experimentation, education.

5) What is an experiment? Does the development of scientific knowledge require experiments? Explain your answer to this question by giving an example to illustrate it.

Student #1: An experiment is a way of testing out an idea. Experiments are required because how else would one prove or disprove an idea? Newton could not just say gravity exists and let it be held as fact. Instead he had to go out and do tests to have evidence that he was right.

Student #2: An experiment tests a hypothesis. The development of scientific knowledge requires experiments, because knowledge can’t be proven without testing them. If you do not experiment to prove your opinion that is exactly what it is - an opinion. Once you have used an experiment to test your opinion it becomes knowledge. An illustration of this would be if someone had the opinion that if you drop a penny off a tall building it would have more force hitting the ground than if it were dropped from a shorter building. You would have to do an experiment of the two situations to turn the opinion to knowledge.

Student #3: An experiment is the action taken to work out a hypothesis. And the development of scientific knowledge may require an experiment at some point though that is not all.

Student #4: An experiment is a process that is done to determine what is going to happen, why it happened, what should happen and how it happened. Scientific knowledge does require experiments, otherwise you have no way of finding out why something happened or what is going to happen.
Student #5: An experiment is part of hypothesis testing. I believe it is important to the development of scientific knowledge. An example of this would be gravity. Various objects would need to be dropped from a specific height in order to observe the effects of gravity upon that object. When all objects hit the ground it gives pretty good reason that gravity is present. Thus because of the uniform findings a theory can be made.

Student #6: An experiment is testing something out to see if you can develop something or if something works. In most cases it does require experiments. For example, if you think that there is a way to create artificial soil then you must try and prove that.

Student #7: Science is a practice based on forming theories and proving their validity. This is done primarily through experiments and as stated in the previous question experimentation is necessary to prove a hypothesis. For example, going back to Columbus illustration, we never would have known if the Earth was round had we not experimented.

Student #8: An experiment is solving a problem kind of like if you want violet paint and all you have is blue and red you would experiment to see how much of both colors was needed to make the color violet. Yes it does. If someone were to say that she runs around the block and that it is a mile and she has never ran anywhere else to judge that opinion on she would not have any scientific knowledge to base her opinion on.

Student #9: An experiment is a trial. A hypothesis is brought about to be proven fact or merely a thought. If we do not experiment and prove these hypotheses right or wrong, we do not have scientific knowledge. If I was of the opinion that taking a piece of wool and dying it with the secretions of snails would color the wool purple, it would remain merely an opinion or thought. But, through experimentation, actually applying the dye to the wool and studying the result, I can have the scientific knowledge of the fact that now, the wool is purple.

Student #10: An experiment is how you find out whether your being hypothesis is true or not. It is the guts between the question and the answer. Scientific knowledge does require experiments because a scientific hypothesis has to be proved or disproved using knowledge gained from the experiments. An example could be if you wanted to know if certain chemicals at certain doses would create a specific color, like green. The only way to truly find out whether it was true or not is to actually do the experiment and record the results. Either the results will turn green or it won’t. That would be the answer. If you believe there could still be a possibility, you can do the experiment multiple times or compare your answers to someone else.

Student #11: an experiment is done to observe whether a change occurs, there is a control group used so as not to bias the evidence. To obtain knowledge you must have experiments. In testing a new drug and its effects there is a control group used half receive placebos and the other medication. The results are measured and used to further their testing.

6) Science textbooks often represent the atom as a central nucleus composed of positively-charges particles (protons) and neutral particles (neutrons) with negatively-charged particles (electrons) orbiting that nucleus. How certain
are scientists about the structure of the atom? What specific evidence do you think scientists used to determine what an atom looks like?

Student #1: Scientists are quite certain about the structure of an atom. They could run charges through it to see the reactions of the charged particles inside the atoms.

Student #2: The structure of the atom is a theory. No one has ever actually seen an atom up close. I thin the scientists used scientific opinion to determine what an atom looks like.

Student #3: I don’t know how certain scientists are about the structure. And I have no idea how they determine what it looks like. Maybe they describe it like a blind person would describe someone’s face. They couldn’t see it with their eyes but can understand it a different way (hands).

Student #5: I’m pretty sure scientists are almost certain the structure of an atom. There have been many experiments to test the individual atoms of many different molecules. Depending on the way an atom acts with others is how scientists determine their physical structure. For example if a magnet is held next to water streaming out of a faucet the water curves. Thus, because of this finding scientists can conclude that an atom of water has a polar end.

Student #6: I really don’t know how certain they are about atoms. I believe that they are still looking into them trying to find more information. I believe that the only thing they have are microscopic telescopes but those don’t show anything so they are kind of blind about their knowledge of these.

Student #7: Scientists are 100% sure of the structure of atoms. They have used the orbits of each subatomic particle to gather a relevant image of what an atom is.

Student #8: Pretty certain because they shouldn’t be teaching us if they weren’t. Knowledge of other things gives them knowledge of atoms.

Student #9: Scientists have a pretty good grasp on the structure of an atom. The evidence is in the fact that we are able to split atoms, drawing them apart.

Student #10: They are fairly certain because they have some evidence to back it up but not able to actual see the atom with the naked eye because of it’s small stature. I think they might know because of how things work, they know what works with what structure by building models and experimenting.

Student #11: They are rather positive to the extreme that they built the atomic bomb based on their knowledge; experimentation.
Appendix 2: Project assignment #1 and sample student report

Project Report:
Comparison of Lake Pigments and Mordanted Dyes

Earlier in the semester you created lake pigments by precipitating a natural dye using a metal salt. These same metal salts are used as mordants when the dyes are used to color fabric; the metal ions bind the dye to the fabric by acting as a “bridge” between the two. In both cases, the color of the dye molecule can be changed by the metal ion. The purpose of this project report will be to measure the hue, saturation and luminosity of the colors of the lake pigments and dyed fabrics that you produced, then compare these values to identify trends in the colors; the trends on which you should focus are: 1) Does a metal produce the same hue, saturation or luminosity in a lake pigment as it does as a mordant? 2) When compared to each other, do metals produce any shifts in hue, saturation or luminosity in both lake pigments and when they are used as mordants?

You will receive, via your learning email account, the scanned files for the paint swatches made from your lake pigments and for the fabric swatches you dyed. You should open these files and use the program Paint Shop Pro Photo X2 to obtain the values for hue, saturation and luminosity of each swatch. The instructions for doing this follow; as you make each series of measurements, you should record them in your notebook.

SCANNED IMAGE ANALYSIS

For each image, use Corel Paint Shop Pro Photo X2 to obtain the mean values for hue, saturation and luminosity; after you have loaded the program to a computer here on campus, follow this procedure to get the information; record the values in your notebook.

1. Open the first image file. It should look very similar to Figure 1.

![Figure 1. Opened image files in Corel Paint Shop Pro Photo X2](image)
2. Open the Crop tool on the Tool bar to the left of the image. As in Figure 2, a crop box will appear in the photo.

![Figure 2. Activating the Crop tool.](image)

3. Expand the box to include the center of the swatch you are going to measure, then move the cursor into the box and double-click the left mouse key to crop the image. The result should appear similar to Figure 3.

![Figure 3. Cropped image](image)
4. To get numerical information for the cropped image, you will need to open the Histogram palette. You do this by clicking on “View” in the menubar, selecting “Palettes” from the dropdown menu, then selecting “Histogram” from a second dropdown menu. This is shown in Figure 4. The Histogram palette should appear as shown in Figure 5.

Figure 4. Dropdown menus that give the Histogram Palette

Figure 5. Histogram Palette
6. On the right side of the Histogram Palette window, choose Hue from the Display channel dropdown menu and click the radio button in by Hue in the bottom of the window. In your notebook, record the value given as the Mean under the Display channel.

7. Change the Display channel to Lightness (luminosity) and check the radio button next Lightness. In your notebook, record the value given as the Mean under the Display channel. This is shown in Figure 6.

![Figure 6. Lightness displayed in the Histogram Palette](image)

8. Change the Display channel to Saturation and check the radio button next Saturation. In your notebook, record the value given as the Mean under the Display channel. This is shown in Figure 7.

![Figure 7. Saturation displayed in the Histogram Palette](image)
Writing the Project Report:

1) Format: Your report should have 3 separate sections: Introduction, Results and Conclusion

   In the Introduction, you should describe the goal of the project, the experimental procedures used to produce the pigments/paints and the dyed cloth and the method used to obtain numerical data for the colors.

   In the Results section, you should present your data; this is detailed more thoroughly under point #2.

   In the Conclusion, you should summarize the observations from the Results section and use this summation to validate whether any observable trends exist.

Following this format and including the appropriate information in each section will be worth a maximum of 12 points

2) Data Presentation: For each of the three values obtained for the color, prepare a table that follows the format given below:

<table>
<thead>
<tr>
<th>HUE (or Saturation or Luminosity)</th>
<th>Aluminum</th>
<th>Iron</th>
<th>Copper</th>
<th>Tin</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabric (Wool or Cotton of Silk)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lake Pigment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>N. A.</td>
</tr>
</tbody>
</table>

Each table should be followed by a short discussion regarding the trends observed in the data for the fabric and for the lake pigments, and any similarities or differences between the two. Each table and its following discussion will be worth a maximum of 16 pts.

3) Grammar, Spelling and Conciseness: These parameters will be graded on a possible maximum of 10 points total
Lake Pigments and Dyes

The goal of our project and experiments was to look at how lake pigments react when combined with different binders in relation to how a dye combined with a mordant (metal transition elements) react on different fabrics. We then measured the hue, luminosity, and saturation of our samples. Colorants can be either organic or inorganic and can be categorized as pigments or dyes. Pigments are generally inorganic compounds prepared by precipitation reactions. When dye molecules and the mordant are mixed together directly in a solution, the two bond, but without fabric, the new compound is precipitated as a solid we refer to as a lake pigment and can be used as paints. The dry pigment is then mixed with a binder and a diluent or solvent. The idea property of pigments is the uniformity of the particles in size so they can be easily dispersed in the binder. With inorganic pigments, the smaller the particle size, the more the light scatters. There appears to be a higher refractive index of the pigment and binder. The hue of the lake pigments will vary according to the binder used.

Preparation of watercolor binder:
1. 4mL of water was placed in a small beaker with 4 g of table sugar (sucrose). The solution was then stirred until it dissolved.
2. 6mL of glycerol and 20 mL stock gum arabic is stirred in.
3. Three or four granules of Alconox is mixed in until the solution is smooth.
4. To measure the mean of each individual sample you must obtain a cropped image, then using the palette command you select the histogram. This will individually measure the mean of your hue, saturation, and luminosity.

<table>
<thead>
<tr>
<th>Visible Watercolor</th>
<th>Lake Pigment 1</th>
<th>Lake Pigment 2</th>
<th>Lake Pigment 3</th>
<th>Lake Pigment 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hue</td>
<td>206</td>
<td>205</td>
<td>195</td>
<td>215</td>
</tr>
<tr>
<td>Luminosity</td>
<td>89</td>
<td>41</td>
<td>48</td>
<td>70</td>
</tr>
<tr>
<td>Saturation</td>
<td>29</td>
<td>24</td>
<td>31</td>
<td>90</td>
</tr>
</tbody>
</table>

In visible light all lake pigments appeared to have a high hue except pigment 3 was lower. Pigment 4 yielded the highest number overall. The luminosity was considerably higher in pigments 1 and 4. The saturation was definitely higher in pigment 4 while the others were consistently lower.
After being exposed to ultraviolet light we see a little change in pigment 3 but a noticeably change in pigment 4. Pigment 1 and 2 varied very little. The luminosity was very high in pigment 1. The saturation levels were consistent except for pigment 4, which was two times higher than the others.

In our control group the hue was consistent except for pigment 4, which had a relatively lower mean than visible light but yet a higher mean than the ultraviolet. The luminosity was still higher in pigment 1 across all the samples with an elevation also in pigment 4. Saturation levels were elevated in pigment 3 with a definite higher mean for pigment 4.

In conclusion we may ask ourselves whether a metal produces the same hue, saturation, or luminosity in lake pigments and mordants? At first I had thought no, because of the scattering that occurs when visible light disperses when pigment particles are combined with binders. The luminosity and saturation appears very consistent in the metal transition elements except for tin. Tin had higher luminosity, twice the mean of its saturation. (Except for the control group) Overall the hue was consistent with the watercolor binder and mordant being used as well as the luminosity and saturation with the exceptions noted under the graphs for the watercolor. There appeared to be no major shifts when you compared the lake pigments and dyed fabric.
Appendix 3: Project assignment #2 and sample student report

Project Report:
Comparison of the Effect of Iron Oxide Content and the Choice of Alkali Metal Salt on the Color of Egyptian Paste

When red iron oxide (Fe₂O₃) is added to the Egyptian paste recipe used in the first part of your experiment, it imparts a discernible rust color; however, after objects made from the paste are fired, this color does not survive in the glaze produced. To investigate this, each group produced a series of pieces, with each series using a different alkali metal salt in the Egyptian paste recipe: they are sodium bicarbonate (Recipe A), sodium carbonate (Recipe B), potassium carbonate (Recipe C), and sodium tetraborate (Recipe D). In each series, the amount of iron oxide added was increased from 5% to 20%. The purpose of this project report will be to measure the hue, saturation and luminosity of the colors of the Egyptian paste pieces in select series, then compare these values to identify trends in the colors; the trends on which you should focus are: 1) Does increasing the iron oxide content change the hue, saturation or luminosity of the color, when the same alkali metal salt is used?, and, 2) Does using different alkali metal salts cause a change in the hue, saturation or luminosity of the color, when the same quantity of iron oxide has been added to the recipe?

The scanned file containing all 16 Egyptian paste pieces will be posted on the eLearning CHM 120 website; in the file, the pieces are arranged in 4 rows (from top to bottom - Recipe A, Recipe B, Recipe C, and Recipe D) and in for columns (from left to right) - 5% iron oxide, 10% iron oxide, 15% iron oxide, and 20% iron oxide) You should open this file and use the program Paint Shop Pro Photo X2 to obtain the values for hue, saturation and luminosity of all the pieces in your assigned recipe and % iron oxide. The instructions for doing this follow; as you make each series of measurements, you should record them in your notebook.

SCANNED IMAGE ANALYSIS: Follow the instructions in the Project 1 assignment to acquire numerical values for the hue, saturation and luminosity for the scanned images of the Egyptian paste pieces.

Writing the Project Report:
1) Format: Your report should have 3 separate sections: Introduction, Results and Conclusion

In the Introduction, you should describe the goal of the project, the experimental procedures used to produce the Egyptian paste and the method used to obtain numerical data for the colors.

In the Results section, you should present your data; this is detailed more thoroughly under point #2.
In the Conclusion, you should summarize the observations from the Results section and use this summation to validate whether any observable trends exist.

Following this format and including the appropriate information in each section will be worth a maximum of 12 points.

2) Data Presentation: For the two series assigned to you, generate the following tables:

<table>
<thead>
<tr>
<th>Same alkali metal salt</th>
<th>5% Iron oxide</th>
<th>10% Iron oxide</th>
<th>15% Iron oxide</th>
<th>20% Iron oxide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hue</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saturation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Luminosity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Same % iron oxide</th>
<th>Sodium bicarbonate</th>
<th>Sodium carbonate</th>
<th>Potassium carbonate</th>
<th>Sodium tetraborate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hue</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saturation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Luminosity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Each table should be followed by a short discussion regarding the trends observed in the data for the fabric and for the lake pigments, and any similarities or differences between the two. Each table and its following discussion will be worth a maximum of 24 pts.

3) Grammar, Spelling and Conciseness: These parameters will be graded on a possible maximum of 10 points total.
Egyptian Pieces Using Iron Oxide

The purpose of project was to investigate how using iron oxide added in increasing amounts from 5% to 20% and combined with sodium bicarbonate in the Egyptian paste pieces changes the hue, saturation and luminosity. And whether different alkali metal salts would change in hue, saturation and luminosity when the same quantity, in this case, 20% of iron oxide was added to the recipe.

When Egyptian Paste is mixed with iron(III) oxide (Fe2O3) it imparts a rusty red color to the unfired piece; however, when the piece is fired, the glaze color turns out to be white to off-white. This change in color indicates that a chemical reaction occurs transforming the iron to a form which does not strongly absorb visible light. One possibility offered by a local ceramics artist involves the “bleaching” of iron by the sodium salt that accumulates on the surface; this is similar to effects seen in a glaze technique called “salt-firing”. To test the influence of various components, each group made up a slightly different recipe of Egyptian paste, then made beads with varying amounts of iron(III) oxide as a colorant. My group was assigned Recipe A.

Egyptian paste, Recipe A, using Fe2O3 as a colorant:

- Nepheline Syenite 39%
- Ball Clay 6%
- Flint 37%
- Sodium Bicarbonate 12%
- Kaolin 6%

Based upon the proportions in the recipe, we calculated and weighed out ingredients for a 50 g batch of Egyptian Paste. Mixing the dry ingredients thoroughly we the divided them into 4 equal portions of 12.5 g each in separate plastic beakers. In the first portion we mixed 5%, by mass, iron(III) oxide; into the 2nd portion mix 10%; into the 3rd portion mix 15%; and, into the 4th portion mix 20%. Beads were prepared from each portion of paste, flattened and placed on a piece of aluminum foil to dry. The Egyptian pieces were then fired. We used the Corel Paint Pro Shop X2 to then measure the hue, luminosity, and saturation of each piece to obtain the results.

Using Corel Paint Pro Shop X2 I first opened the image file and used the crop tool on the left of the image bar. I expanded the box to include the center of the swatch and doubled clicked on the left mouse key to crop the image. To get the numerical information of the cropped image, I clicked view on the menu bar and selected histogram from the second drop down menu. On the right side of the histogram palette I chose either the hue, luminosity, or saturation and recorded the value given as the mean for each.
Results:

<table>
<thead>
<tr>
<th>Same alkali metal salt</th>
<th>5% Iron Oxide</th>
<th>10% Iron Oxide</th>
<th>15% Iron Oxide</th>
<th>20% Iron Oxide</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hue</strong></td>
<td>21</td>
<td>23</td>
<td>13</td>
<td>32</td>
</tr>
<tr>
<td><strong>Saturation</strong></td>
<td>55</td>
<td>50</td>
<td>40</td>
<td>51</td>
</tr>
<tr>
<td><strong>Luminosity</strong></td>
<td>210</td>
<td>177</td>
<td>127</td>
<td>94</td>
</tr>
</tbody>
</table>

Does increasing the iron oxide content change the hue, saturation or luminosity of the color, when the same alkali metal salt is used? Yes, when evaluating whether increasing the iron oxide content changed the hue, saturation, and luminosity we find a distinctive linear pattern in the luminosity. The cream color at 5% increasingly became darker as the iron oxide was increased up to 20%. The more iron oxide was added to the Egyptian paste bead, the darker the color. I found a definite decrease in the hue and saturation when 15% iron oxide was added and a significant increase of the hue when 20% of the iron oxide was added.

<table>
<thead>
<tr>
<th>Same 20% Iron Oxide</th>
<th>Sodium Bicarbonate</th>
<th>Sodium Carbonate</th>
<th>Potassium Carbonate</th>
<th>Sodium Tetraborate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hue</strong></td>
<td>32</td>
<td>22</td>
<td>30</td>
<td>46</td>
</tr>
<tr>
<td><strong>Saturation</strong></td>
<td>51</td>
<td>81</td>
<td>49</td>
<td>51</td>
</tr>
<tr>
<td><strong>Luminosity</strong></td>
<td>94</td>
<td>77</td>
<td>105</td>
<td>71</td>
</tr>
</tbody>
</table>

Using Corel Paint Pro Shop X2 I first opened the image file and used the crop tool on the left of the image bar. I expanded the box to include the center of the swatch and doubled clicked on the left mouse key to crop the image. To get the numerical information of the cropped image, I clicked view on the menu bar and selected histogram from the second drop down menu. On the right side of the histogram palette I chose the hue, luminosity, and saturation and recorded the value given as the mean for each.

Does using different alkali metal salts cause a change in the hue, saturation or luminosity of the color, when the same quantity iron oxide of has been added to the recipe? Yes, the hue had a sharp drop in the mean when using sodium carbonate and a marked increase when using sodium tetraborate. The saturation levels were consistent except in the sodium carbonate. Luminosity in the sodium bicarbonate and potassium carbonate were higher than the sodium carbonate and sodium tetraborate.

In conclusion using the same alkali metal salt and increasing the increments from 5% up to 20% showed a linear pattern and trend in the luminosity. I found a distinct difference was shown in the saturation and hue when using 15% iron oxide. When using the same amount of iron oxide and different metal salts showed a distinct difference in the sodium carbonate in the hue and saturation. The sodium bicarbonate and potassium carbonate showed a higher mean in luminosity.
Appendix 4: Project assignment #3 and sample student report

Project Report:
Lightfastness of Paints made from Lake Pigments

In one lab period earlier in the semester you created lake pigments by precipitating a natural dye using a metal salt, then in a subsequent lab period you made paint swatches using these lake pigments. Compared to inorganic pigments, paints made from lake pigments tend to be less stable when exposed to light. To test this assumption, these swatches were placed in light boxes and exposed constantly to visible or ultraviolet light over a 6 week period; additionally a set of swatches was kept in a dark drawer to provide comparison.

At the end of each week the swatches were scanned and the files stored by date; these have all been posted on the eLearning site for CHM 120 in the Project Report 3 folder. You will also receive in your eLearning email account, the files you will be responsible for analyzing. You should open these files and use the program Paint Shop Pro Photo X2 to obtain the values for hue, saturation and luminosity of each swatch. The instructions for doing this follow; as you make each series of measurements, you should record them in your notebook.

SCANNED IMAGE ANALYSIS: Follow the instructions in the Project 1 assignment to acquire numerical values for the hue, saturation and luminosity for the scanned images of the lake pigment swatches.

Writing the Project Report:

1) Format: Your report should have 3 separate sections: Introduction, Results and Conclusion

   In the Introduction, you should describe the goal of the project, the experimental procedures used to produce the swatches and the method used to obtain numerical data for the colors.

   In the Results section, you should present your data; this is detailed more thoroughly under point #2.

   In the Conclusion, you should summarize the observations from the Results section and use this summation to validate whether any observable trends exist.

Following this format and including the appropriate information in each section will be worth a maximum of 12 points

2) Data Presentation: For each of the three values obtained for the color, prepare a table that follows the format given below:
<table>
<thead>
<tr>
<th>HUE (or Saturation or Luminosity)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposed (UV or visible)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Each table should be followed by a scatter plot to present a graphical picture of the data and by a short discussion regarding the trends observed in the exposed paint swatches vs. the control. Each table, graph and the following discussion will be worth a maximum of 16 pts. (Instructions on how to prepare a scatter plot using EXCEL 2000 will be posted on eLearning.)

3) Grammar, Spelling and Conciseness: These parameters will be graded on a possible maximum of 10 points total.
Lightfastness of Lake Pigments

The purpose of this project is to test whether paint swatches made using lake pigments tend to be less stable when exposed to light, in comparison to inorganic pigments. We created lake pigments by precipitating a natural dye using a metal salt. We produced these pigments by reacting dyes to produce insoluble solids. In another lab period we made paint swatches using these lake pigments. In order to test our assumption of whether lake pigments when exposed to light, become less stable, we placed the swatches in light boxes and exposed them continuously to visible or ultraviolet light over a six week period of time. To have a comparison we additionally kept a set of swatches in a dark drawer. The swatches were removed at the end of each week and scanned.

In order to prepare a paint that can be used for decorative purposes, a dry pigment must be mixed with some sort of vehicle containing a binder and a diluent or solvent, which will enable it to be spread evenly and smoothly. The binder secures the pigment to the surface to prevent flaking. A binder can be either a film or an adhesive. Film binders protect the colorant and must be tough, durable and flexible. The diluent increases the fluidity of the paint to improve spreadability. With a few notable exceptions, the same pigments can be used in almost any type of paint formulation. Therefore, the real difference between types of paints lies in the binder used in the formula. The binder type in turn dictates what solvent system will be appropriate. The common property of most paint binders is that they contain either macromolecules (polymers) or else they contain smaller molecules that will form macromolecules (polymers) upon exposure to air and moisture. Probably the four most important types of artists’ paints used over the centuries are: (1) egg temperas, (2) oils, (3) watercolors, and (4) acrylics. I prepared my egg tempera binder as follows:

PART A: Preparation of Binding Media
Egg Tempera Binder
1. Transfer 10 mL of the prepared egg yolk mixture to a graduated cylinder. Pour the yolk into a small beaker and add an equal volume of deionized water. Stir well to form a pale yellow emulsion.

PART B: Making Paints
When making paints the pigments are usually ground with the binder using a glass muller to ensure thorough coating of the pigment particles with the binder. I used "gloss squares" and a spatula to mix my pigments and egg tempera binder. To make mixing of paints easier, all the pigments were finely crushed and ground in a mortar before mixing with a binder.

I. Inorganic Pigments.
We were assigned Logwood as our inorganic pigments, and had synthesized it earlier in the semester; and placing the prepared mixture of that pigment with the egg tempera binder in Part A and made paint using the following procedure:
Procedure

Placing a small pile of pigment on a gloss square (such as the weighing papers by the balances) I added the egg tempera binder a few drops at a time. I mixed it well with a palette knife or spatula until completely blended. Mixing strongly for 25-50 rubs to get thorough blending. With each paint, we made 3 small swatches on white index cards. The cards were placed in light boxes and exposed continuously to either visible or ultraviolet light over a six week period of time. Additionally, as a comparison, one set of swatches was kept in a dark drawer. The swatches were removed at the end of each week and scanned.

Using Corel Paint Pro Shop X2 I first opened the image file and used the crop tool on the left of the image bar. I expanded the box to include the center of the swatch and double clicked on the left mouse key to crop the image. To get the numerical information of the cropped image, I clicked view on the menu bar and selected histogram from the second drop down menu. On the right side of the histogram palette I chose either the hue, luminosity, or saturation and recorded the value given as the mean for each.

I acquired the numerical values for hue, saturation and luminosity for my assigned swatches, and tabulated the numerical data. After each table, I included a scatter plot of the data, so that I could visualize how each parameter changed over the six weeks; for each scatter plot.
1) Open the EXCEL 2007 program from the “Programs” menu > “Microsoft Office” menu; the page displayed should appear similar.
2) In the cells, enter “Week Number” (A1), “Exposed Value” (B1) and “Control Value” (C1), then input your values.
3) You are now ready to produce a scatter plot. To do this, first click the “Insert” tab in the menu-bar, then move the cursor to the “Scatter” icon in the “Charts” section of the drop down menu and click on the down arrow; from the menu options, click the upper right box to produce a scatter plot with smooth lines. The program should give you a scatter plot of your “Exposed Values” and “Control Values.”
4) To add a title to your graph, click the “Layout” tab in the menu-bar, then move the cursor to the “Chart Title” icon and click on the down arrow. From the menu options, click “Above Chart.” A text box with “Chart Title” should appear. Highlight the text to position a cursor inside the box then type in your title.
4) To add a title to your X-axis, click the “Layout” tab in the menu-bar, then move the cursor to the “Axis Titles” icon and click on the down arrow. From the menu options, click “Primary Horizontal Axis Title” and click on the right arrow. From the secondary menu, click “Title Below Axis.” Highlight the text to position a cursor inside the box then type in your title.
5) To add a title to your Y-axis, click the “Layout” tab in the menu-bar, then move the cursor to the “Axis Titles” icon and click on the down arrow. From the menu options, click “Primary Vertical Axis Title” and click on the right arrow. From the secondary menu, click “Rotated Title.” Highlight the text to position a cursor inside the box then type in your title.
6) To copy the graph to your paper, highlight the graph in EXCEL, then right-click to obtain a dropdown menu and click “Copy.” Add it to your paper by choosing “Paste” from the Edit menu in your word processing program.
Results:

<table>
<thead>
<tr>
<th>Logwood</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
<th>Week 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hue</td>
<td>243</td>
<td>243</td>
<td>242</td>
<td>243</td>
<td>244</td>
<td>242</td>
</tr>
<tr>
<td>Control</td>
<td>243</td>
<td>243</td>
<td>241</td>
<td>241</td>
<td>240</td>
<td>240</td>
</tr>
<tr>
<td>Exposed Ultraviolet</td>
<td>237</td>
<td>237</td>
<td>237</td>
<td>237</td>
<td>237</td>
<td>238</td>
</tr>
</tbody>
</table>

In the scatter chart the control value significantly dropped in the third week, with another drop occurred during the fifth week while the exposure to ultraviolet light increased during the fifth week. The characteristic of hue is wavelengths, so by my chart the swatch kept in a dark box showed a definite reduction in the control value when the swatch was not exposed to a light source.

<table>
<thead>
<tr>
<th>Logwood</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
<th>Week 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luminosity</td>
<td>82</td>
<td>58</td>
<td>60</td>
<td>62</td>
<td>61</td>
<td>54</td>
</tr>
<tr>
<td>Control</td>
<td>65</td>
<td>64</td>
<td>58</td>
<td>54</td>
<td>52</td>
<td>55</td>
</tr>
<tr>
<td>Exposed Ultraviolet</td>
<td>68</td>
<td>52</td>
<td>58</td>
<td>56</td>
<td>56</td>
<td>56</td>
</tr>
</tbody>
</table>
The exposed value and control value became directly correlated and equally showed a relationship to each other from the third week on. There was some reduction in the luminosity values.

<table>
<thead>
<tr>
<th>Logwood</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
<th>Week 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saturation</td>
<td>87</td>
<td>87</td>
<td>75</td>
<td>76</td>
<td>74</td>
<td>71</td>
</tr>
<tr>
<td>Control</td>
<td>83</td>
<td>80</td>
<td>76</td>
<td>76</td>
<td>73</td>
<td>75</td>
</tr>
<tr>
<td>Exposed Ultraviolet</td>
<td>80</td>
<td>64</td>
<td>64</td>
<td>61</td>
<td>61</td>
<td>61</td>
</tr>
</tbody>
</table>

The saturation values for the exposure to the ultraviolet light showed a decline from the second week and basically evened out from the fourth week on. There was some change in the control value. From the level of exposed value, I have to conclude that lake pigments would be less stable over a greater time period.

In conclusion the hue showed a definite reduction when the swatch was not exposed to a light source. The exposed and control value in luminosity remained relatively the same. However, the exposed swatch to ultraviolet light showed a consistent decline. So I would have to conclude that lake pigments would be less stable over time.