The infusion of collaborative independent investigations throughout a biology curriculum – *"Teams & Streams."*

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INTRODUCTION

Science is classically defined as the pursuit of new knowledge and scientists practice this process every day by employing techniques (both conventional and novel) in their laboratories. However, when science students (especially in introductory courses) work in the classroom laboratory, they rarely experience this process. It is not unusual for a college freshman to change their science major after their first semester, reasoning, "I don't think I could do that stuff, like in my 101 lab, for my career." It is difficult to explain to the student why the experience in that classroom lab has little to do with the fun in a real lab. The current standard of educating undergraduate students in the art of laboratory biology seems to involve issuing a laboratory manual and charging the students with replicating a "science experiment" that thousands of other students have done before them. The assessment of learning that follows often is based on only if they replicated it well or not, and if they write a good lab report. The fact that hundreds of similar papers for each lab written by students from "semesters past" are floating around campus, further complicates matters of assessment. The thought behind this traditional teaching method is to expose students to a variety of techniques that they will come to understand and appreciate later, but many of the students don't stick around for "later."

In introductory Biology classes at the Lyman Briggs School of Science at Michigan State University,[1] our students have encouraged us to challenge (and indeed change) this model. When we asked students what they liked least about their laboratory experience we consistently got answers that revealed: "labs are boring and time-consuming." Students repeatedly told us that it wasn't how they imagined science would be. Upon reflection we agreed that "real science" was very different then the way we taught it. Why couldn't we teach all the important techniques *and* allow them to think and problem-solve like a real scientist, even at this introductory level?

We decided to change our classroom laboratory curriculum. Our goal was to allow students to develop a biological question and then devise a series of experiments that would enable them to gather evidence to support or refute their hypothesis. We also strived to create a formula that follow the mantra, "Less Teaching, More Learning." We knew the new approach would only be sustainable if we could decrease the workload of the teacher(s) while at the same time increasing the learning of the student. As we developed rigorous goals for the students' experiments as well as their learning, we soon realized that the burden of this project would likely be too great for one student to bear alone. With the help of cooperative learning experts like Karl Smith, we decided

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[1] Lyman Briggs School of Science is a residential undergraduate science program established at Michigan State University in 1967. It is essentially a residential college (modeled after those at Oxford University) that has a focus of educating undergraduates in a liberal science curriculum, ie a solid foundation in the sciences *and* a significant liberal education in the history, philosophy and sociology of science.

that group work would give us more flexibility, be more like “real science,” and enable us to “raise the bar” and expect a higher level of learning *and* research from the students. After all, scientists rarely work in isolation. What we strived to create were structured, *Learning-Teams* that experienced active and cooperative inquiry during independent research projects. Additionally, to foster group identity and ownership, we decided to give the teams a permanent home in the lab. They would be provided with their own lab bench for the semester and appropriate modern molecular biology lab instruments (including a computer, digital camera, microfuge, pipetmen, vortex, spectrophotometer etc). We wanted their lab bench to mimic those in our own laboratories, in both appearance and functionality.

CURRICULAR REVISIONS

We started examining the traditional “cookbook” laboratory sequence first only in our Cell & Molecular Biology Course (Introductory Biology II), later these revisions were also applied throughout the Organismal Biology Course (Introductory Biology I). The classroom laboratory had previously been divided into numerous 3-hour lab experiments that students performed individually. The schedule of the laboratories mirrored that of the lecture topics and like them was brief and diverse. Although we, as instructors, “saw” the relationship between all the labs, the students did not. To them it was just a buffet of a different topic every week. The first few traditional labs were cell biology-related and dealt with macromolecules and carbohydrate chemistry, hormones and plant tissue culture, enzymes kinetics, and light and dark reactions in photosynthesis. The second half of the semester used traditional “cookbook” labs that were more molecular biology-related and had been recently revised to involve the students in a slightly more proactive version of learning standard techniques in molecular biology (Transformation, Miniprep and DNA restriction analysis), (Wilterding and Luckie, 2002). For the purposes of simplicity and space in this report, we will only focus on the first half of the semester, what we call Stream I.

Developing long-term independent research experiences aka “Streams”

Semesters at MSU are 15 weeks in length so we divided the laboratory sequence into two 7-week streams. In our revision of the laboratory curriculum of Stream I, we wanted students to choose their own topics and design their own long-term research projects. We decided the first stream would need 1 week of orientation followed by 6 weeks of laboratory time in which the students would be exposed to new material, equipment, and techniques and then implement them in their unique research projects. But how would we get students to learn proper techniques and still allow them independence?

For us, the answer was to divide the six weeks into three 2-week blocks (Carbohydrates, Photosynthesis, Enzymes) and to take the first week of each block and devote it to having the student group’s perform of our best traditional cookbook lab on that topic (Table 1). The traditional lab served to train the students in techniques and assays, and its results could be utilized as initial experiments (controls, in fact) for their independent investigations. The second week was “open” and allowed students to apply the methods learned in the week 1 to test their own research questions during week 2. For example, in the first traditional lab week, the team would perform various chemical assays on carbohydrate solutions of glucose, fructose, xylose etc. They would test known sugars for structural characteristics like aldehyde vs. ketone groups, polysaccharide vs. monosaccharide status etc, as well as then characterize an unknown sugar.

After this traditional lab, during week 2, students could utilize any of these techniques/assays (or find/create their own) to perform experiments to help answer their research question. Thus each student group would follow a structured schedule where they complete a traditional lab on carbohydrate macromolecules followed by a week of independent research, next perform a traditional lab on photosynthesis and a week of independent inquiry, and again, one week of a structured lab on enzymes followed by an open research week (Table 2). While this restructuring of the curriculum was laudable by itself, the most important requirement we implemented was that all the different experiments performed and the manuscript created by the research team, needed to focus on just one research question (and a first draft of the entire research plan for all six weeks be submitted at the end of week 1). Some of the titles of research plans have been "Differences in Carbohydrates, Polyphenoloxidase, and Photosynthesis Between *Pinus strobus* and *Malus domestica";* "The Chemical Difference Between Pancrease and Lipram"; "A Description of How a Pluot is Similar to a Plum Through Carbohydrate, Pigment and Enzyme Activity Tests." (*See many more online* http://surf.to/teamstreams/)

Creating cooperative groups with individual roles *aka "Teams"*
During the first day in their laboratory, the students meet their group and immediately assign roles for the rest of Stream I. Although each student in the group (typically 4 people) is expected to help out in all tasks to complete the assignment, each student has a primary *role*. These roles were labeled: Primary Investigator (PI), Protocol Expert (PE), Data Recorder (DR), and Laboratory Technician (LT). For example, the PI is responsible for primary organization of the team as well as oversight of the experiment as a whole. It is the job of the primary investigator to be responsible for implementing troubleshooting techniques throughout the investigations. The PE, on the other hand, is responsible for overseeing the creation of scientific protocols for each week's independent investigation (what experiments/steps you plan to do) as well as is responsible for construction of websites (when necessary), and other computer related activities. These individual roles help to organize the team and give each person a role in the group.

Assessment of the student group's performance in their research project was designed, like in real science, to be highly dependent on their capacity to communicate their findings via a publication. In addition to attendance in the lab and at group meetings, and passing interviews along the way, the students were charged with presenting their research via several drafts culminating in the submission of a final manuscript formatted for publication in a scientific journal of their choice. This process required the groups to come together and prepare for labs, record data diligently during labs, study the prose used in scientific journals (ie. American Journal of Physiology, Nature, Journal of Molecular Biology, etc) and then emulate it. The difficulty in grading a group paper is, of course, the challenge of individual assessment. How do we assign *individual* grades from a *group* assignment? We decided to also evaluate "individual authorship." Not unlike the division of the group into specialty roles that were responsible for particular lab tasks (above), different members in the group were also assigned the responsibility for authoring different sections of the paper for each draft. This individual authorship responsibility rotated, ie. for draft 1, the PI authored the Introduction and Methods, for draft 2, PI authors/revises Results and Figures, etc. As a final method of getting the group involved in all the sections, we require that each student sign a "group responsibility contract" attesting to the fact that each of them has read through the entire paper and agrees that it is complete, accurate, original, and cohesive and that they accept their grade will be a 50%:50% mix of their individual section and the full manuscript scores.

ASSESSMENTS IN REVISED CURRICULUM

Writing

The capacity to assess the student's laboratory research results as well as their understanding has always been dominated by writing in our courses. In the traditional curriculum that was replete with cookbook laboratories, assessment strategies were primarily based upon individual lab reports of various sizes. These reports were many and their topic was the explanation of the cookbook lab from the prior week. Since all reports were written individually and there were a number of them, there were numerous reports to grade every week and the superficial way they were graded was not something to be proud of. Because many reports from past semesters were available on campus, much effort also had to be focused on looking for signs of plagiarism. Student wrote many of these reports and they were very constrained in what they were "allowed" to write. From one semester to the next, the topics students were supposed to discuss in their report were changed to make copying from last semester more difficult. Appendices called "signed data" were also added to the lab reports and represented time-stamped proof the student had actually been to lab at the appropriate time and written down relevant data that appeared original. Under these circumstances much effort came from the student to create numerous reports about the same things their roommate and older sibling may have done before (which was frustrating to the student, one student comment was: "I'm just doing the exact same thing every student did before me and I'm not even free to decide what to write about in my own Discussion section") and much effort came from the instructors in their attempts to detect plagiarism (which was frustrating to the professor "If the students just want to cheat and don't care about their learning, why should I?"). Clearly this is not the optimal scenario but it is not unique in introductory biology classes at large universities.

In our new curriculum student groups write only about their research project. They are not expected to write anything about the cookbook labs they perform unless it's relevant to their own research (ie. as control experiments). In addition, instead of writing multiple reports about different topics, the student group composes multiple drafts of their manuscript for one topic, their own. This approach allows them to chose what themes and subjects to discuss in their own writing, to experience multiple drafts with revisions suggested by the instructors and their peers (through peer-review) AND the possibility of plagiarism diminishes significantly. Given every student topic tends to be unique, all the resulting manuscripts are quite diverse. Students also create a final website to report their findings, and next semester's students read the research published by prior cohorts for inspiration, but since that work has already been done, new projects must be developed (just like in the real research world). We believe this approach has more creativity, collaboration, better writing experience and is more "real science." We consider it closer to the optimal scenario and it is somewhat unique in higher education at large universities. We also find it less tiring to run this curriculum then the traditional one. Hence we believe it succeeds in supporting our mantra of "Less Teaching, More Learning."

In the first week of the semester, the student groups write about their research projects and initially submit a DRAFT 1. In this draft, the students spell out what they propose to do in their six week research project and what results they predict will find from the experiments they plan to do on the topic.

This DRAFT 1 serves as a proposal but is written in the format of a final manuscript being prepared for publication where the Results section includes the students' predictions, and the Discussion section are their interpretations of the expected results. We feel the first week of the semester is the ideal time to place this large burden on the student group. It requires them to read all the labs, meet and discuss potential research projects, study up on the topic, take on roles in the group and write and edit a full manuscript. All these challenges occur right when the rest of classes on campus are still just reading through their syllabus in lecture and present no competition for student time and effort. In fact, if the group workload at the start of the project doesn't seem to be a heavy burden for a group, overachievers will not value working in a group and will start asking for the opportunity to do the project solo. "Front-Loading" the course in this manner helps to ameliorate another problem our students had mentioned which we optimistically term– *Retroactive Learning*. We heard even our best students explain: "I didn't really understand how the laboratory was relevant until after the exam/paper." Requiring the students to page-through the manual and organize the content/topics in their heads well before beginning their lab experience has helped this considerably.

Interviews

After student research teams have completed and submitted their DRAFT 1 manuscript, we require the group to pass a formal interview with the Professor before being allowed to proceed in the laboratory. All four students in a group schedule a 60 minute meeting with the Professor to sit down to discuss their idea and plans. This is amazing. The fact that this new curriculum allows an Instructor to have private meetings with every student in the course is quite novel. Previously our class was composed of at least 100 individuals where there really was no way to set up 100 meetings. But now the class is composed of 25 teams and over about 10 days the most experienced scientists in the course (Prof) can meet and discuss research with their students. The interviews are often very predictable. In most cases while the group is rather excited about the topic they have chosen to investigate, they need to think about what's practical in the time allotted, what "controls" and "replicates" are needed and so on. Also any supplies they need are identified and the group is encouraged to find and buy things on their own. Once a group has "passed" the interview, they are given an interview receipt with comments that will then alert TAs in the lab that this group is permitted to begin their independent research. These interviews go on during all of week 2 (when lab is just a traditional cookbook experiment) and into week 3 as the deadline for their first independent research days approaches. This moment, early in the semester, is once again a time in the course that helps the student see that the activities of this class are going to be different then what they may have expected. Sitting down with the professor and chatting about their research project is an excellent model of what should happen in introductory biology. We believe this approach moves closer to the optimal experience for undergraduates and is quite exciting for the instructor (another experience that may be too rare).

Peer Review

DRAFT 1 feedback comes from the instructor-level (ie the Prof), and DRAFT 2 a few weeks later is evaluated again at this level based on how well the group responded to the Professor's comments. Yet in addition to feedback from the Instructor, DRAFT 2 is individually peer-reviewed by four classmates from another research group. The reviewers are graded upon how well they follow the guidelines on a peer-review worksheet (that requires them to evaluate both the science and the writing), yet their evaluation of DRAFT 2 is not used in the class grading of the manuscript. This peer-review process is quite effective at both alerting the group to problems in their own manuscript, but even more so, at allowing a student to view another group's manuscript (and become very reflective about their own). As they follow the format of the peer-review worksheet they are often asked to read a section and then explain what the research topic is and how it's being done etc. When they read either a poorly done draft or an excellent one, they think about their own paper and how well it would hold up under the same scrutiny. Of course they soon find out when receiving the reviews of their own work.

Quizzes

In addition to charging the students with reading and understanding the nuances of the "canned" lab experiments an the workings of the lab, we employed a means of assessing the students knowledge of lab and lecture related material throughout the eight weeks via quizzes. These quizzes, given weekly in the recitation meeting acted to help bridge lecture and lab while prompting the student to continuously be reviewing their lab manuals. Students were allowed to drop 2 quizzes throughout the semester (of their choosing). Admittedly the quizzes were a great deal of upkeep to continually generate and grade; however, we are currently considering a method utilizing LON-CAPA (Computer Assisted Personalized Approach) to generate and grade the quizzes. The students have a less-than favorable opinion of these quizzes and as instructors we found this to be initially very disheartening. They felt that the quizzes were "too much for them to do." At the end of the semester, however, student feedback was far more positive with students admitting that the quizzes really forced them to continually review the material.

Concept Maps

We have observed brilliant students that could teach their peers the intricacies of DNA replication but were stumped by a question that requires them to explain the relationship between a gene, DNA and a chromosome. Students often seem to understand the details, but do not see the big picture or the connections between a new concept and the last. In an attempt to stimulate thinking that is reflective and shared between students about the "big picture" and all the connections between these seemingly disparate topics in the textbook, lecture and laboratory in the course, we use online concept map exercises with automatic grading.

In our own learning as scientists, we use visual models to understand complex systems, to communicate our ideas to our peers, and to deduce testable hypotheses. Models are one of the common themes in science; they are "the main vehicle by which science actually produces its explanations and predictions" (Casti 1990, p. 31). Students and scientists alike should use models to describe, evaluate and learn science. In our own quest to find modeling approaches that could help our students reflect on the big picture, we discovered a cornucopia of educational tools. Vee diagrams, venn diagrams, concept maps, flow charts, and storyboards were all developed by experts to resolve this dilemma. In our research we found that many tools showed potential, but the concept mapping approach developed by Novak et al (1984, 1998) is the best studied and validated visual tool for student learning. It forces students to confront and grapple with the conceptions and misconceptions they bring to their learning. Twenty years of research and numerous studies show concept maps can succeed as both an effective instruction and formative assessment tool for higher-level learning. Currently, online formative assessment tools are rare and web-based concept mapping software is either not readily available or does not exist. Therefore, as a part of a National Science Foundation project entitled “C-TOOLS: Concept Connector Tools for Online Learning in Science” we created software that delivers online concept mapping capability with automated feedback.

While concept mapping is quite powerful for learning, students rarely have any experience with it, and like their previous experiences “working in groups,” their previous experiences with concept mapping are not necessarily good ones. Thus we must teach them both about concept mapping and about the online C-TOOLS software we want them to use. We start this the first day of class. In lecture on the first day of the semester, students write information about themselves on one side of a large index card and on the back build a simple concept map about themselves (ie John Smith -> loves -> Tennis; has a -> sister Mary; etc). We then demonstrate the software and ask the student to transfer their map from their index card to the online mapping software. Before we assign any concept mapping homework on topics like Cell Biology and Photosynthesis, we spend a considerable amount of time in our small group recitation sections introducing the purpose of- and how to make- concept maps (as well as how to use the online software). We have students perform “hands-on” exercises where groups (of 4-5 students) work together arranging index cards pre-labeled with terms like: “Photosynthesis”, “Energy”, “Sugar”, “Light reactions”, “Chloroplast” “Thylakoid Membrane” etc, to slowly build good concept maps. These group exercises are wonderful teaching moments where students both learn each step to building a good concept map and discuss and debate the appropriate arrangement and linking words. Once students have had ample opportunities to master the idea and method of concept mapping they are assigned homework concerning cell biology, photosynthesis and respiration and their relationships (http://ctools.msu.edu/).

With this online software, students complete two basic concept maps as an integral part of the course (two assigned homework problem sets at week 5 and 10 of the 15-week semester). To complete one particular problem set, students login to a website [http://ctools.msu.edu/ -> select Assignments “Cell Biology (LBS145)” and “Carbon Cycle (LBS145)”] and are presented with instructions and a new concept map with only 10 pre-defined concepts (in a cluster). Students need to move the concept words around, organize hierarchy, add linking words and lines. Students first construct a map individually, submit it to the computer and receive a score and visual feedback about good vs. poor links. They then can revise the map and resubmit. Finally when they complete their individual assignment, they then work with a partner to create a revised collaborative concept map where they must add 5 more concepts to end with a 15 concept group map.

<u>Essay Questions on the Midterm Exam</u>

In addition to administering traditional in-class multiple choice exams to evaluate lower-level knowledge of the basic vocabulary, anatomy and processes of biology. We also provide essay style questions at the beginning of the semester for all exams. In the course packet, for each exam, we identify six essay questions and indicate “two of these will be on your test.” Example grading rubrics and excellent example answers from previous students are also provided. These questions are more challenging “prediction” or “design an experiment” type experiences and serve to evaluate whether students over time can master all the material and synthesize it to show their mastery of the experimental design and scientific thinking.

Two examples:
1. Predict how many *photons* of light are minimally required to create one glucose molecule in photosynthesis (or two glyceraldehyde-3-phosphate molecules) and explain your reasoning? Assume 3 protons (H^+) must travel through the ATP Synthase for it to make an ATP. Illustrate the light reactions and dark reactions involved, and where the energy molecules are created and used to make sugar.

2. You have just completed your M.D./Ph.D. degree at Stanford University and received a 10 million dollar grant from the NIH to develop treatments for cancers caused by over-expression of an oncogene. Explain what antisense treatments are and how they work. Combine your knowledge of transcription and translation as well as that of antisense therapies to design a strategy to cure this horrible disease.

Thus we have a number of diverse formal assessments that attempt to provide to both the student and the instructor formative feedback and summative evaluation of their learning during the classroom laboratories. These assessments tend to assay the individual and group scientific thinking and experimental design from an intellectual perspective. In the future we would like to add some simple performance based assessments to better evaluate individual accountability in learning how to operate equipment and solve basic questions as in the laboratory. In addition to all these formal assessments, there is a much more valuable informal learning assessment that dynamically evaluates teams and provides continuous personalized feedback, the laboratory teaching assistant. In this paper, we will not even begin to consider the numerous valuable learning moments (and assessments) that occur in the day to day operation of the classroom laboratory but our “teaching assistant” to “research group” ratio in the lab is often 1:1. Hence our TAs adopt a group for the duration of the stream, know their project, know their experiments last week etc, and help further increase personalized teaching to a near 1 to 1 Socratic level.

RESULTS/DISCUSSION

Clearly, there was a good amount of overhead organization to be done before the student research projects in the laboratory even started. Teams had to be generated; students had to be mandated to read the laboratory manual (the entire first stream) during the first week, and then the teams needed to be facilitated, by laboratory instructors (undergraduate teaching assistants), in coming up with an idea for independent investigation. We were apprehensive initially that it would be too challenging for a team of students who had never worked together to come alive and produce a rough draft of their final paper (which included predicted results and interpretations) during the first week of class. Much to our surprise/delight, the students not only rose to the occasion, but were excited about the learning and came up with ideas for research projects that we could have only dreamed of (see list of some research project titles or view a documentary film online http://surf.to/teamstreams/ click “Results” button).

In Spring 2001, during the first semester of running the Stream I laboratory in this new manner we were surprised by our students many times. Perhaps one of the most staggering to us was that a majority of the groups were coming to us and requesting additional laboratory time. The Lyman

Briggs School of Science has traditionally had “open laboratory hours” for biology classes. What this meant was two undergraduate TAs staffed the lab during various open hours throughout the week and students would choose when (and how often) to go to lab to complete their experiments. In creating this new Stream I we did assign groups to specific lab sections (and took attendance), but we continued this “open laboratory hours” approach by simply keeping at least one unassigned bench in each section available. This was a huge success and actually led to some student teams frequently reserving “open” benches and working in the lab for upwards of 10 hours/week. What more could a teacher ask for? Students going out of their way to *do science*!

This format has given us, as instructors, a wonderful template to work with. With great anticipation we look to each coming semester as a chance to enrich this curriculum. Currently we are working with the idea of instituting a modular lab system where the students can swap out certain “structured” lab experiences and insert others in their stead in effort to further add to their autonomy as scientists. We hope to further diversify student’s lab experiences and enable them to develop even more novel connections between the labs. Utilizing the unique environment of the Lyman Briggs School of Science, we are hoping to bring sciences other than biology into this model and encourage students to utilize chemistry, physics, computer science, mathematics, biology, and STS (science and technology literature and writing) in an integrated fashion.

J.H. Wilterding and D.B. Luckie (2002) Increasing Student-Initiated Active Learning with Investigative 'Streams:' A Molecular Biology Example. *Journal of College Science Teaching* Vol 31(5): 303-307.

Table 1: **BEFORE**: The Traditional Curricular Design and Assessment Strategy of Introductory Biology prior to re-design (first half of a semester-long Introductory Biology classroom laboratory, second half of semester *not shown here*).

Week	Laboratory Topic	Assessments Used	Assessed "Skill"	Bloom Level
1	No lab	NA	NA	
2	Lab 1: **Traditional "Structured" lab**: Cell Structure via Microscopic Analysis	'Notebook check' at end of lab	*Indirectly*: using microscope and following directions.	1-Knowledge
3	Lab 2: **Traditional "Structured" lab**: Tissue Culture and Hormones (5 week long experiment)	See week 8 (**TC lab report** on the process and answering questions posed in lab manual).	Capacity to write a lab report well and understand topic	1-Knowledge 2-Comprehension
4	Lab 3: **Traditional "Structured" lab**: Carbohydrate Chemistry plus lipids etc	QUIZ, Individual **CHO lab report** (on the process and answering questions posed in lab manual).	Sugar content knowledge, writing a report, draw sugars.	1-Knowledge 2-Comprehension 3-Application
5	Lab 4: **Traditional "Structured" lab**: Photosynthesis I (Light Reactions).			
6	Lab 5: **Traditional "Structured" lab**: Photosynthesis II ("Dark" Reactions).	Individual **PHS lab report** (on the process, questions, described in manual).	Photosynthesis content knowledge, writing a report.	1-Knowledge 2-Comprehension
7	Lab 6: **Traditional "Structured" lab**: Enzyme Kinetic Studies.	**Midterm** Exam (draw illustrations and in class multiple choice exam)	Macromolecular structures and biol. content knowledge	1-Knowledge 2-Comprehension
8	Lab 7: **Traditional "Structured" lab**: Enzyme Kinetic Studies II and finish the Tissue Culture (Lab 2 completed).	Individual **lab report(s) on Enzymes** and **TC studies** (on the processes described in manual).	Content knowledge on lab procedures and topics.	1-Knowledge 2-Comprehension

Table 2: **AFTER**: The Curricular Design and Assessment Strategy of *Stream I* after the redesign described in this paper (first half of semester long Introductory Biology classroom laboratory, second half of semester, *Stream II, not shown here*).

Week	Laboratory Topic	Assessments Used	Assessed "Skill"	Bloom Level
1	Introduction to "Teams and Streams." (read labs, meet group, make plan)	**DRAFT 1** of group manuscript (proposal) on student topic.	Experimental design, writing, content knowledge	1-Knowledge 2-Comprehension 4-Analysis
2	Lab 1: **Traditional "Structured" lab**: Carbohydrate Chemistry	QUIZ, Formal **Interview** by Prof	Sugar content knowledge, Experimental design	3-Application 4-Analysis 5-Synthesis
3	Lab 1: ***Inquiry*:** Apply sugar tests to your question/investigation.	**DRAFT 2** of group manuscript (only on group's topic, experiments and data, etc not traditional lab).	Writing, content know., data analysis, experimental design	1-2-Know/Comp 3-Application 4-Analysis
4	Lab 2: **Traditional "Structured" lab**: Photosynthesis (Light Reactions).	**Peer Review** of DRAFT 2	Reflective critical analysis, data analysis, design	4-Analysis 6-Evaluation
5	Lab 2: ***Inquiry*:** Apply photosynthesis tests to your inquiry.	**Concept Maps** (online)	Connections in content knowledge	1-Knowledge 2-Comprehension 5-Synthesis
6	Lab 3: **Traditional "Structured" lab**: Enzyme and Protein Studies.	**Midterm** Exam (essay questions, and in class multiple choice exam, then in class pyramid exam)	Content knowledge -exam, exp design knowledge -essays.	1-Knowledge 2-Comprehension 3-Application
7	Lab 3: ***Inquiry:*** Apply enzyme tests to complete your group's inquiry.	**DRAFT 3** final manuscript (only on group's topic, experiments and data, etc not about traditional labs).	Writing revisions, data analysis, math, interpretations.	1-Knowledge 2-Comprehension 4-Analysis
8	Debriefing and Prep for Stream II (complete group writing, clean up areas, prepare for next stream)	(interested in adding a form of performance based assessemnt here, aka a practical skills test)		