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C-TOOLS

Concept-Connector Tools for Online Learning in Science

Douglas B. Luckie, Janet McCray Batzli, Scott Harrison and Diane Ebert-May

Abstract

This manuscript describes the activities of an interdisciplinary team of faculty from Michigan State University in a three-year National Science Foundation (NSF)-funded project to develop and validate a new assessment tool, the Concept Connector, consisting of a web-based, concept mapping Java applet with automatic scoring and feedback functionality.

The value of knowledge scaffolding tools such as concept maps, flow charts and venn diagrams is that they reveal student understanding about the direct relationships and organization among many concepts, elements not easily assessed by multiple choice questions or even extended responses. The Concept Connector tool is being designed to enable students in large introductory science classes to visualize their thinking online and receive immediate formative feedback. The Concept Connector's flexible scoring system, based on tested scoring schemes as well as instructor input, has enabled automatic and immediate online scoring of concept map homework. The Concept Connector has been successful in 'making transparent' when students do not understand concepts and has motivated students to address these deficiencies.

The validity of the Concept Connector is being determined by a 'design' experiment (Suter and Frechtling 2000) that involves testing the tool with undergraduate science-majors in introductory biology, geology, physics and chemistry courses. A cohort of over 1000 students, those enrolled in participating courses, are being recruited to test the effectiveness of the tool to assess (mis)understanding.

Introduction

The Model

In teaching, how many of us have walked away from a wonderfully engaging class feeling confident our students understood the material we presented, to later be disappointed with the exam scores? In our biology classes we have observed brilliant students that could teach their peers the intricacies of DNA replication but were stumped by the "easy" questions on the exam that required 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

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new concept and the last. Those of us that teach science should reflect on our best practices as scientists. 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). Hence we have come to believe that students and scientists alike should use visual models to describe, evaluate and learn science. In our own quest to find modelling 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, to name just a few, were all developed by experts to resolve this dilemma. But what does the research literature say about the effectiveness of each tool? And can we get a good online version that all students can access and use?

In our research we found that many tools showed great potential, but the concept mapping approach developed by Novak et al (1984, 1998) was the best studied and validated visual tool for student learning. It forces students to confront and grapple with the alternative or mis- conceptions they bring to their learning. Nearly thirty 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. After much discussion with colleagues who teach large introductory science courses and the realization that "(they) won't really use it, unless it grades itself," we decided to create software that delivers online concept mapping capability with automated grading feedback.

As a result, an interdisciplinary team of faculty from the College of Natural Science and the Lyman Briggs School at Michigan State University (Figure 1) are developing, validating, and disseminating a new assessment tool called the "Concept Connector" (now available in beta version at http://ctools.msu.edu/). The Concept Connector is a web-based concept mapping Java applet that is being developed and paired with automatic scoring and feedback functionality. This tool will enable students in introductory science courses (and any other courses that find concept maps useful) to visualize their thinking online as well as to receive immediate formative feedback. The assessment tool and the methods of its application in the classroom are being designed to motivate students to reflect, revise and share their thinking with peers as an extension of the learning process. The value of knowledge scaffolding tools such as concept maps, flow charts and venn diagrams is that they reveal student understanding about the direct relationships and organization among many concepts, elements not easily assessed by multiple choice questions or even extended responses.

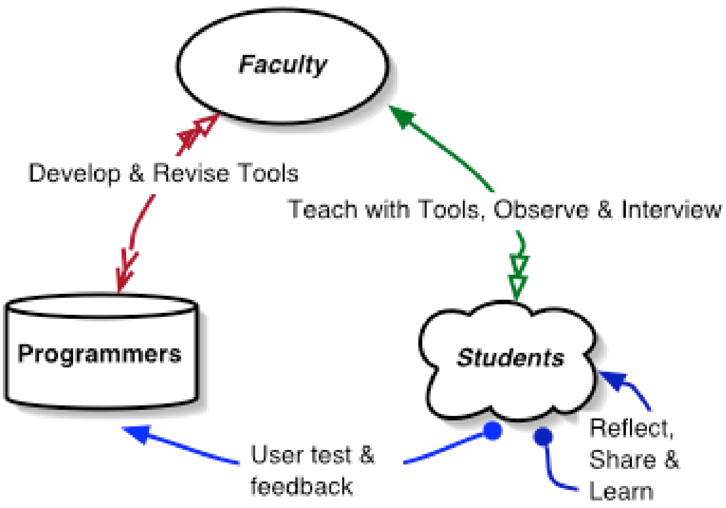


Figure 1
A flow diagram of the C-TOOLS project activities. *Faculty* will work with *Programmers* to develop the software, as well as the problem sets with concept maps for their courses. *Faculty* will teach using the Concept Connector in online homework assignments and arrange to observe and interview some students working on the homework. *Students* will work individually and in groups reflecting on the concepts they learned in class and also talk to the *Faculty* and *Programmers* about problem sets, software and science.

Background on Concept Maps

Knowledge diagramming tools like concept mapping can enable students to organize and retrieve ideas, to construct new knowledge and link it to existing knowledge. The ability to connect seemingly disparate terms and ideas is one of the skills that distinguishes expert from novice problem solvers. A meta-analysis of 19 studies revealed that concept mapping had positive effects on both student achievement and students' attitudes toward science (Horton *et al.* 1993). Students construct new knowledge from their personal experiences and communication with others by adding new concepts to memory, making new connections between concepts and subdividing existing concepts (Edelson 2001). These tools enable students to build on scientific ideas as they develop more interconnected understanding of scientific principles and abstract concepts (Linn and Hsi 2000).

Concept maps and semantic networking have been the focus of many researchers' studies, particularly at the K-12 level (Novak and Gowin 1984, Mason 1992, Novak 1998, Mintzes *et al.* 1999, 2000, Fisher 2000). Among the most comprehensive reviews of concept maps as assessment tools was Ruiz-Primo and Shavelson (1996). They compared 21 different methods of assessing concept maps for level of validity and found Novak and Gowin (1984) among the best techniques. We will use a similar algorithm as the starting point of our automated scoring functionality while allowing instructors to add new algorithms through the validation process. Concept map scores will be based on hierarchy as well as a graduated scale of valid to invalid nodes and links between nodes.

Although the idea of concept mapping has been recognized for nearly three decades and computer-based tools for implementation are available to university faculty, few are web-based and none of the online tools have embedded assessment components for automated scoring (‘Visio’ by Microsoft, ‘Concept Mapping with Multimedia’ by IBM, Anderson-Inman and Zeitz 1993, ‘Inspiration’ Inc. 1995, ‘PIViT’ 1996, ‘MindJet/MindMapping’ by Buzan, ‘Concept Map Toolkit’ by IHMC, ‘Decision Explorer’, ‘VisiMap’, ‘Cmap 2.0’, ‘ECCE!/LifeMap’, Anderson-Inman *et al.* 1998, ‘SemNet’ Fisher *et al.* 1990). “SemNet” by Kathleen Fisher’s group is the most impressive tool we have found (Fisher 2000). It is an excellent example of the power of tracking and scoring student work using visual models (spider-style concept maps). Unlike SemNet, our Concept Connector tool will be web-based, use hierarchical concept maps, and send automated scoring feedback to both students and instructors. We believe this approach will improve student learning and make the tool very useful for faculty. Automated feedback to students will allow instructors to use the tool on a large scale, and web-based concept mapping can enable students to save, revisit, reflect upon, share and explore complex problems in a seamless, fluid manner from any internet terminal (Pea *et al.* 1999).

Theoretical Framework of Concept Mapping

Our project is influenced by Bruner (1960, 1966), Ausubel (1963; 1968) and others who have studied the role of representation (Fosnot 1996) and visualization in learning (Pea *et al.* 1999). While we recognize that students are continually constructing meaning of information, we also know that we, as teachers, can aid this process through our pedagogical strategies and instructional designs. Research on learning theory indicates that the use of generative learning strategies, such as making concept maps or semantic networks, facilitates meaningful learning by helping students build new mental relationships and/or reconstruct prior conceptions to further learning (Wittrock 1992, Fisher 2000, Ritchie and Volkl 2000). Since concept maps are not domain-specific, using them across different disciplines can provide a knowledge structure to students as they explore complex problems in other courses (Pea *et al.* 1999).

Concept maps have been referred to as the “cartography of cognition” (Wandersee 1990) because a learner maps words in a network where each word refers to other words in a spatially defined relationship. For instance, the concept ‘sun’ conjures up the sensory and perceptual terms: heat, yellow, bright, light, round, ball of fire (Figure 2).

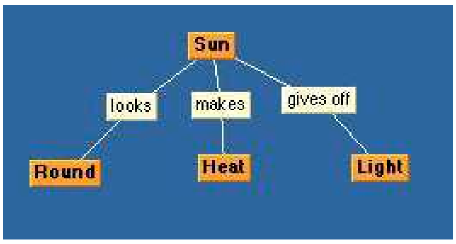


Figure 2
A hierarchical concept map of ‘sun’ constructed using the ‘Concept Connector’ Java applet containing initial sensory terms of student.

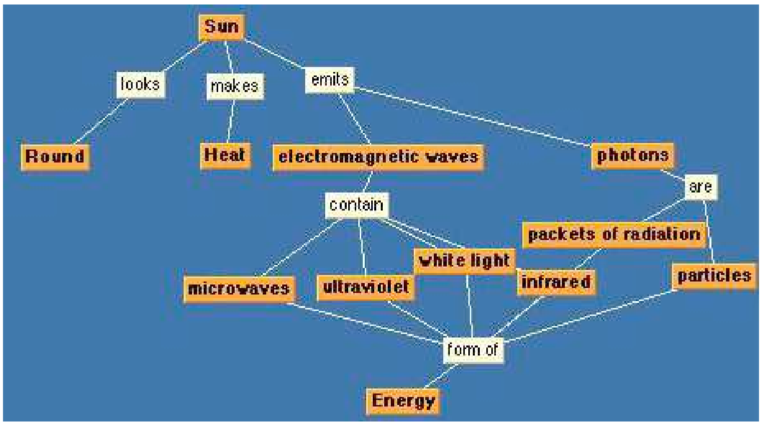


Figure 3
A student's concept map constructed after more learning about 'light.'

With more experience the learner may integrate additional terms like: photons, radiation, and energy. Each of these terms is connected slightly differently to the concept of 'sun'. These different relations and organization can be modelled in a concept map so that they are explicit, easily recognizable and comparable (Figure 3). The relationship between concepts given on a map is defined with the use of 'linking words' that reflect the meaning and context of the concepts being used. Although explanations of connections are possible through the use of textual or spoken explanations alone, the multiple connections are not as explicit as they are in the form of a concept map. "To achieve integrated understanding, students link and connect ideas. Students with integrated understanding have a cohesive view of a domain and can apply their ideas to personally relevant problems." (Linn 1995, p.104).

Overview Of C-TOOLS Project

I. The Goals and Timeline

With both the literature providing a solid theoretical basis for using concept maps and the field of computer science providing the proper software development tools and technology, the C-TOOLS project began in late 2002. A team of faculty from Michigan State University spent much of the first year of a three-year project "developing" both the Java applet, called the Concept Connector, and the problems sets with concept maps for science students. In parallel with software development is the study of how students use the tool. The validity of the Concept Connector is being determined by a 'design' experiment (Suter and Frechtling 2000) that involves testing the tool with undergraduate science-majors in introductory biology, geology, physics and chemistry courses. A cohort of over 1000 students, those enrolled in participating courses, are being recruited to test the effectiveness of the tool to assess their (mis)understanding and help them progress in their learning. In addition to students, the C-TOOLS project also strives to help faculty develop skills and best practices to use concept maps in their classroom and further disseminate good teaching practices to their colleagues.

The specific goals and timeline (Figure 4) of the C-TOOLS project are:

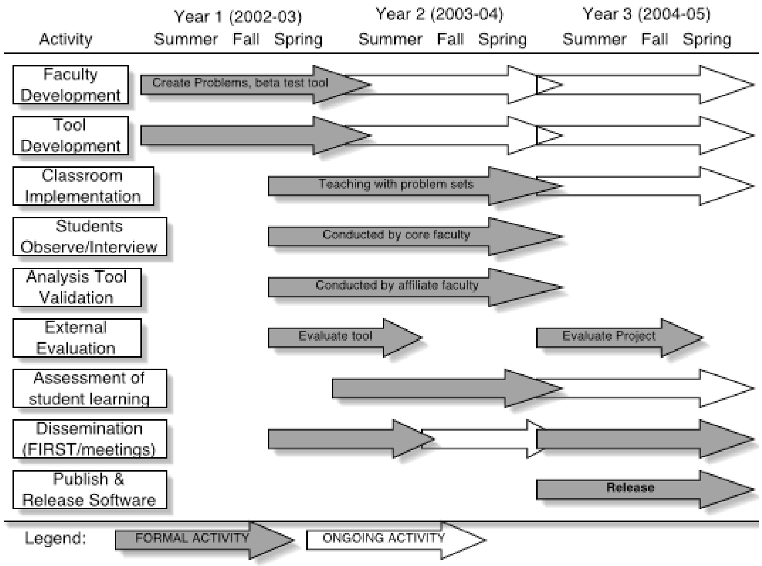
- Develop and validate a web-based concept mapping tool that can provide immediate feedback (automated) to both students and instructors.
- Develop and test concept map-based problem sets made for biology, chemistry, geology and physics courses that are designed to motivate students to grapple with the relationships and organization among fundamental concepts within and between each discipline.
- Enable students to use and revise concept maps individually, and then explain and modify the maps with their peers (to recognize their own area(s) of incomplete understanding).
- Document how undergraduate students use web-based concept mapping individually and in groups (and correct their own area(s) of incomplete understanding).
- Detect and document students' misconceptions regarding relationships between concepts (*e.g.*, relation between ecology and quantum physics, or structure and function of DNA).
- Provide affiliate faculty workshops to design curricula that enables students to represent their understanding, to use and revise concept maps and the Concept Connector, and to assess student learning throughout the process.
- 

Figure 4

The C-TOOLS project timeline. During years 1 and 2 of the project, faculty create problem sets, test the tool, and teach with problem sets. Additionally, PIs conduct observations, interviews and start the dissemination process. Programmers began developing the primary tool during year 1, followed by revisions/support. Students were first involved in the project to test the tool in spring 2003, and used the tool in classroom online homework problem sets.

II. The Programmers: Software Development

The Concept Connector beta version has been created as the combination of an online Java applet that serves as a map drawing tool residing in an html page that communicates with unix-based (unix, linux, osx) server side software to allow students to seamlessly create, save in a "gallery", restore, revise and submit concept maps and receive automatic scoring feedback. The system also allows faculty to develop problems, review student maps and send feedback online via freeware course management software (currently using "Moodle"). In year 1, the automatic scoring feedback, named "Robograder", gave only feedback concerning the validity of the semantic relationship between linked words in a proposition (*i.e.* concept A -> linking word -> concept B; see colour feedback in Figure 5). In year 2, feedback concerning the arrangement of hierarchy (more broad concepts above subordinate concepts etc) will be added to the software.

In terms of architecture, as a technology, C-TOOLS does not require anything sophisticated. Cross-linking databases, resource-specific handlers, and the usage of servlets for interactivity have been in effective widespread use, and while the software is "bleeding edge" we are not reinventing the wheel. Our current working Java applet is browser-compatible on every OS platform and presents a menu-driven, interactive GUI (Figure 5). The applet is only 37 kilobytes in size and thus functions well at data speeds relevant to modem connections.

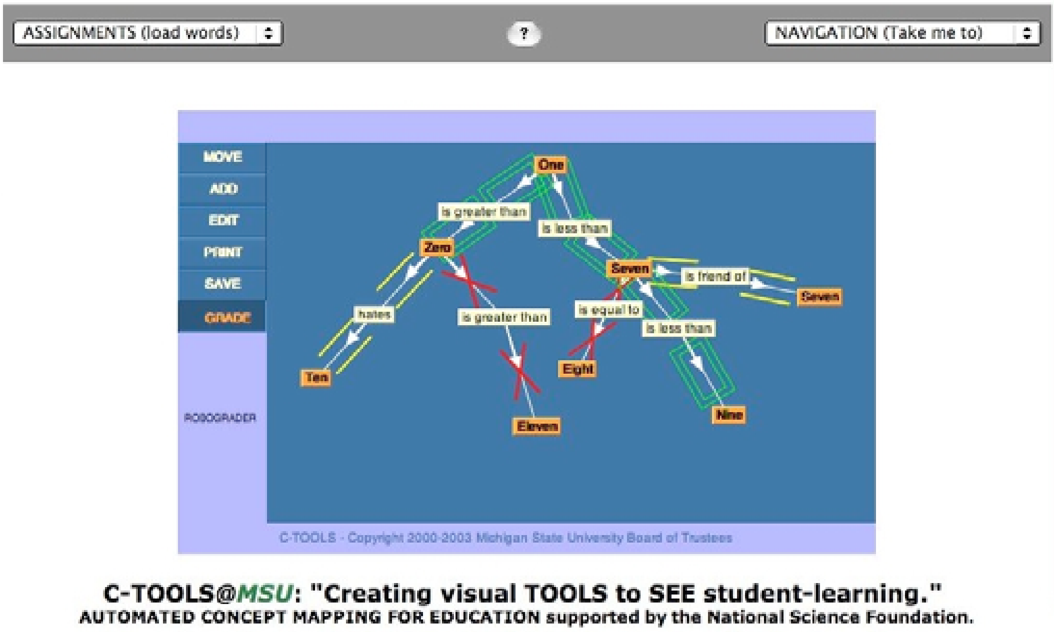


Figure 5
A screenshot of the C-TOOLS website and Concept Connector Java applet graphic user interface (GUI). Along the top grey bar are two javascript pull down menus for *Assignments* and *Navigation* respectively, as well as a help *?* button to provide user assistance. This particular screenshot shows the Java applet's GUI (blue coloured areas), how the software draws a concept map, and how new colours (green and yellow rectangular halos or red X's) appear when the *Robograder* is asked to *GRADE* a concept map (try it yourself online at http://ctools.msu.edu).

Figure 6 provides a simplified view of how the C-TOOLS software will be designed. Our primary interest is focused more on the two 'ends' of the flowchart, the instructor/student interface and the assessment algorithms. Much of the middle region of the schematic can be replaced with any other database and communication system. The central portion consists of 6 relational databases that are cross-linked together and interact with data from the student or instructor via 'handlers'. Currently free course management software called Moodle is being used but during the C-TOOLS study, software will be run from MSU's LON-CAPA course management system and these databases and handlers provide a simple, stand-alone functionality to the C-TOOLS application, yet they can be replaced in whole or in part with course management systems like Angel (http://www.angel.com), Blackboard (http://www.blackboard.com) or WebCT (http://www.webct.com). At MSU we are still exploring licensing issues associated with this integration, but the ability to integrate into other educational server systems ensures longevity and a robust design methodology.

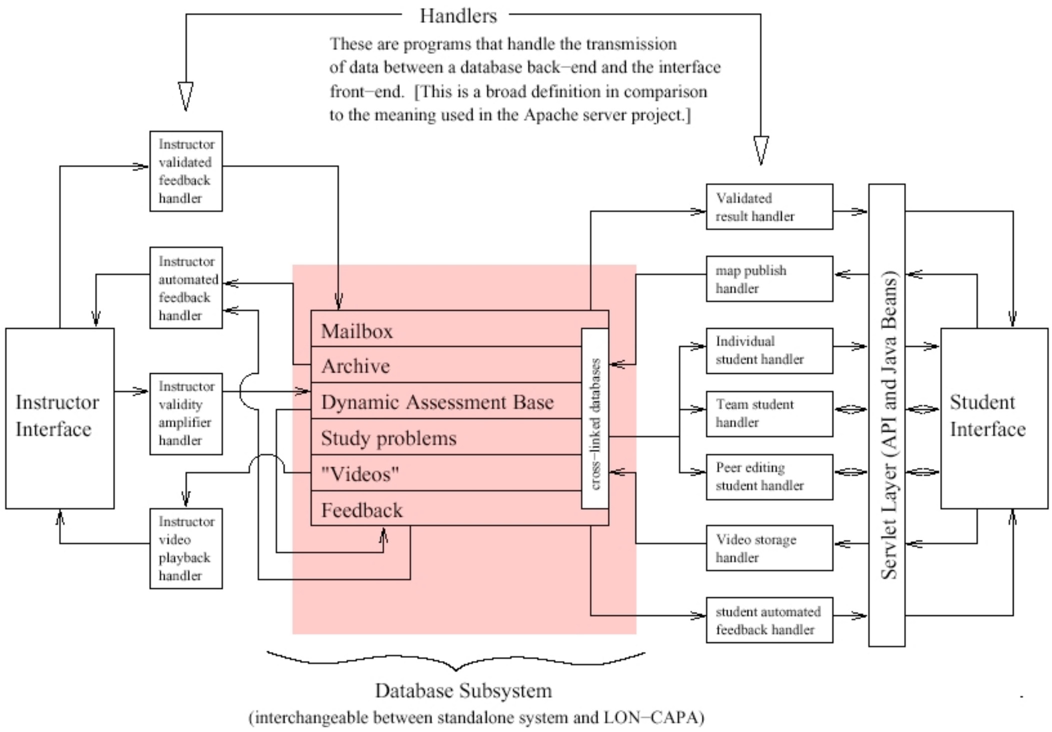


Figure 6
A flow diagram of the software architecture of the Concept Connector. The flow chart provides a simplified view of how software will be modularised.

Automated scoring algorithms are being developed and embedded in the Concept Connector to allow for immediate feedback to students. The Concept Connector's flexible scoring system, based on tested scoring schemes as well as instructor input, will enable automatic and immediate online scoring. As expert faculty score connections on a graduated scale, their input will be added to a growing computer-based library that will ultimately have full capacity to score all connections stored in the library automatically. Criteria for scoring will be based on agreed upon structure and connections by "expert" faculty in the content area. Faculty will conduct and analyse students' dialogue as they use the Concept Connector and conduct focus group interviews about the students' use of the tools and their resultant maps. In this project we strive to develop a tool for detection of problems in learning that include inaccurate, incomplete or vague conceptual understanding. The Concept Connector will enable faculty and students to readily recognize when students do not understand concepts and motivate both to address these deficiencies.

Supporting a concept tool in an interactive system presents a number of open-ended design challenges. In creating the software tool two main challenges exist: (1) *algorithm design*, the effective construction of automated grading algorithms, (2) *interface design*, the effective construction of the appearance of guided input/output of the computer in response to users.

Algorithm Design

It is reasonably straightforward to set up an online functional automated grading system. Compared to asking a computer to grade an essay (which is also possible), grading a concept map is relatively simple. Automated grading is both technically feasible, reliable and testable since the Concept Connector software will have many controlled parameters to work with from its scoring database (10 concepts, a 'linking word' pool, valid and invalid proposition information etc). *Initial* scoring will count and assess items such as:

- Valid links; validity of links drawn from link pool or compared with criterion maps.
- Hierarchy; grid system evaluates if major concepts are on top with subordinates beneath.
- Crosslinks; detection of connections between distinct clusters of concepts.

Beyond initial scoring, the software will automatically be able to "learn" to be a better grader as it gathers more data. The software will start with a discrete pool of information derived from expert criterion maps, but the pool is automatically expanded by the actions of an instructor. For each concept map hand-graded online by an instructor (with the toolbox, Figure 8) more entries are added to the database. As a result the computer will slowly learn. The software will first work with small maps with 10 concepts, yet this system is designed to ramp up to larger maps and ultimately to assess maps where concepts are student-generated.

Interface Design

A functional interface (intuitive appearance) is important. It will be important to create and revise a user-friendly interface so both the instructor and student can focus on the task and not the software. Our current working applet shows that the entry and output of map data can be done online. The presentation of automated feedback and other features associated with C-TOOLS is a stylistic question relying on surveys and observation as opposed to experimental proof. Example interface designs are shown in Figures 7, 8 and 9.

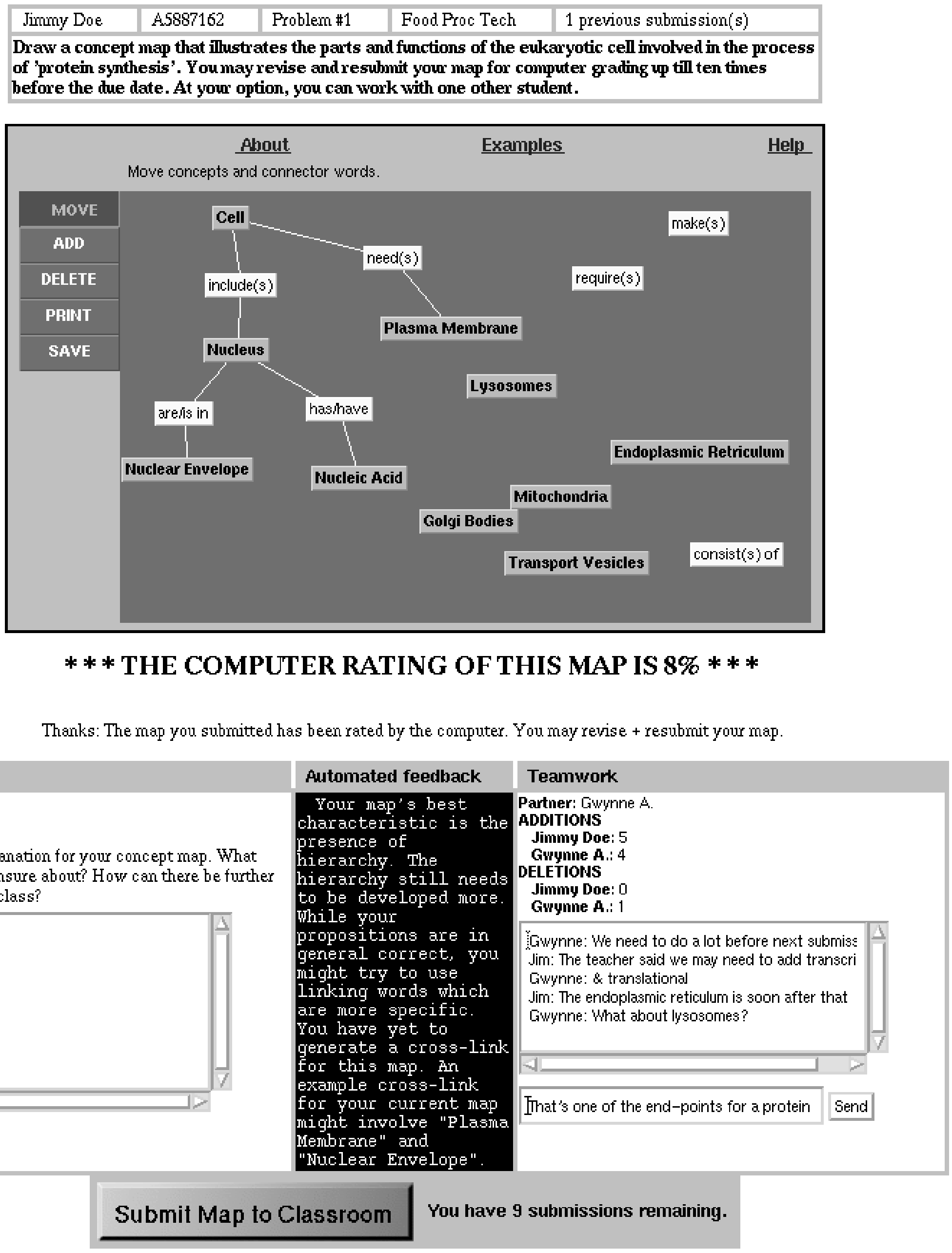


Figure 7
A "Student's View" of the interface after their first attempt at a concept map has been submitted to the server. Notice the student rating and feedback for better scores etc.

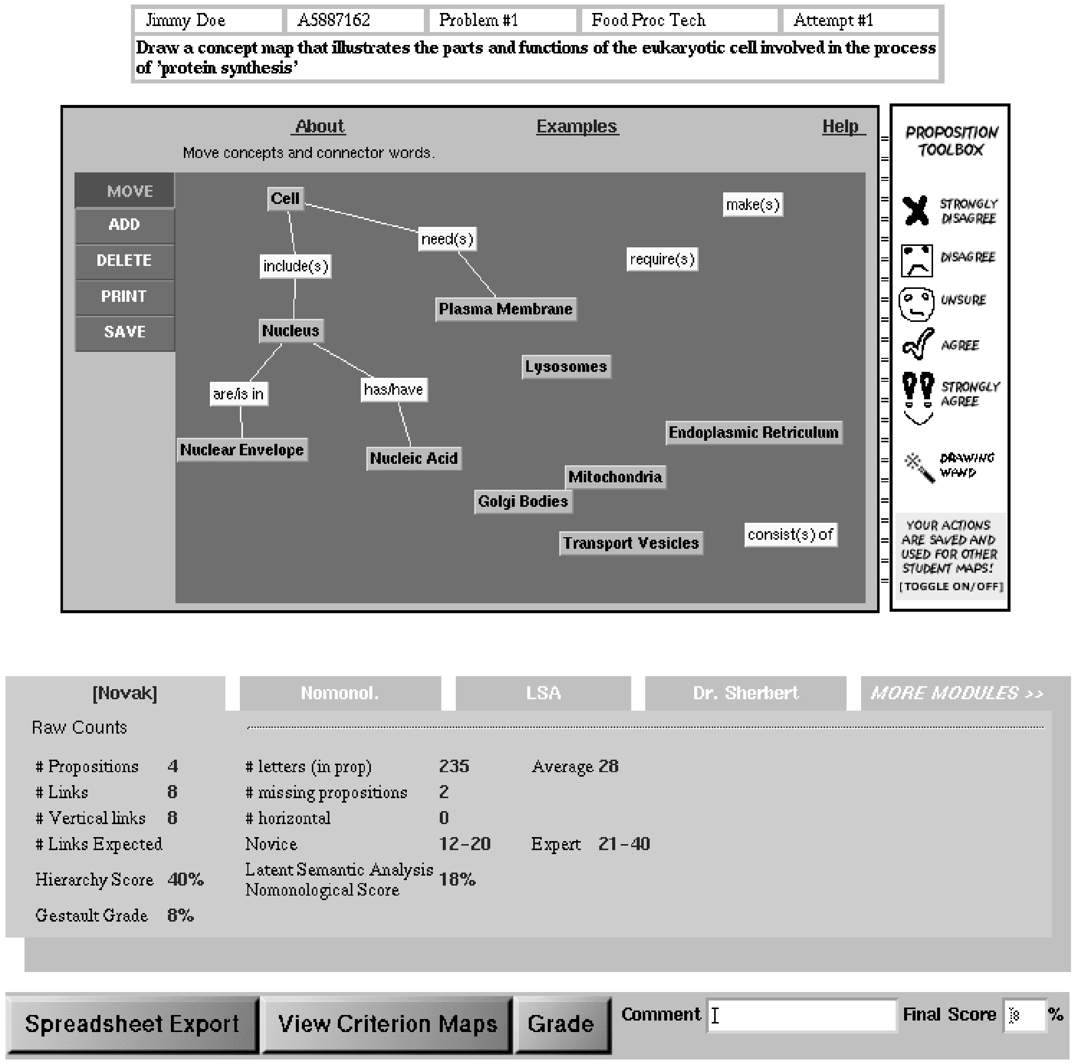


Figure 8
An "Instructor's View" of the map from Figure 7. After the computer sends the student automated feedback the instructor can view student data, try different scoring algorithms/modules and use export buttons to move data to a Microsoft Excel spreadsheet (Figure 9). The instructor can decide to give personal feedback to this student and use the proposition toolbox (top right) to hand score a map or just use the 'drawing wand' to circle problem areas for the student to revise.

	A	B	C	D	E	F	G	H	I	J	K
1	A5887162, Problem #1, Matrix format (connect rows to columns)	Cell	Nucleus	Nuclear En	Nucleic Acic	Plasma Mer	Lysosomes	Mitochondr	Golgi Bodie	Transport \	Endoplasm
2	Cell		include(s)			need(s)					
3	Nucleus			are/is in	has/have						
4	Nuclear Envelope										
5	Nucleic Acid										
6	Plasma Membrane										
7	Lysosomes										
8	Mitochondria										
9	Golgi Bodies										
10	Transport Vesicles										
11	Endoplasmic Reticulum										

Figure 9
Exported data of the same map from Figure 7 represented in a spreadsheet.

III. The Faculty: Developing problem sets with concept maps.

In each course the instructor designs a question or problem that actively engages the students in the topic and has the potential for diagnosing students' misconception about the topic. The students explore the problem and make predictions and/or hypotheses based on their current knowledge and assumptions. Students illustrate the relations among the key concepts in the problem by constructing a concept map with the web-based tool. Then students can explain their map to the computer and explain their understanding to their peers verbally and in writing. Following this, students have the opportunity to revise their visual representation of the map. In each course, for two problem sets, students create a minimum of 5 concept maps for data analysis. The concept map problem sets can be developed and used by a faculty member in different instructional contexts. "Sources" faculty use for the concept maps include: analysis of readings from the scientific literature, answering a particular homework question designed to be solved with the tool, or creating concept maps in which student demonstrates their mastery of the topic discussed in a class meeting. The concept maps are designed to:

- Actively engage students in critically analysing and reflecting on what they know.
- Illustrate their understanding of relationships and revise their representation as they learn.
- Make predictions and/or hypotheses based on assumptions and arguments.
- Reveal fundamental deficiencies in the students' understanding of the topic.

Whatever the objective of the instructors' problem set in their course, the maps and procedures for using them follow a protocol. Each instructor creates two concept map-based problem sets for their class. In creating a concept map to answer the problem, at first, a list of 10 concepts about a topic is generated by the instructor (this is all the student will be given). Then the instructor and colleagues create 'expert' criterion maps (keys). Expected hierarchy and an inventory of links and propositions are extracted from the criterion maps by the computer for its scoring database. WebPages are designed by the instructors and incorporated into the Michigan State University 'Learning Online Network' system (LON-CAPA, http://lon-capa.org/) to present the problem sets and mapping tools to the student. Students 'login' to a problem set on LON, grapple with the 10 pre-defined concepts and develop their own concept maps. Once a finished map is submitted, the computer then compares a student's map to the scoring database and sends the student their score and constructive feedback immediately. Currently this feedback is colourized halo's around the various links (Figure 5).

Each of the faculty involved in the project plan their instruction based on use of the online Concept Connector twice during their course(s). This represents a unique framework for research because faculty from four different disciplines (biology, chemistry, geology, and physics) each will use the tool differently in the context of their courses, yet the tool itself is the same. Therefore, a case study of each faculty's use of the tool and subsequent student learning outcomes will enable us to triangulate the data to determine the effect of the tool in the context of six different courses. The case studies will provide data about the following questions:

- How was the course designed and instruction implemented using concept maps?
- What was the basis for the instructor developing two specific problems and/or instructional units that involved using the tool? *e.g.*, Was the problem selected because students have a particularly difficult time understanding the concepts involved?
- What is the role of hierarchy of concepts in the problems developed by the faculty?
- How were students introduced to the use of C-TOOLS in class?
- How do the students go about learning the tool and completing the assignment? (Data from student interviews in the selected courses).

During spring 2003, three faculty utilized the Concept Connector in three different courses: Organismal biology (LBS-144), Cellular and Molecular biology (LBS-145), and Environmental science (ISB-202). Each instructor implemented different strategies for using concept maps in their course and at the end of the semester, Luckie and Ebert-May interviewed students from each other's courses about use of C-TOOLS.

Interviews

In each course we use interviews and observations to examine student constructions of maps using the Concept Connector. After students complete all their individual work on the concept maps, eight students from each course (4 pairs, two students selected randomly from quartiles based on grades) are selected for observation and interviews while they work together on the online maps. All interviews are transcribed and analysed by established inductive analysis methods in social science (Bodgen and Bilkin, 1998).

Protocol for Interviews: We recruit 4 pairs of students/course to observe and interview while they are constructing a concept map. First, we describe the project in terms of two objectives; (1) how useable is the concept connector, (2) what is the students' current understanding of the problem. All interviews are audio-recorded. Each student writes a short response to the problem or question before they use the tool. Then together the pair of students design a concept map and discuss aloud comments, ideas, questions and rationales for what they are constructing. The instructor observes only. After the students complete the map, the instructor then discusses the process and content of the map with them. The students explain further their understanding of the problem and experience with using the Concept Connector. After the interview is completed, the instructor hand-scores the maps to provide comparison data for the programmers. Concept maps are scored by hand as described by Novak and Gowin 1984 (p.37) based on hierarchy, valid relationships, and cross-links (if valid and significant).

IV. The Students: Using concept mapping in large classrooms.

For the C-TOOLS study, we are recruiting a cohort of ~1000 freshman and sophomore students enrolled in each of the six introductory science-major courses: Biology I & II, Chemistry I & II, and Physics I & II, as well as two non-major science courses Introductory Biology and Geology. The faculty have agreed to collaborate throughout the duration of the project (Table 1).

Table 1
Targeted C-TOOLS courses for testing Concept Connector assessment tool.

	C-TOOLS courses, instructors and enrollment		
Course (Sequence)	**Title**	**Instructor**	**Enrollment (semester)**
LBS 144 (I)	Organismal Biology (I)	James Smith	150
LBS 145 (II)	Cellular Biology (II)	Douglas Luckie	85
LBS 171 (I)	General Chemistry (I)	Lynmarie Posey	250
LBS 172 (II)	General Chemistry (II)	Steven Spees	200
LBS 271 (I)	Introductory Physics (I)	Walter Benenson	200
LBS 272 (II)	Introductory Physics (II)	Walter Benenson	200
ISB 202	Integrative Studies in the Biological Sciences	Diane Ebert-May (non-majors)	250
ISP 203	Integrative Studies in the Physical Sciences	Duncan Sibley (non-majors)	250

Many of the same students will take more than one of above the listed courses. We predict ~1000 different individual students will participate in the C-TOOLS study. The students are asked to participate in the project as described in the approved Michigan State University UCRIHS (University Committee on Research Involving Human Subjects) protocol.

Students complete the concept maps as an integral part of the course (two assigned homework problem sets at week 5 and 10 of the 15-week semester). During class meetings in computer laboratories, students learn how to use the web tools. As indicated, online concept map-based homework assignments may vary from analysis of scientific literature to answering a particular homework question. To complete an assignment students login to a website (LON) 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. They then can revise the map and resubmit. Finally they work with a partner to complete the final concept map (Figure 7). Each new concept map submitted receives a new (frequently improved) score.

Broader Impacts Of Project

We believe the results of this project will strategically contribute to the development of a readily accessible and acceptable assessment tool that will enable science faculty who teach large, introductory science courses to gather substantive data about student learning. Ideally, these data will motivate faculty to critically examine their educational practice and consider implementing various instructional designs that enable more students to learn. Through use of the Concept Connector, we hope students will strive to find interconnections between their science courses, recognize concepts that span disciplines more readily and, therefore, find greater meaning in further study.

Intellectual Merit

In order for Science, Technology, Engineering, and Mathematics (STEM) faculty to achieve the new expectations advocated by the NSF (1996) and the NRC (1999), faculty need to develop and use more effective curricula and instructional designs. Importantly, faculty within SMET departments who wish to pursue the requisite research on how individuals learn must be provided support to do so. Given the importance of this challenge, it is striking to note the paucity of substantive research that has actually influenced the development of curricular materials, technological tools, and accompanying instructional design of undergraduate science courses. Scientists traditionally are not trained in the conduct of educational research, thus, this research represents an example of a study that integrates research with practical applications for scientists who teach undergraduates science. Just as the Force Concept Inventory (Hestenes et al 1992) captured the attention of physics instructors who thought their students understood mechanics, we hypothesize that the Concept Connector will reveal to faculty and students a useful picture of their understandings and misconceptions.

Companion Projects and Support

Our assessment project has the support of colleagues and facilities associated with several other funded initiatives at Michigan State University including: a Howard Hughes Medical Institute grant (“First Year Online” PI Estelle McGroarty) to develop online learning modules in biology, a NSF ITR grant (“LON-CAPA” PI Gerd Kortemeyer) and a Hewlett Foundation grant (“Assessing Student Outcomes in Integrative Studies” PI Duncan Sibley) to develop a technology infrastructure to support and research online learning. This C-TOOLS proposal articulates well with another Michigan State University proposal recently funded under the National Science Foundation’s ASA program called “DQA” (PI Joyce Parker). The “DQA” project is intended to diagnose student misconceptions of which the concept connector tool should dovetail nicely to illuminate the nature of misconceptions. Dissemination of the findings of the C-TOOLS project is already utilizing an external network of faculty involved in the “FIRST II” NSF grant (PIs Diane Ebert-May, MSU, and Jan Hodder, University of Oregon.) FIRST II is a faculty development project that creates a national dissemination of instructional practices, materials such as C-TOOLS, and support systems that give faculty the ability to help all students learn science. C-TOOLS is delivered through the Learning-Online Network (LON-CAPA) test administration system developed at Michigan State

University in 1997 (http://lon-capa.org). This system supplies the infrastructure (hardware and software) with which to reliably deliver our web content 24 hours/day.

Final Dissemination

The C-TOOLS faculty are committed to disseminating their findings and approaches to their colleagues. When the 'gold master' final version of the Concept Connector software is completed at the end of 2005, the source code and all supporting documentation and resources will be released and open for usage and further development under the June 1991 General Public License (http://www.gnu.org/copyleft/gpl.html). Although the software is still in development, all software is freely available online to any and all instructors interested in using online concept maps in their course (http://ctools.msu.edu/).

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