Report of the C³M Project:
Connecting & Collaborating through Concept Mapping

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1. Catalysts: the Birth of the C³M Project. The C³M Project grew out of existing relationships among Elliott Gimble, a high school biology teacher at Lexington High School (Lexington, MA, USA), Barbara Newkirk, an LHS special needs teacher, and Jane Heinze-Fry, a parent/science education researcher. Elliott had been communicating with Barbara Newkirk about strategies to help students deal with the seemingly overwhelming content of his Level 1 biology classes. Jane Heinze-Fry had done her research on concept mapping strategies with college biology students in 1987 and had learned about CmapTools, software that enabled easy construction and revision of concept maps to facilitate meaningful learning. As a bonus, the software was freely downloadable to educators. Barbara had called Jane to consult about possible environmental education projects for her students. Jane asked if any teachers were interested in new learning strategies to address science content. Barbara introduced Elliott and Jane. With the support of Principal Michael Jones and Science Department Head Jacqueline Crowe, Elliott wrote a proposal to the Lexington Education Foundation (LEF). (See Appendix B1; C³M Public Cmap: Lexington Education Foundation) The LEF grant crystallized the C³M Project taking it from dream to reality.

The direct beneficiaries were Elliott’s three biology classes and some of Barbara’s special needs students. Elliott demonstrated mapping to his classes as a tool to visualize an overview of the whole course and offered an example in the study of Macromolecules. Students actively created concept maps in two pilot units: “Cell Structure and Function” and “Cell Reproduction.” Barbara initiated a trend in her students from a learning strategy of memorizing flash cards to creating connections and clustering concepts.

The Project has drawn on the resources of an extended learning community. Dr. Joseph Novak, researcher and “father of concept mapping” and Jim Gorman, who is introducing CmapTools in all of this chemistry and physics classes at Northbridge High School have offered their research, advise, and encouragement. The LHS technical support team worked to make CmapTools available on two banks (total 24) of LHS computers. The technical support staff of the Institute of Human and Machine Cognition (IHMC) consulted with LHS tech support with technical problems in using the software. The chemistry department generously offered the use of a select set of their laptops to support the mapping work by Elliott’s classes. A concept mapping team, composed of Joseph Novak, CmapTools researcher Alberto Cañas, and teacher/implementers Jim Trifone, Jim Gorman, and the C³M team has proposed a Short Course for Boston’s 2008 National Science Teachers Association Conference. It takes a village. There are kudos enough to go around.

Documentation. Many of the observations and claims made in this report are supported by documents available in the three Appendices. In addition, most documents are available on the Website of the C³M Public Concept Map: http://cmapspublic3.ihmc.us:80/servlet/SBReadResourceServlet?rid=1179699420813_77797797_6123&partName=htmltext
Documents available on the website can be accessed by clicking on the icons of the indicated concepts to which they are linked. (When the titles of documents linked to that concept appear, simply click on the title of interest.) Throughout this report, such references will be indicated by “C³M Public Cmap: ‘particular concept’.”
2. **C³M Goals and Questions.** The C³M Project proposed introduction of an innovative teaching tool to shift students from rote memorization to more meaningful understanding of biological concepts. The C³M team introduced concept mapping to student populations in three biology classrooms and in the resource room in multiple subjects. Targeting cell structure and function and cell reproduction, key biological concepts that align with the district curriculum and state frameworks, the C³M Project enhanced student learning by emphasizing: (1) connections between the “forest and the trees” (superordinate and subordinate concepts); (2) individual and team learning; and (3) collaboration among students, parents, and teachers.

To meet its goals, the team addressed some specific questions: 1. Could the tech team successfully download *CmapTools* software onto the school’s computers? 2. Could the teachers create concept maps and be effective in teaching their students to concept map and express their maps with *CmapTools* software? 3. Were students able to create concept maps both individually and as a team? 4. Did concept mapping facilitate meaningful learning by the students? Did it help them see the forest and the trees in context? 5. Would participation in the project collaboratively build the Lexington educational community, especially relationships between student-student; student-teacher; and teacher-teacher? 6. How did students feel toward the mapping experience? 7. What would be the logical next steps in the use of concept maps?

The C³M Project unfolded in sequential phases: Installation of the *CmapTools* software; the Development of the C³M Team; the Implementation of Concept Mapping for Students; and the Sharing of the Project with the Educational Community.

3. **CmapTools Installation.** Could *CmapTools* be loaded onto school computers? The Lexington High School technical support team was able to download *CmapTools* onto some school computers, but not without some effort. There were some compatibility issues between the *CmapTools* software and other software loaded onto the Lexington High School systems. The compatibility issue revolved around different software packages that teachers wanted to use requiring different versions of Java. There was updated Java which allowed other programs to run and to allow that older version of *CmapTools* (v. 4.03) to run on those machines, the tech team would have had to reinstall an older version of Java which would have been a step backward and put those other programs at risk for not working. This issue was resolved for the C³M Project through the cooperation of the Chemistry Department. They had two banks of Mac laptop computers onto which the *CmapTools* software was downloaded. As of the end of June, 2006, hardware and software checked out although a few unusual glitches appeared during the pilot study. Unfortunately, Barbara Newkirk did not have access to *CmapTools* in the resource room. She did download *CmapTools* onto her home computer, however. What needs to be investigated is whether the newest version of *CmapTools* is compatible with LHS software, in particular Java compatibility. Further downloading of *CmapTools* onto LHS computers requires that the Java compatibility be resolved.
4. Development of the C³M Team

4.1. Initial planning: The C³M Team invested one July evening to “get on the same page.” Discussion wove among research, class assignments, student assignments, interconnections between Special Needs and Classroom learning. Roles and responsibilities were decided. Plans were made for Elliott and Barbara to read recommended resources on concept mapping and to create their own concept maps. Ideas for introducing concept mapping to students were discussed.

4.2. Results: Following through on the planning meeting, the team wrote implementation plans and other documents. Jane provided grounding and additional resources to the team members and used the Second International Conference in Concept Mapping to answer the team’s questions. Some documents were developed before students began mapping. Others were developed over the course of the project. Elliott and Barbara read background material and created their first concept maps.

Early work
Implementation plans to serve as roadmaps for the project are available in Appendix A or by clicking on the “Implementation Plan” concept on the C³M website. Elliott Gimble produced the C³M Timetable and Activities; Jane Heinze-Fry produced the C³M Logic Table and the C³M Evaluation Matrix. These structure documents served as roadmaps for the project, but were carried out with flexibility as the project unfolded.

Other documents also resulted from this meeting. (See Appendix B2: Summer Planning Documents; C³M Cmap: Follow-Through.)
- Summary of Summer Meeting: reads like minutes of a business meeting clarifying roles and commitments.
- C³M Reading List: Proposed reading list for Elliot and Barbara over the summer.
- CmapTools Conference Questions: includes questions that the team wanted addressed when Jane would attend the 2nd International Conference in Concept Mapping
- Concept Map Directions: a simple one-page set of directions developed by Heinze-Fry
- Rubric to Evaluate Concept Maps: this is a general map that can be adapted for different chapters and units.

Elliott worked on his initial and edited concept maps as he took an evolution professional development course at Harvard. Key understandings for him were distinguishing concepts (scientists) from examples of concepts (Darwin) and the ability to link visual resources to concepts. He found the “Theory Underlying Concept Maps and How to Construct Them” (Novak and Cañas) to be a very good introduction both to concept mapping and CmapTools. The concept map about concept maps was a useful illustration. His notes suggest concerns about his own understanding and student understanding of the what and how of concept mapping: “Students need early understanding (and possibly a simpler definition or one with a few examples) of “concepts.” Regarding “perceived regularity or pattern,” what happens when students get to the specific concepts (at the bottom of the map) and are tempted to break the rule? We need to prepare students by helping them understand the difference between concepts and specific examples. Also, what will help them understand the meaning of a “propositional statement” and how to make them? Definition of terms is vital.
**Barbara**, by downloading *CmapTools* onto her personal computer, produced an initial map of the planets. Unfortunately, she was assigned to Earth Science, rather than Biology students. Consequently, while the learning process of concept mapping bridged the team members, the content areas did not overlap. Barbara's emphasis is more on collaborative connections among students' flash card strategies. As her work developed, *CmapTools* was NOT the highest priority for her and her students so much as the simple idea of CONNECTEDNESS, a skill upon which concept mapping is predicated. Most of her students learned by using individual flashcards. Her focus turned toward getting students to collaboratively draw connections among the "essential concepts." Having access to a school computer loaded with *CmapTools* would have facilitated her use of the software.

**Throughout the Project**
Over the course of the project, **Jane** provided the team with grounding and additional resources on the theory and practice of concept mapping. She wrote and revised a draft of *CmapTools for Teachers*. (See Appendix B3; C^3^M Public Cmap: Teachers.) The list of grounding resources has grown with the project. Resources linked at the C^3^M Cmap: "Teachers" location include:

- The Theory Underlying Concept Maps and How to Construct Them by Novak and Cañas
- The IHMC CmapTools download website
- Geolookup: Shows “Who in the World is Using CmapTools?”
- CmapTools Learning Object: a tutorial on how to use CmapTools developed by the University of Wisconsin
- Concept Map of Concept Maps produced by Joseph Novak

Additional resources available for teachers linked at the C^3^M cmap: Resources concept include:

- Links to IHMC CmapTools Publications, White Papers, and Reference List
- Applications of CM, v9: a paper written by Heinze-Fry describing various applications of concept mapping in introductory science classes at Emerson collegeboard.com
- CmapTools facilitates alignment, v8: a paper by Heinze-Fry and Ludwig describing how concept mapping can be used to demonstrate alignment of Lexington Science Benchmarks and the Big Backyard Program with the Massachusetts Framework
- Lexington Public Schools Cmaps: Powerpoint describing applications of concept mapping in the Lexington Public Schools
- Concept Map Applications 2.1: Powerpoint of applications of concept mapping at Emerson College
- Program and Proceedings of the First International Conference in Concept Mapping

**Fall Progress.** In September, 2006, Jane attended the Second International Conference in Concept Mapping. A number of the team’s questions were addressed at this conference. Access to all the papers from the conference, including papers that might be of particular interest to the C^3^M project are linked to the “2nd International Conference” concept on the C^3^M concept map. Of particular note were the ‘parking lot concept’, access to the CmapTools tutorial, the new research paper by Novak and Cañas, and questions driving the nature of the concept map process. (See Appendix B4.1; C^3^M
4.3. Conclusion. The summer planning was a crucial time for the team members to talk about their work and interests. It was a time to talk about how we operated independently, but also the strengths that we brought to the team project. This meeting and two subsequent team meetings in the Fall sparked the collaborative efforts of the team. If Barbara had been assigned to some of Elliott’s biology students, the collaboration would have been stronger. If Barbara’s school computer had been loaded with CmapTools, her experimentation with the software would have been better facilitated.

5. Implementation of Concept Mapping with Students. “Gradualism” is the best single word to describe the C^3M team approach to introducing all students to concept mapping. In the biology classes, students first simply observed concept maps of varying depth and breadth. They then actively created and collaborated to produce concept maps using CmapTools in two different units. In the special needs setting, students grew from sole use of flashcards to seeking connections among the concepts on the flashcards. Each implementation explored a different method and consequently demonstrated different results and conclusions.

5.1 Observing Examples of Concept Maps. Initially, biology students just observed concept maps. During the first week of school, Elliott distributed a concept map demonstrating an overview of the field of biology. He gave a handout and explained the pilot study to parents at Back to School Night. In the Fall, students observed an example of a CmapTools-generated skeleton map of macromolecules linked to detail maps of the four major groups of organic molecules. (To view maps for student observation, see Appendix C1; C^3M Public Cmap: Students Observing Cmapping.)

Introducing the overview map, Elliott suggested to students that they could create a “graphic outline of sorts,” linking concepts or ideas. He used the biology overview map to demonstrate both hierarchical conceptual content (the organization of living things at the core) and interconnections between concepts linked to each other in multiple ways. He gave students the general idea of concept mapping without putting too much theory into his explanation. He reassured them that they would be working with concept maps in some assignments and established the expectation that mapping might help some learners.

General feedback was tough to gauge at student level. Based on a start-of-year survey, very few had worked with concept maps significantly (less than 10% is a conservative estimate) but several of those had found them useful. None had worked with CmapTools; so all were open to the idea. Students were generally acquiescent, cooperative, no big over- or under-reactions. According to Elliott, “Some parents at ‘Back To School’ night seemed excited about the biology overview concept map and I used it to help them get a feel for the year’s progression. It helped them see where we were headed, and I think several saw the potential benefits to learning. In addition, concept maps can help teachers reach parents who might be intimidated by the scope of
the course. I think some were impressed and excited that the whole of the year could be put on one side of one page. The overview map can also offer a useful entry point for them to discuss the course with their children.

5.2. Creating Concept Maps: Unit 1: Cell Organelles. Our objective for the students’ first concept mapping experience was to simply build student security with and confidence in the process.

5.2.1. Methods. Elliott chose “Cell organelles” for the students’ first active concept mapping experience. We offered the class a skeletal overview map and a general template from which to create their own maps. “Cell membrane” was given as a model. (See lesson plan, student handout, directions for creating cell organelle concept map using CmapTools, debriefing and reflections from classroom implementation in Appendix B5; C3M Public Cmap: Experience 1 Cell Organelles, Text icon.) Individual students were to sketch out hand drawn maps of the structure and function of one assigned cell organelle as a homework assignment. In school, they were to collaborate with a partner to edit their map and search for visuals that represented the structure and function of their organelle. They were also to include the significance of the organelle (or what would happen if it didn’t function properly.)

Collaborative aspects of this assignment were ‘student-student’ in creating their individual cell organelle maps and ‘student-teacher’ in creating the class concept map of all the cell organelles and ‘student-student’ once again when the students presented their maps to the class. A technical breakthrough on Elliott’s part was to link the class maps to his link on the school’s website.

The team felt it was important to have student presentations of their work for the Unit 1 implementation. Giving and observing presentations offered students three key opportunities for learning: a. development of technical skill with the software and projecting hardware; b. learning biological content connections made by peers; c. development of mapping strategies and innovations demonstrated by peers.

5.2.2. Results. Results from this effort were straightforward. Results include C3M team observations of students concept mapping in class; the actual students’ maps that were created, and student evaluations of their concept mapping experience. Two-student teams mapped each organelle and the C3M team linked each of the organelles of a class map. Elliott linked the red, blue, and green class maps to the Lexington High School website. To view the skeleton of the cell structure and function map, a cell organelle template, the cell membrane example map, and student maps, see Appendices C2 and C3; C3M Public Cmap: Experience 1 Cell Organelles, concept map icon.)

Were individual student maps improved through collaboration with a classmate? According to Elliott, “Student maps were improved through collaboration. I definitely think so. In more cases than not, two heads were able to clear up the misperceptions and misinformation that may have surfaced in one. I think that concept maps, while they might sometimes seem to take much time (because students and teachers are less used to working collaboratively in a process-oriented learning activity), I’m not convinced they actually did take more time than more conventional approaches (e.g., lecture, students
researching, combinations of these). While I have no data, I found that the time paid off and had we cut the time short, the payback would have been missed."

**C3M Team Observations of the Classroom Mapping Experience**

1. **Student empowerment.** Significantly, the students dove right into the mapping work with no hesitation. Elliott thinks we can credit some of that to advanced groundwork laid with familiarity with the concept mapping process and the assignment for students to create individual maps as homework, and the class time dedicated to creating a "shared map" and researching resources on the web. Therefore, students were prepared to use the double-block to focus on the use of CmapTools to create clear maps that they could then share with the class and that would be linked to a synthesized class map. All student teams successfully created Cmaps, attached resources, created folders on “My Concept Maps” containing both their maps and resources and transferred this folder to shared resources on the IHMC Public Server/ LHS GimbleHFry Folder.

2. **Linking.** It took about an hour to use the synchronous collaboration function of CmapTools between the Heinze-Fry computer and a student computer to link the student maps to the overarching class map. The collaboration function seemed to be required, even though the folder had open “Permissions” for “Everyone” to add to the folder. The Permissions were made as open and accessible to “Everyone” as possible. We find complex and varied results when students try to drag and drop their concept map icons from their folders in IHMC Cell Organelle Resources to the Class Concept Map. Sometimes, they make the linkage successfully. Sometimes they receive a pop-up window advising them to ask for a collaboration session. Sometimes they are asked to enter a password. Sometimes they have difficulty saving the change. It appears that the problem comes when everyone is trying to edit simultaneously. “We can’t keep up with the rate of changes.” We need to close down in order to “refresh” and get the new added folders. Elliott and Jane seem to have no problems when we go to add the student cmaps at the end of the double block.

3. **Directions.** Some directions were confusing.

4. **Map enhancements.** Some students do innovative mapping with the Styles Pallette (color, line curvature, etc); by adding animations and/or video clips instead of still shots only; by using the Help function and learning to create “annotations;” by adding copy/paste symbols from Word into the concept maps.

5. **Technical.** There were minor technical glitches. One computer was not loaded with CmapTools. That issue has been addressed. One team opened up CmapTools and successfully created a brilliant concept map but was unable to save their resource. We gave them a different computer, and they re-created their map.

6. **Management.** Absence of one of the partners creates problems. One option is to have students come in during the other double-blocks that will be held on Monday.
7. **Student presentations.** Students presented their work to the class. Elliott reports, “The goal and benefit to having students present was that they helped teach each other the organelles, one-by-one, while presenting their own concept maps and resources that went with them. Time was an issue but not as important as efficacy. The maps were too small to read and the presentations too quick so that even if students could see the maps, they wouldn’t have had time to digest them. I also found myself summarizing the key points after the presentation so everyone got those down. Note-taking in the chart provided was a good way to keep student focus. In short, I don’t think students were able to improve their own concept map style because of A) the above explanation and B) the maps were so standardized (and that was a good thing for this first time out). What was helpful was putting the organelle mini-maps into the larger class meta-map. Differences between the ‘only in plant’ vs. ‘only in animal’ organelles, for instance, were reinforced.

According to Elliott, perhaps a better approach might be to show the meta-map again and remind them of what was done (“we incorporated your maps into this larger one, note those organelles only found in plants....”) then set up a worksheet that students can use with laptops as they reviewed all the organelle maps at their desk, in pairs. Include incentive or requirement to have them evaluate or comment on the maps they visit along with their answers/notes for each organelle. This would allow them the chance to get both the content and some exposure to style. One problem here is that they have no tour guide and this could take considerable time. A combination approach could be students presenting while their observing classmates use laptops and answer worksheet questions. Teachers would, as usual, need to monitor student use of the computers to ensure they are looking at the concept maps and not surfing.”

Elliott queried how to assess the maps at this point. The goal is to help students learn. An assessment can improve learning both by offering specific feedback about the conceptual content and the mapping process. Additionally, an assessment indicates to students that the process “counts” and is worthy of their attention and effort.

5.2.3. **Conclusions.**

1. Students need to be encouraged toward hierarchy and away from creating “spider web-type maps.” Students need to be encouraged toward one-word concepts that represent a noun (usually an object, such as ‘chromosome’ or event such as ‘reproduction.’) Verbs, adjectives, and adverbs work well as “connecting words or phrases. Long phrases make the maps more like paragraphs instead of targeting specific concepts. Words in **BOLD** in the textbook are likely to be important concepts to map. Whole sentences and phrases don’t belong in concept boxes, although they can be “added information” that pops up when concepts are scrolled over with a mouse.
2. The effectiveness of collaborative linking may be improved through collaboration with Jim Gorman at Northbridge High school and IHMC technical staff.
3. Directions needed to be clarified and revised. (See Appendices B5.3 and B5.4; C³M Public Cmap: Experience 1 Cell Organelles, Text icon, “Cmap Directions” and “Debrief on Cell Structure.”)
4. There needs to be a backup plan to address student absence or to give students more time if they don’t finish in the time allotted.
5. We need more written formative feedback and map assessment strategies. It would be valuable to develop class rubrics as the educational community continues to develop. Lists of innovations should be kept during class presentations. Elliott suggested a “key mapping characteristic” column to the Table students will fill out during class presentations. Students who finish early should be encouraged to enhance their maps.

5.3. Creating Concept Maps: Unit 2: Cell Reproduction. For this final mapping experience of the C³M Project, the team’s objective was to try out the “parking lot” strategy and to challenge the students. Elliott knew that students often confuse the processes of ‘mitosis’ and ‘meiosis.’ While the individual steps of each process tend to be sequentially linear over time, confusion often arises in comparing and contrasting these two processes. Both types of cell division are important for the well-being of living organisms.

5.3.1. Methods. Elliott wanted to try the “parking lot” strategy described in the concept mapping literature. Students were given key concepts in the chapter, asked to map them and add their own concepts. To aid clear visualization, we decided to provide the classes with visuals from their textbook’s CD. (Elliott’s classes use Benjamin Cummings’ Biology Concepts & Connections, 4th ed., 2003, by N.A, Campbell, J.B. Reece, L.G. Mitchell, and M.R. Taylor. See student handouts in Appendices B6.1 and B6.2; C³M Public Cmap: Experience 2, Cell Reproduction, Text icon.)

Students worked individually on a broad concept map of cell reproduction or detail maps of the processes of mitosis and meiosis. Two-student teams collaborated on linking their detail maps to the overview cell reproduction map. Student maps were numbered and made accessible on the school’s website (C³M Public Cmap: Experience 2, Cell Reproduction, Text icon, “Gimble Website.”) Heinze-Fry created “expert maps,” which were shared with the class as a test review. (See Appendix C5.)

Facing time constraints from holidays and exams, we asked for very simple open-ended feedback from the students. We asked: What was most effective about your concept map? What needs improvement? What did you learn through this process? What would you do differently next time?

5.3.2. Results. As expected, student performance was much more varied in this implementation. While some students “flew with the assignment and really enjoyed it,” others were overwhelmed and had difficulty finishing in the time allotted. Some student maps can be observed in Appendix C4; C³M Public Cmap: Experience 2, Cell Reproduction, Text icon, “Gimble Website.”

Team observations were made of student conceptual development, technical implementation, and classroom management. General C³M Team Observations are summarized below. Detailed reflections are available in Appendices B6.3 and B6.4; C³M Public Cmap: Experience 2, Cell Reproduction, Text icon, “Reflection...”

Results of a student self-assessment about their concept mapping experiences are summarized after the team observations.
**Conceptual Observations**

1. Students were responsible for a much larger chunk of conceptual knowledge this time around. It took more than a double block to create and link the maps and resources. The leap from unit 1 to unit 2 was a big one.

2. Hierarchy was a bigger problem this time. Many of the students are doing vertical "flowcharts" of the mitosis and meiosis processes, and it’s clear they don’t have hierarchy straight in their minds. Hints that hierarchy is an issue are: repetition of concepts in the map and closed polygons where parts of the map reunite (not a crosslink).

3. While there was little to distinguish the prior tightly structured organelle maps, there was considerable variation among this second set of maps. One student struggled with simple descriptions of the phases of mitosis and was clearly unprepared for the concept mapping work. Other students, however, had creative and deep questions about the relationship of 'cell cycle' to 'cell reproduction'. (This led to a faculty discussion of maps reflecting a particular focus question, in which case a more general concept, such as 'cell cycle', could actually occur farther to the bottom of the concept map than a more 'specific concept', such as 'cell reproduction', because the more specific concept was more salient to the focus question. Another area of discussion was the relationship of 'somatic cells' (usually associated with asexual reproduction) and 'sex cells' (usually associated with sexual reproduction). BUT the nature of the queries led to the concept of the development of undifferentiated cells through meiosis to form egg and sperm. .. which is in the next unit.

4. A variety of misconceptions emerged from viewing the maps. One misconception screamed from the map: “Animal cells carry on sexual reproduction. Plant cells carry on asexual reproduction.” Relationships among some other concepts were commonly confused: prokaryotes, eukaryotes, plant cells, animal cells; telophase and cytokinesis; the hierarchical relationship of cell cycle to interphase (and its subsections) and mitotic phase (and its subsections); chromatin, chromosomes, sister chromatids, and homologous chromosomes. The introduction of sex chromosomes and autosomes at this point created a lot of confusion. Students generally didn’t know what those concepts had to do with haploid and diploid and with mitosis and meiosis. View a summary of misconceptions and numbers designating the map where the misconception was found in Appendix B7.1; C³M Public Cmap: Experience 2, Cell Reproduction, Text icon, “Feedback Cell Reproduction.”

Elliott suggests, “What may have fed the misconceptions about animal and plant reproduction being sexual or asexual (respectively) was the parking lot (or perhaps lack of critical thinking). Students wanted to fit the concept map together like a puzzle using the parking lot concepts as pieces. This went along with the idea that there is a right way to create a map and so there must be a fit somewhere for these concepts. When their knowledge or creativity was insufficient for them to think otherwise, they forced a fit to make the puzzle work. I think encouraging students to think of their blank concept map as a clear palette is important so they feel free to think out of the box and don’t fall into the “plug it in” trap of education. Reducing the number of concepts might
have helped but in this regard, I'm not sure that was the problem. Some simply couldn’t make good logical connections using these four concepts unless they saw that the four didn’t have to go together one to another in one-to-one fashion as some did.”

5. Feedback was given on the first 24 individual maps that were posted on the school website. (See Appendix B7.1; C^M Public Cmap: Experience 2, Cell Reproduction, Text icon, “Feedback Cell Reproduction.”

**Technical observations**

1. Technical: cannot access internet. Solution: Go to menu and change “transmitter” from the computer carts. There are different transmitters for the E and F carts.

2. Technical problems, such as inability to ‘save’ or “doesn’t start,” disappear upon rebooting and going through the appropriate student return protocol. One computer still has a sign up that appears automatically that requires a password, and we don’t want to go that route because want linkage among all the folders.

3. Random technical issue of boxes appearing rather than letters. Difficulty with choosing font. Three students had this problem. Solution is to click outside the map structure. (Select all?) Select the font. Some effort was through fiddling with Default command.

4. One computer wouldn’t start up. Dead battery? Solution: Make sure the computer is plugged in securely at the cart and get a different computer.

5. Students failed to upload work to the public server that needs to be worked on again. Solution: Reclaim the same computer that still has the prior work saved.

6. How to merge maps. Individual students create folders (own initials) and make links to digital resources on their own computers. One student transfers folder with concept maps and resource folder to the Public Server. The name of the folder is changed to include initials of both partners. The partner can then open the public server folders and drag their concept maps (without resource folder) to the shared folder and then make links to the partners’ maps. Alternatively, the partner’s map on the server can be opened and the new maps can simply be dragged and dropped onto the appropriate concept; thus adding submaps as a resource to the overall more general map.

7. Some resources disappeared from the resource folder. We need to strategize allowing access to and locking resources.

8. One student dragged a visual to a concept, and the whole background showed the visual rather than a linkage forming. “We haven’t seen that before. My main concern is not to lose all the work you’ve already done. Was this saved before you tried to attach the visual? No? Hm, this is the kind of technical problem that students often solve.” “Student: Why don’t you save it to a new map?” So we did. Delete prior version. Problem solved.
Classroom management challenges

1. When work was interrupted by a weekend, students were not quite ready to pick up where they had left off. They seemed to have “lost it” over the weekend.

2. Time limitations. Elliott only has two class periods before students must be tested. We agreed to give students one more class to finish up. (About 20% are already finished.) The more time we gave them, the more breakthroughs occurred. I watched as one student’s maps went from full of misconceptions to much improved and very near accurate. After the unit test, a student remarked that the concept mapping and the time we took on them helped him understand and consolidate the content.

3. Absenteeism is difficult for partners.

4. Maps are number coded and put on Elliott’s website for evaluation.

Results from Student Self-Evaluations about their concept mapping experience

In general, students reported successful mapping experiences. In an open-response student self-assessment about their participation in the C3M project, they offered insights into what they found effective and what they would do to improve their maps. They wrote about how participation in the program affected their learning, both in terms of biological conceptual knowledge (i.e., cell reproduction, mitosis, and meiosis linkages) and in terms of metacognition (i.e. forming connections, refining linking words, making crosslinks, clarifying organization, affect on learning and memory.) And they offered suggestions for improvement.

What students found most valuable in their concept maps was ‘clarity and organization’ (21/50). Also highly valued were good linking (17), broad, yet detailed, coverage of conceptual material (13), interconnections (10), and color coding (10). A few students mentioned good pictures (3) and accuracy (3). Priorities listed to improve maps ranged from simplification and clarification (16); better organization (14); better linking (14); more detailed information (13); addition of resources (9); addition of crosslinks (6); and a few targeted grammar (3), palette refinements (5), and correction of errors (2).

What did they learn out of the process? In learning about cell reproduction, students mentioned mostly broad connections among the cell reproduction systems and key concepts (18) while a few mentioned specific conceptual linkages (4). A number of students described what they learned about the concept mapping process: Several (7) mentioned organization, understanding of the overall picture, comparisons, and clarity. Several (6) also mentioned making connections among concepts and the same number also mentioned visualization and the use of pictures. Also mentioned were better and deeper understanding, improved memory, and that it is a long process. Eventually it felt that way but it was necessary.
Attitudes toward mapping itself showed some range. Four positive comments ranged from “I learned how to make an awesome map” to “they are very helpful and I like to make them, too. There was one mixed comment “They helped learn a little, but not a lot. Concept mapping is difficult.” Six students made more negative claims: “I don’t find concept maps very useful; to “Don’t learn well from concept maps; I’m not good at mapping; to “I don’t like doing concept maps; they take too much time.”

Students offered areas in which they had difficulties and recommendations for future efforts. Greatest difficulties reported were too many key words (9) and the need for more time (8). Six mentioned difficulty in learning how to organize and place concepts in maps. Four mentioned difficulty with linking words. Two recommended not assigning mapping just once. Two mentioned that the textbook wasn’t always helpful and one reported issues with neatness.

Some students reported technical difficulties: saving issues at the beginning of the program and saving to the server offered the biggest challenge (5); some were confused copying resources and saving in one folder with the concept maps (3). Two reported general technical issues; two software; one hardware issue. Social problems about working with partners, absentee issues, and synthesizing partner maps were issues.

Student comments are summarized in the charts below and found verbatim in Appendix B7.2; C3M Public Cmap: Evaluation, “Student Verbatim..."

**Student self-evaluation of their participation in concept mapping pilot study (n=50)**

1. List at least two things about your map that you like or that you feel make it a useful and effective concept map.

| Clarity (not too many crosslinks); neat; simple; precise; not confusing; concise; nice to look at | 21 |
| Organization; orderly; Understandable; easy to follow; readable; helpful; easy to read | 21 |
| Good linking words (detail); tied together; links work well (2) | 17 |
| Lots of information (helps on tests); wide range of material; good use of key words and connections to many of the topics; detailed | 13 |
| Ideas interconnect; like how small details connected to summarize the whole; crosslinks that connect the different maps; crosslinks within map; way maps link | 10 |
| Color coding; bold font easier to read | 10 |
| Good pictures | 3 |
| Accurate; correct | 3 |
| General concepts were prokaryotes and eukaryotes. | 1 |
2. List at least two changes you would make to improve your map or maps.

<table>
<thead>
<tr>
<th>Change</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simplify; shorten words; more readable; less confusing; needs clarity; messy</td>
<td>16</td>
</tr>
<tr>
<td>Better organization: too linear; conceptualize better; bubbles don’t always progress downwards; adjust spacing (reduce stretched out or increase spacing); avoid repetition of concepts</td>
<td>14</td>
</tr>
<tr>
<td>Need to specify linking words; more links; better linking words; link maps; connect prokaryotes and binary fission</td>
<td>14</td>
</tr>
<tr>
<td>More information; finish input mitosis and meiosis; connect to Meiosis II as a resource; add detail; tetrads line up in Meta 1; include Mitosis; explain abbreviations</td>
<td>13</td>
</tr>
<tr>
<td>Add resource links; make links work</td>
<td>9</td>
</tr>
<tr>
<td>Add crosslinks</td>
<td>6</td>
</tr>
<tr>
<td>Grammar: Capitalization inconsistency; spell-check</td>
<td>3</td>
</tr>
<tr>
<td>Palette refinements: color code; add arrows to lines; different line styles to link</td>
<td>5</td>
</tr>
<tr>
<td>Fix error; some concepts in wrong area</td>
<td>2</td>
</tr>
</tbody>
</table>

3. What did you learn out of this process, either about cell reproduction, concept mapping or how you learn?

**A. Learning about Cell Reproduction**

<table>
<thead>
<tr>
<th>Learning</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>General learning:</td>
<td>18</td>
</tr>
<tr>
<td>Difference between mitosis and meiosis; how terms interact with m/m;</td>
<td></td>
</tr>
<tr>
<td>How cells divide; cell reproduction as a whole; reinforce learning; mitosis body cells, meiosis sex cells; m/m and processes come together for cell growth and tissue repair; learned vocabulary; can identify key words; cell reproduction is complicated.</td>
<td></td>
</tr>
<tr>
<td>Specific conceptual learning:</td>
<td>4</td>
</tr>
<tr>
<td>Cell cycle is a huge part of cell reproduction. Binary fission is how asexual organisms reproduce. Understanding crossing over and its significance</td>
<td></td>
</tr>
</tbody>
</table>

**B. The Concept Mapping Process**

<table>
<thead>
<tr>
<th>Process</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organization: Understand overall picture; made the idea clear, straightforward, organized; maps help organize concepts in easy, manageable fashion; help understanding. Concept maps help me understand comparisons; helps you learn how things relate to each other; better connecting of concepts</td>
<td>7</td>
</tr>
<tr>
<td>Connections: Numerous processes are connected; everything is connected in some way to something else. Understand connections; made connections I didn’t make before</td>
<td>6</td>
</tr>
<tr>
<td>Visualization: I learn visually; pictures helpful</td>
<td>6</td>
</tr>
<tr>
<td>Better understanding: Deeper understanding in order to map; better understanding of concepts</td>
<td>2</td>
</tr>
<tr>
<td>Memory: I learned that connecting familiar concepts together helps me remember.</td>
<td>1</td>
</tr>
<tr>
<td>Observation about mapping work: Concept mapping is a long process if there are many words to link.</td>
<td>1</td>
</tr>
</tbody>
</table>

**C. Attitudes toward Concept Mapping**

<table>
<thead>
<tr>
<th>Attitude</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive: I learned how to make an awesome concept map. Learned how to more effectively use the concept map tool. They are very helpful and I like to make them, too,</td>
<td>4</td>
</tr>
<tr>
<td>Moderate: Helped learn a little, but not a lot. Concept mapping is difficult.</td>
<td>3</td>
</tr>
<tr>
<td>Negative: I don’t find concept maps very useful. Don’t learn well from concept maps. I’m not good at mapping. Don’t like doing concept maps (too much time)</td>
<td>6</td>
</tr>
</tbody>
</table>
4. What about this assignment was difficult for you and how could we improve it for future classes?

<table>
<thead>
<tr>
<th></th>
<th>Difficulties</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Difficulties</td>
<td></td>
</tr>
</tbody>
</table>
| Concept mapping process | Difficult using ALL vocabulary words; finding key words; fewer key words | 9  
|                             | Need more time                                                              | 8  
|                             | Learning how to set up the map/ placement/ organization/ putting together   | 6  
|                             | Hard to link; how to use linking words                                      | 4  
|                             | I wasn’t exactly in the know about cell reproduction. Learning steps of    | 4  
|                             | cell reproduction. Need to learn before making the map... do after the test? |  
|                             | Don’t assign mapping just once. “It’s difficult to make something you don’t | 2  
|                             | often use, so it was kind of confusing.                                    |  
|                             | Textbook doesn’t always explain things the way you need it to.              | 2  
| Neatness                    |                                                                            |  
| Technical process           | Saving to server; saving at the beginning                                   | 5  
|                             | Confusing to copy resources and create one folder with maps                 | 3  
|                             | General technical issues                                                   | 2  
|                             | Computer/software cut off bottom of map. CmapTools can mess up sometimes.    | 2  
|                             | Computers didn’t work well                                                  | 1  
|                             | Using software was difficult                                                | 1  
| Social process              | Partner (absentee or other) problems; synthesizing partner’s maps          | 4  
|                             | Worked alone, but would have liked partner sometimes                        | 1  
|                             | Pick partner next time?                                                    | 1  
| B. Recommendations          | Conceptual parking lot: Make vocabulary easier to tie together; need more   | 3  
|                             | concepts in Part B. Word bank restricted mapping too much.                  |  
|                             | More visual resources                                                       | 1  
|                             | Teacher critique of initial maps would be helpful                           | 1  

5.3.3. Summative Conclusions from the Biology Class Implementation.
“Gradualism” best describes the team’s approach to implementing concept mapping as a learning strategy with the biology students. Students were shifted from observing an annual overview map to observing a chapter overview map linked to submaps to creating and collaborating on submaps to taking individual responsibility for maps and collaborating on their linkage. Our emphasis was more on implementation than evaluation, which could have been more rigorous.

Progress from the tight, controlled experience of Unit 1 to the broader, more challenging experience of Unit 2 was based upon observing the students as they learned, making note of difficulties, creativity, and breakthroughs. While no formal formative evaluations were completed, anecdotal observations were recorded. These observations, as well as research, formed the basis for the Unit 2 student use of concept mapping.

The overall approach of increasing familiarity worked well.

The results of the implementation phase of the C³M Project address the team’s questions about mapping and meaningful learning, collaboration, and attitudes. Meaningful learning of biological concepts was clearly demonstrated through connections and hierarchy on the posted concept maps. Students were able to create maps individually at home and collaboratively using CmapTools in the classroom. Collaborative
maps are clearly demonstrated at the LHS website and posted on the C³M Concept Map. Students were challenged in the second implementation experience. Clearly, some students were much more successful than others in conceptual linking of a large parking lot of concepts into a base map and detail maps and in linking of resources to those maps and loading them onto the server. These efforts required individual learning, collaborative learning, creativity, and technical skill.

Individual maps varied with the understanding and ability of each student. Team maps were both fruits of cooperative, synergistic dialogue or the final product of a dysfunctional pairing of students who may or may not have been equally suited to the task or who had personality clashes. Poor preparation for some of these groups was a key factor in their ability to succeed; when one or both did not complete the at-home assignment or if an absence put them at different steps of the process, their chances of success diminished.

There is considerable variation in level of conceptual performance within the class. Some of the students seem to be struggling to make the connections at all while others are ready to defend why they set up the hierarchy the way they did, even if it differs from the instructor’s recommendation. Establishing clear clusters and hierarchy appeared more difficult in the overview maps than in the Mitosis and Meiosis detail maps. The maps are very useful in identifying misconceptions and easily confused concepts.

Concepts that are joined by time sequential or “flowcharting” graphic representations present a conceptual challenge. Such was the case for Mitosis and Meiosis concept maps. When written vertically, the implication is that one phase flows into the next on a time sequence. When written as a concept map, the hierarchy generally indicates that the higher concept is more general (the whole) and the concepts below it are more specific (the parts).

While the C³M team succeeded in challenging the students, it is possible the team jumped a bit too far on the second student active mapping unit. Some students were overwhelmed by the amount of mapping vocabulary. A number of students said they needed more time, and a smaller “parking lot” might have been one solution. Student performance on the second set of concept maps as indicated by the C³M feedback, the incomplete and late-finished maps, and student feedback support that claim. But many students noted that they liked the breadth and depth of the assignment. While there may be issues with lack of time commitment by students at home, it is likely these students may have issues with making connections among concepts mentally, and they simply don’t do it.

Use of technology has its challenges. Some technical problems were higher frequency and have fairly simple solutions (See Technical Observations 1-5). Some technical challenges, such as linking maps to resources and linking maps to other maps, can be addressed through multiple pathways (See Technical Observations 6-7). What is most important is for students to find a pathway that works for them. However, it’s likely that a particular pathway is more efficient. Some technical problems are simply idiosyncratic (See Technical Observation 8).
Classroom management policies need to address different levels of learners, time management issues, social management issues, privacy and accrediting issues. How much time to give students to map in class is a challenge. Since CmapTools was ONLY available to them at school, they could be assigned to map at home, and just do the tech work at school. Students DID ask for more time. Students who don’t do their homework WILL need more time. According to one student, mapping needs to be done more than once. The team’s conclusion is that if you’re going to invest time in learning to concept map and use CmapTools, the real benefits come from more use. IF they’ve gone to all that work, it actually gets easier and more fun with time, as well as faster. (One student asked if he could finish at home, even after his diligent work in class, since he had downloaded the CmapTools software on his own there.)

Collaboration. After the first unit, students presented their work to the class. This approach offered a chance for feedback on maps and strengthened student-student collaboration. In the second unit, students received feedback from the C3M team as they constructed maps on CmapTools. The design of the feedback strategy can address the teacher’s time management and promote student-student and student-teacher collaboration. Such a process might model peer editing in the language arts classrooms.

Other than informing parents about their children participating in the project, we made no effort to involve parents in this pilot project. We received no feedback from parents, positive or negative about their students. Nor did we solicit parent feedback at this point. The C3M team can imagine that a natural extension of this project would be to make mapping a continuous part of the learning process, both in and out of the classroom, at school and at home. Whether that takes the form of overall class assignments or optional/alternative assignments for some remains a topic for discussion. However, as technology develops, one of the strengths of CmapTools is that the maps can be shared across the web. There is a need to expand the computers loaded with CmapTools on which students can work, such that their mapping time is not limited to class time.

Special needs and classroom collaboration relies on definition of “essential concepts.” According to Barbara Newkirk’s experience, you can’t just leap into concept mapping with special needs students. Barbara’s approach and contribution is that many of the special needs students, for whatever reason, are not even looking for connections. They are busy trying to memorize flash cards. These students are overwhelmed. Students need to learn to simply make connections between concepts. Other aspects of concept mapping such as clustering and hierarchy can come later. Teachers need to identify the ‘essential’ concepts. The quantity of concepts needs to be reduced.

Attitude and Performance. In open-ended questions, students range from loving and thriving on mapping to feeling that it doesn’t help their learning or they can’t do it. We could use more insight into the basis for these responses. Some attitudes may reflect problems decoding the text and dealing with vocabulary. Some may not even realize that connections exist among those vocabulary words. Research and practice with learning styles might also offer those insights, but were beyond the scope of this project. Elliott observed, “My sense was that students with a poor attitude (though most were open) or, more importantly perhaps, those with poor preparedness may have
felt like they slogged through it and subsequently felt bad about the experience (both because they didn’t get it, not having prepared, and because they grew frustrated, bored, or both.) For those who were prepared and who embraced the activity, there was plenty to do and perhaps just enough time to initially explore the software capability.”

5.4. Making Connections: the Resource Room. In Barbara Newkirk’s experience working at the 9th grade level, teachers frequently make the faulty assumption that students are able to understand and make connections between concepts. While many students can make more or less accurate connections, many others, particularly those with learning disabilities, have not developed the active learning skills that allow them to build understanding and meaning from new information. They tend to be passive in their learning and do not intuitively connect new learning to old or consider what prior knowledge may help them in understanding new information. Teachers will often begin a lesson by having students consider what they already know about a topic, a very helpful strategy in leading students into new learning. It is necessary, however, to consistently help the students make connections between concepts all through a unit of study.

5.4.1. Methods. Concept mapping is a very effective means of both fostering and assessing student understandings and can be initiated very simply as a step beyond using flashcards as a study tool. Barbara reported, “Although I do not have access to CmapTools in my resource room, I have worked with my students to move beyond rote memorization toward better understanding of concepts by building on their ‘flashcard strategy’ (otherwise known as the "If I memorize everything on these flashcards, I'll be able to pass the test" technique). We started by taking the flashcards several of them had made when studying for an Earth Science test and spreading them out on a table. I asked each student in turn to select 2 or 3 terms they saw were connected in some way, pick up the cards and explain the links they made. As they explained the connections they saw and began to feel comfortable with this "new" way of thinking, the students began to "piggyback" on the connections others were making and added more concepts and verbal links to the collection of cards. Knowing the difficulty my students have expressing their thoughts in writing, we stuck with oral explanations for a while. In the next stage, I put the terms and concepts they needed to understand on sticky notes and placed them on the whiteboard. I had the students work as a group to "clump" the concepts they felt were connected together. We then took each "clump" and thought about the ways the terms were connected. Students placed the sticky notes according to the connections they saw and added lines to link them with a few words to establish the connection.”

5.4.2. Results. In follow-up discussions after these activities, some of the students expressed that it was easier to see how the details fit in to make a bigger picture when they studied in this way. Though many of them still fall back on rote memorization, they are beginning to think more effectively about the concepts they are learning. They are also becoming more adept at making and expressing connections between concepts.

5.4.3. Conclusions. Teachers need to keep in mind that not all students know how to think effectively. Many need to learn the process step-by-step. Until they have some confidence in themselves, it is difficult for them to move out of their comfort
zone. The initial steps need to be quite concrete and build on what is familiar and comfortable to them. They need a lot of practice building connections before they move on to more complex mapping.

The C³M Pilot Project offered a simple taste of the value of meaningful learning. With each iteration, students gain experience and see what others are doing, and it’s that practice and continual development that enhances their meaningful learning. They learn not only biological concepts; they learn how to learn. While the goals of the project were, for the most part met, there are barriers which need to be overcome if the project is to be expanded.

6. Recommendations. From its inception, the C³M Project has been an educational community project. The results and conclusions of the C³M project point toward answers to their last question. Where to from here? How can the C³M pilot project leverage continuing development of the concept mapping meaningful learning strategy in the educational system?

For the Institute of Human and Machine Cognition. IHMC’s use of an older version of Java for CmapTools 4.03 limited downloading CmapTools onto the majority of the Lexington High School system. As new versions of CmapTools are created with compatible software, perhaps it can be downloaded onto the system without disrupting other programs that the system supports. Communication between technical staff of LHS and IHMC is strongly advised and vital to further progress.

For the educational community. Offer workshops in concept mapping and use of CmapTools to enhance professional development. Such workshops can be offered through institutions of higher education, Content Institutes by the Department of Education, educational collaboratives, and individual school systems. Concept mapping can be used successfully at all ages. The need of a teacher-friendly illustrated introduction to concept mapping (not just CmapTools) is recommended: preferably breaking down to beginner, intermediate, advanced. This may help beginners develop sound understanding of theory, practice, and assessment. Good reference points which start along this track are found at: http://www.ctools.msu.edu/ctools/tutorial.html; http://www.msu.edu/~luckie/ctools/.

Professional science teacher organizations, educational researchers, and textbook publishers should support classroom teachers through development and dissemination of concept maps that integrate basic disciplinary content.

For the school system. Continued technical support for the software is needed. Increase the number of computers loaded with CmapTools so students can work on homework outside the classroom time. Encourage downloading of software at home. Experiment with collaboration among and within departments. Special needs teachers need to be teamed with classroom teachers.

For the science department. Quantify parameters of prime interest depending on faculty questions about learning. Inquiry experiences need to be added to the maps. In order to make decisions about best implementation of concept mapping, it would be
helpful to move toward more quantitative assessment. Feedback and student self-assessments in this project were all anecdotal in nature. Assessment was challenging, confounded by the collaborative nature of the assignments, varying levels of student preparedness and the lack of ‘make-up’ time for those who were behind. The development of rubrics might prove more useful in the future. A sample rubric is found in Appendix B2.5; C³M Public Cmap: Follow-Through, “Rubric...” Assignments that can somehow accommodate absences (e.g., stretch it out over a few days to allow after school make-up time or something along these lines) might also alleviate some issues.

For the classroom teacher. Practice mapping. Use it to integrate components of your educational duties: goals, objectives, content, inquiry process, and assessments. Learning to map is like working a clay pot. Teachers should develop feedback strategies to promote continual development of the mind through refined use of mapping techniques, raising the quality of thinking and maps incrementally; increasing the complexity of the parking lot; eventually turning over identification of key concepts to the students rather than supporting them with a list. Experiment with teams both to offer high challenge and remedial assistance to target groups, but also mixing it up for peer review. Mix assigning groups and student-chosen groups. Have student help develop rubrics as skills develop with mapping in the learning community. With concept mapping strategies, teachers take on a more facilitative and less authoritarian role. The long-term vision is making lifelong learners enabled to think on their own.

The C³M team recommends a “gradualism” approach in introducing students to concept mapping: observing first, then actively mapping. Teachers may want to experiment with different concept mapping methods. There are many. We found the “skeleton map” approach and the “parking lot” approach to be effective. Size of the parking lot and questions that the map is to address are important. The aim should be for students to learn incrementally beginning with reading the text and other sources of information, integrating their learning from laboratory/field experience, and deciding the significance of these experiences in their decisions and construction of their lives. Collaborative components are important to implementation: teacher-teacher; student-teacher, and student-student.

Teachers should start mapping at the beginning of the year. For teachers, the single most important thing is to ascertain what the students already know. Give them the key unit names and have them create a map. Then you know their beginning mapping ability and you know their beginning conceptual ability. Have them map at the beginning of each chapter. This will prevent you from shooting over their heads and from repeating what they’ve already done. This moves toward individualized instruction. As Elliott says, “I need 20 of me in the classroom.” On the other hand, it may promote grouping to address particular needs of groups. The important thing is to move each group forward so everyone is learning. Linking the mapping to literacy and peer review makes sense.

Choosing mapping directions that focus students on key parameters is important. The method needs to match the goal. Our goal was to get all students to map. And they did that. We wanted to challenge the class more. And we did. (Consequently, there was more spread in performance.) What is structure? What is function? What is the personal/social significance of the concepts? (Why does it matter?) Attach visual
digital resources. A ‘next step’ would be to attach inquiry work. Science learning is BOTH content and process. Sadly, students often end up separating their laboratory experience from their textbook learning. Concept maps offer an opportunity to bridge that gap. It’s the connections and organization of knowledge that foster integrated learning and long term memory, as well as the emotional meaning for that particular student.

In offering feedback on student maps, it’s helpful to discuss various types of feedback as well as mechanisms. Types of feedback include quantity of conceptual material, accuracy of linkages, hierarchical arrangement and clarity of arrangement, presence of crosslinking connections, use of digital resource support. It is worthwhile for teachers to be aware of the prominent misconceptions in any area in which they teach. Those for mitosis and meiosis that were identified can be used from this study. Another excellent source is *Making Sense of Secondary Science: Research into Children’s Ideas* by Driver, et al. (RoutledgeFalmer, 1994). Feedback mechanisms include: parent review, partner review, peer student review, and teacher review. It is worth thinking about how to handle the integration of hierarchical relationships and more sequential or “flowchart” type experiences. In general, the C3M team recommends rather than rigidly sticking to the “parts related to the whole” hierarchy of concept maps that it is more pragmatic, especially at this level, to accept a vertical or a horizontal representation of time-sequentially related information. (Another place this would show up is in biogeochemical cycles and in any process with phases.) Another possibility is to simply link flow chart graphic representations to the concept they represent on a concept map.

Address different levels of mapping performance. Set an acceptable educational goal and schedule enough time to meet that goal. Target most students meeting basic criteria of map construction; advanced students pressing the edges of the Style Palette and technical options; special needs assistance for those having difficulty drawing connections and targeting essential concepts only.

Manage time wisely. Provide time for most students to finish the mapping exercise. Homework can be assigned if *CmapTools* is available in other places. Don’t extend a mapping activity over the weekend. Coming back up to speed takes too long. Plan for absenteeism and opportunities for mapping outside the classroom.

Carefully consider mapping teams: teacher appointed or self-selected. Teacher appointed may be to cluster kids or mix them up. Self-selected may result in cliques, but also in commitment to working together for the same reasons.

Consider privacy and accreditation. Share student work with the whole community. Some consideration needs to be used here. Elliott numbered the maps to protect the names of the creators. It is appropriate for faculty to use maps to demonstrate strengths, weaknesses, and misconceptions in different maps. It is respectful to obtain student permission before showing their work. If demonstrating a positive quality, it is respectful to give the student credit (with their permission.) If demonstrating a negative quality, it is perhaps wiser to use a number or example from a different class. Consider an award structure to recognize superior learning performance.
Listen to the students. Don’t assign mapping just once. “It’s difficult to make something you don’t often use.” The C3M team recommends assigning students chapter maps throughout the year and integrating them together as a Culminating Event at the end of the course. Edit the parking lot: make the vocabulary easier to tie together. More visual resources and teacher critique of initial maps were also suggested.

Technical recommendations. Create a handout or FAQ with typical problems and solutions as a trouble-shooter guide for other members of the learning community (teachers and students). Identify best practices about linking, organization of files, permissions with access to folders and resources, and incorporate those into the directions for students. Tolerate alternative routes, as longs as the goals of the work are met. Tolerate the odd idiosyncratic glitch. Utilize tech support and challenge students who are computer savvy to solve the problem. Reward generously with appreciation.

Enhance collaboration with special needs faculty. The best thing a classroom teacher can do for a special needs teacher is to identify the key concepts that students MUST know. Identify students with learning difficulties at the beginning of the school year. IF the kids claim they don’t like mapping or can’t do it, a good solution would be to pull these kids together for after school training early in the year. A good partnership would be between classroom teachers who identify students with learning difficulties and special needs teachers who assist these students with learning strategies.

For the special needs teacher. Target the essential concepts in each discipline. Encourage connective thinking. Start with a very small group of concepts and add slowly. Build on skills students are already using. Move toward hierarchy. Save the technology til students can learn vocabulary, make connections, and create hierarchy. Assist the classroom teachers with identified students having difficulty with mapping.

For students. Download the software at home. Make maps throughout a course. Link it all together. Produce a map that shows how your ideas develop over time: an interdisciplinary portfolio that showcases your developmental progress in academics and extracurricular activities. Anything in digital format can be linked. Use it to showcase your strengths! Link the content and the process of the course. Learn from peers. Offer constructive criticism. Examine expert maps. What makes them expert? Help develop rubrics that bring continual development of learning and mapping skills.

Students should be “in” on creating rubrics to evaluate concept maps. This should be a sharing of maps, so students can see how to progress. They should see other students’ maps so they learn new cool things to do and short cuts. And they should learn to overcome typical problems like “spaghetti maps” and difficulty with linking words. Soon they’ll be discussing moving sections of maps around to reduce visual confusion; the finesse of color-coding; the details of line that clarify meaning; and the best visuals in the text to promote understanding. Thus, rubrics should develop as the class develops. We know that evaluations can be designed for different success rates. The educational community and teacher should work together to decide “levels of excellence” and how best to get there.
7. **Sharing with the Larger Educational Community.** Our work has been well-received by the broader educational community. Communication about the C3M Project has been ongoing within a larger educational community context. Progress of the Project has been reported to two educational collaboratives: tec and EDCO. Our project has benefited by communication with the Northbridge High School, particularly physics/chemistry teacher Jim Gorman. The posting of student work has been shared with the Massachusetts Department of Education and a number of colleagues in the concept mapping community. Both Elliott Gimble and Barbara Newkirk will join Joseph Novak, father of concept mapping, and Alberto Cañas (IHMC), and two other high school science teachers in presenting a Short Course (*Concept Maps: Windows to Seeing What Learners Know*) at NSTA Conference 2008 in Boston, MA. Elliott and Barbara are scheduled to present their work to their departments. The C3M Project was also featured in the LEF Newsletter sent out to the community.

Finally, just imagine a world in which: the ultimate goal is to develop the minds of students who create a series of K-12 concept maps that demonstrate their learning and growth through the years. Maps can be interdisciplinary and link any digital resource meaningful to the student: laboratory work, concerts, pictures of artistic creations, creative writing, analytical writing, research papers. By the time they graduate students will be able to demonstrate the breadth and depth of their learning as members of an educational community. Further, they will be empowered as lifelong learners.