Creating ACTIVE LEARNING ENVIRONMENTS in Undergraduate STEM Courses

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This booklet has been written to specifically support a culture of active learning in the science, technology, engineering and mathematics (STEM) oriented fields at the University of Georgia. This booklet is for STEM faculty who instruct undergraduate students, but may not know why or how to improve their instruction. It provides a general overview of learning, and then suggests a variety of instructional approaches that can better support student learning. The instructional approaches align with active learning, which promotes student learning by allocating more time for student thinking and working during class. With this booklet, STEM faculty who instruct undergraduates will be able to determine the level of active learning they are currently using, and then identify additional instructional approaches to enhance the learning of their students.

WHAT IS THE CURRENT STATE OF UNDERGRADUATE STEM EDUCATION IN THE US?

Science and technology play an increasingly vital role in our everyday lives and the future of the planet (PCAST, 2012). With this emerging orientation, there is a need to expand the number of students who have a basic knowledge in STEM areas or engage in STEM careers. Ultimately, students become citizens who will need enough knowledge in the STEM fields to assess issues that are presented in the media, to support sound instruction in the schools, and to navigate their own personal decisions. Students may also pursue STEM careers, which may result in their making significant scientific and technological contributions. Continuous discoveries and innovations by STEM faculty and researchers have driven the STEM enterprise, enhanced our understanding of the natural world, and improved our quality of life.

In higher education, student enrollments in general have increased overall, yet enrollment in STEM fields has stayed consistent over the years (National Science Board (NSB), 2014). Within STEM fields, there are clear participation trends. For instance, according to the NSB (2014), enrollment in biological and agricultural sciences has increased, while enrollment in mathematics, statistics, and computer sciences has declined. Also, the number of participating women and minorities has increased over time, but they are also leaving the STEM fields in greater numbers.

One way to attract more students to STEM careers is to enhance the learning experience of students in introductory STEM courses. Instruction that uses an active learning approach is one way to improve undergraduate learning -- especially for women and minorities, which are groups traditionally underrepresented in science (National Research Council (NRC), 2013). ***In an active learning environment the instructor stops lecturing for some to most of the class period to give students time to solve problems, contemplate their level of understanding, and interact with the presented material.*** Studies focused on the use of active learning with STEM undergraduates have shown that students increase their conceptual understanding, are more focused on the instruction, develop critical thinking skills, and increase in their potential to persist in STEM fields (Freeman et al., 2014; Prince, 2004).

Even with compelling data about the importance of an active learning environment, STEM faculty often find this form of instruction

Methods you use in "all" or "most" of the courses you teach	*STEM (%)*	*Other Fields (%)*
Term/research papers	25.8	51.2
Student evaluations of each other's work	12.4	24.8
Class discussions	61.5	91.6
Cooperative learning (small groups)	47.4	60.9
Teaching assistants	22.6	8.2
Extensive lecturing	63.0	36.8
Student-selected topics for course content	11.9	23.3
Electronic quizzes with immediate feedback in class	10.8	5.9
Using real-life problems	58.1	54.3
Using student inquiry to drive learning	36.5	50.1

Table 1. Self-reported methods used by undergraduate faculty from the 2010-2011 report (adapted from Hurtado et al., 2012).

challenging. According to a team of researchers from the University of California at Los Angeles, undergraduate STEM instruction is often oriented towards traditional forms of teaching. Since 1989, Hurtado and his colleagues have been surveying faculty about their practices in undergraduate instruction. Table 1 provides an overview of key findings from a recent survey by Hurtado el al. (2012).

In general, Hurtado et al., (2012) found that STEM faculty used instruction that was inconsistent with their goals for students. Specifically, STEM faculty wanted their students to develop their critical thinking, creativity, and an ability to evaluate information, yet these opportunities were not emphasized heavily in STEM classrooms. Most STEM faculty, regardless of class size, favored traditional instruction that did not include class discussions, group work, or student inquiry. Faculty in the humanities, social sciences, and professional fields, however, were more likely to use student-centered, active learning instructional approaches. These approaches were often embedded in opportunities for students to write and work with their peers in class. In the humanities, social sciences and professional fields, this type of instruction took place without assigned teaching assistants.

WHAT DOES IT MEAN TO 'KNOW' IN STEM FIELDS?

Possessing knowledge of a STEM field means knowing more than facts. A complex understanding of a STEM area also includes knowing the purpose of the field, and how knowledge in the field is generated.

Within the STEM fields, there have been attempts to articulate the knowledge that is needed by undergraduates. In biology, for instance, the authors of *Vision and Change in Undergraduate Biology Education: A Call to Action* (American Association for the Advancement of Science, 2011) suggest that there are five core concepts. In chemistry, the American Chemical Society (www.acs.org) has guidelines for undergraduate courses that include content knowledge, laboratory experiences, and the skills found in chemistry.

In K-12 education, there has been a focus by educators and policy makers on articulating the knowledge that students should know in science, engineering and technology. While the *Next Generation of Science Standards* (NGSS) (NGSS Lead States, 2013) was written for the K-12 setting, it has been recognized as a useful resource in undergraduate STEM fields (see Singer, Nielsen, & Schweingruber, 2012).

The NGSS articulates three forms of knowledge that are important for students to know: science and engineering practices, crosscutting concepts, and disciplinary core ideas (NGSS Lead States, 2013). Scientific and engineering practices highlight the behaviors of scientists. The importance of explanations, arguments and questions are some highlighted practices. Crosscutting concepts are ideas that cross different fields of science, and include cause and effect, systems and system models, and structure and function. The disciplinary core ideas are situated within each science field and are important to a field. They can be a key tool, relate to students or are connected to society, or can be taught to different levels of complexity. An example core idea in the life sciences is adaptation, while a core idea in chemistry is chemical reactions.

It is important to consider the knowledge that comprises a STEM field. Fortunately, there are several resources available to help faculty focus their instruction on the important knowledge in a field.

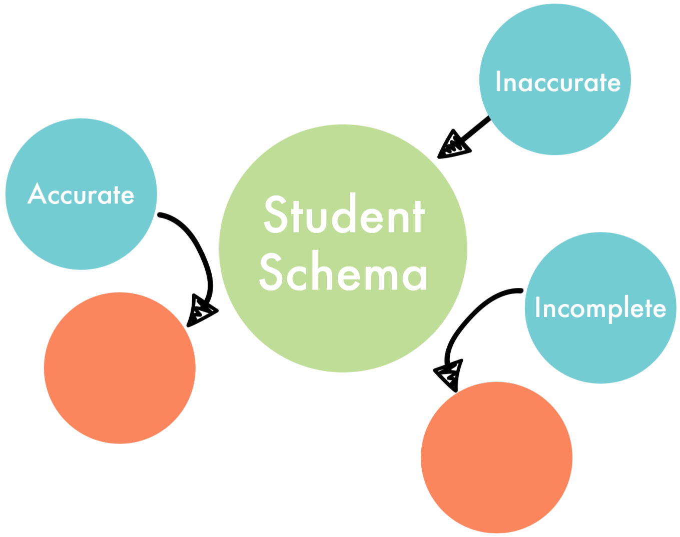


Figure 1. Building student understanding

HOW DO UNDERGRADUATES LEARN IN STEM FIELDS?

When planning instruction for undergraduates, faculty need to consider how their students learn. How faculty view student learning will ultimately guide their instructional decisions. For instance, when students are viewed as actively constructing their knowledge during a course, faculty present the content in a sequence that builds understanding. Faculty also select instructional strategies that require students to interact with the content. When students are viewed as recipients of knowledge, faculty use instructional approaches that share a significant amount of information in a non-interactive format.

In STEM fields, learning is both an individual and a social process. As individuals, students come with their own ideas about the subject matter that will be taught in the course. Cognitive researchers have suggested that students can have ideas that are scientifically/mathematically accurate, incomplete, or inaccurate (Kober, 2015). Within these different levels of understanding, students will incorporate presented information through the least resistant pathway. This may result in a better understanding, some modification of understanding, or more inaccuracies may be incorporated into the student's schema, which is a storage site for knowledge (see Figure 1).

The social side of learning occurs when students draw upon their current knowledge to explain phenomena, interpret an event, or predict an outcome to their instructor or peers (see Figure 2). When students are asked to make their understanding explicit, they reveal their accurate, incomplete, or inaccurate knowledge. This shared knowledge can then be challenged and modified by the instructor or peers. Learning is enhanced when it is a social process. An ongoing cycle of elicitation and modification ensures that students build accurate scientific understandings.

WHAT CAN BE DONE TO HELP UNDERGRADUATES LEARN?

Learning requires a change to take place in students' initial conceptions of science, mathematics, or engineering phenomena (Vosniadou, 2012). In order to achieve learning, faculty need to determine what students know before teaching about a topic. Faculty need to know if students have an accurate, incomplete or inaccurate understanding of the topic (Kober, 2015). The knowledge that students have before a time of formal instruction is referred to as *prior knowledge* (see Figure 2).

With an understanding of the prior knowledge of an undergraduate or a class of undergraduates, the instructor can select specific instructional approaches that will ensure students construct their knowledge in an appropriate manner. Instructional approaches that require students to examine and share their knowledge will support their learning. These approaches provide an opportunity for students to confront and modify their existing knowledge.

As a student engages with the presented content, the student's current ideas are compared to his or her prior knowledge. During this time, interacting with the instructor and peers can further support the revision of knowledge. In the midst of this interaction, the student subsumes varying amounts of the presented information into his or her schema. Knowledge that aligns with the student's schema maybe accepted readily, while knowledge that is inconsistent with the student's knowledge may be modified or ignored (see Figure 1). This is the process of *knowledge construction.*

Accepting, modifying, or ignoring information is based upon the prior knowledge of the student. If the student's prior knowledge has helped the student understand his or her natural world, then this knowledge will guide the incorporation of new knowledge, even if it is inaccurate. Only when a student realizes the limitations of his or her prior knowledge will new and accurate knowledge be subsumed.

In order for students to accurately enhance their knowledge, an instructor must constantly *assess their knowledge*. This assessment occurs through the questioning of students, observation of student work, inspection of the results of problems worked in class, or an examination of the explanations provided by students. Assessing a diverse group of students will better reveal the understanding of the class, rather than assessing a few students who volunteer their answers.

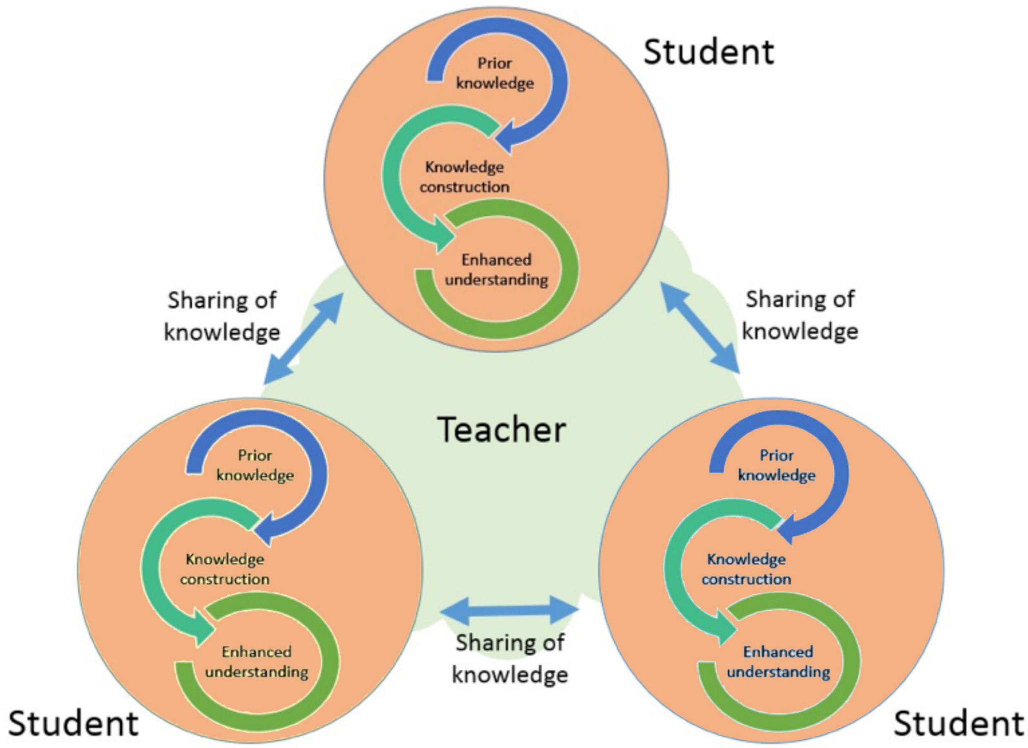


Figure 2. The social side of learning

WHY IS ACTIVE LEARNING IMPORTANT TO STUDENT LEARNING?

Active learning is an instructional orientation that draws upon research on student learning and advocates for faculty and students being cognitively active in the classroom. Faculty are constantly monitoring the learning of their students, while students are constantly engaging in the presented material. Active learning can take a variety of forms, which can include: the use of clickers, group problem-solving, or in-class explorations. Regardless of the form, active learning encourages the instructor to stop lecturing so students have time to think individually and test their ideas socially.

The recent meta-analysis study by Freeman et al. (2014) revealed that active learning is effective in supporting student learning. This study specifically illustrated that student performance, as measured by examination scores, improved significantly in active learning environments. Specifically, in an active learning setting, students could increase their understanding of the content and improve their grades in the class. For a student earning a C+ the grade could rise to a B-, or from a B- to a B.

Active learning recognizes the primary educational goals of institutions of higher education: the development of critical thinking skills, the ability to communicate clearly in both written and spoken language, and the ability to define and solve problems (Kim, Sharma, Land, & Furlong, 2013). Active learning experiences have the potential to support the development of these skills. In its ideal format, the active learning environment can also improve student performance by encouraging students to be responsible for their own learning.

WHAT IS THE DIFFERENCE BETWEEN ACTIVE LEARNING AND TRADITIONAL LEARNING?

An active learning environment is different from the typical, traditional classroom environment. The most important difference resides at the student level. In an active learning setting, students are actively refining and building (constructing) their knowledge. In a traditional classroom, information is given directly to the student and there is little opportunity for students to contemplate, evaluate, or examine the presented information.

Faculty organize classes and interact with students differently in traditional and active classrooms. In the traditional classroom, faculty provide information in a direct and sometimes entertaining format. In planning the class, faculty carefully organize each PowerPoint slide, focusing mostly on what he or she will do in class instead of on what the students will be doing. In an active learning class, faculty create lessons in which students provide responses to questions, both in-

Traditional Classroom	*Active Learning Classroom*
Students: • are viewed as "blank slates" (recipients), • sit and listen to the instructor, • take notes, • primarily work alone, and • do homework after class to reinforce presented material. Teachers: • present information, • have material they must cover, • typically lecture, • explain, then demonstrate, • emphasize science facts, • give exams to document what students know at certain points, and • format the course in way that does not allow for a return to earlier ideas.	Students: • are viewed as thinkers, • work primarily in groups, • talk to one another to make sense of the content, and • complete assignments prior to or following class in order to engage in the presented lesson. Teachers: • ask students questions, • encourage students to talk to one another, • monitor the learning of students, • make the content relevant to the students' lives, • use framing questions, • emphasize science content and the process of science, • use assessments to understand student learning and guide instruction, and • vary the class content to support student learning and the course objectives.

Table 2. Comparison between traditional and active learning classroom at the undergraduate level

dividually and in groups, and receive feedback on their responses from peers and the instructor.

In planning this class, faculty consider the knowledge the students hold and selects instructional activities that help students recognize their level of understanding, construct their knowledge, and reveal the understanding of students. Table 2 is a comparison between traditional and active learning classrooms.

HOW DO I PLAN TO USE ACTIVE LEARNING?

In learning how to create an active learning environment, one simple place to begin is the internet. Videos of effective active learning approaches can be found on websites designed for undergraduate faculty. Faculty who work in STEM education can point out useful websites.

After seeing different active learning environments, it is time to create an environment that supports student learning. When planning for active learning, faculty should consider adopting a cycle of instruction model. This model includes planning, instructing and reflecting (see Figure 3).

In the planning phase, the instructor decides upon the learning goals for the lesson and selects various instructional materials and approaches. Learning goals are the instructor's desired outcomes for the lesson. Good instructional goals focus on concepts, skills, or practices that allow for the utilization of specific facts. Concepts are representations or generalizations of phenomena, and they allow students to make explanations and predictions about the phenomena. Instructional materials and approaches are the tools of teaching, and may include several active learning techniques.

The instructional phase takes place in the classroom, and involves the use of selected strategies that support student learning and an assessment of the learning of students. The ongoing assessment of student learning during instruction is essential. As the instructor interacts with students, the instructor is collecting information about the learning of the students by listening carefully to what students say, looking at students' work, asking students follow-up questions, or giving them additional problems to solve. Sometimes an instructor can respond in class to what he or she learns from the students. More often, collected student data

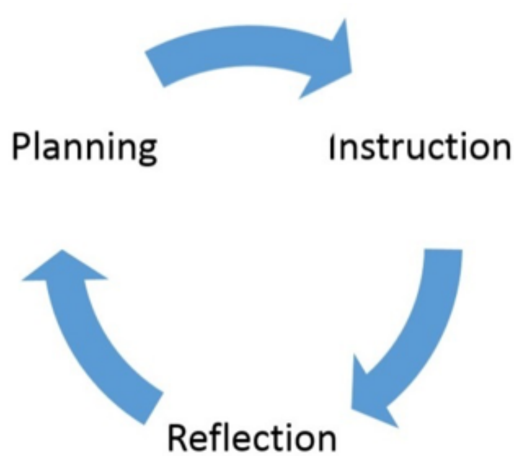
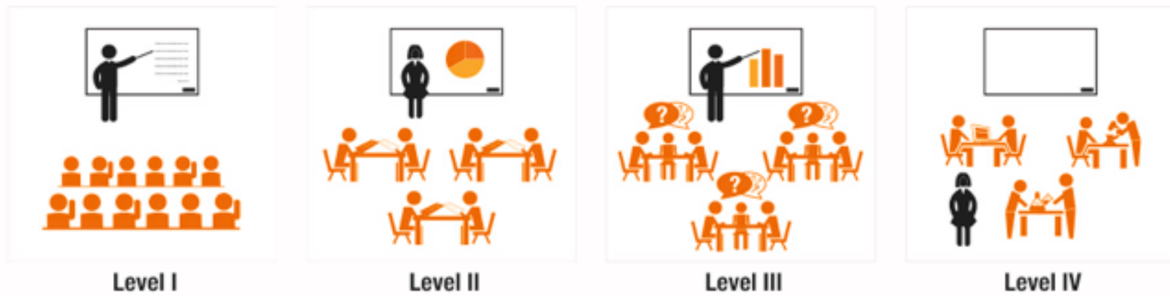


Figure 3. Cycle of Instruction



Qualities/ Attributes of Level	Teacher presents content and elicits responses from students about their knowledge acquisition.	Teacher presents content and elicits responses from groups of students.	Teacher shares essential/selected content. Groups of students represent, contemplate, or revise the content in new ways.	Teacher creates an environment in which students examine concepts. Students are responsible for generating knowledge in groups.
Example Techniques*	• Clickers • Raising hand • PowerPoints with blanks in the text • Minute papers • 24/7 summary on 3x5 cards	• Note check • Think-pair-share • Ink shedding • IF-AT group tests	• Concept maps • Generating explanations from data • Generating questions • Predict-Observe-Explain (POE)	• Flipped classroom • Case-based instruction • Peer teaching • Workshop

*These are defined in the Lingo of Learning section

Table 3. Different levels and example activities to support student learning

can guide the instructor in the revision of future lessons.

The reflection phase involves a purposeful examination of the taught lesson after class. This is as important as the planning of a lesson, because this is when the lesson is evaluated in light of student learning. During the reflection phase, instructors look at the documents students completed in class, or reviews notes about student learning that were taken during class. These different sources of data allow faculty to evaluate the learning of the students and plan for future lessons.

WHAT ARE DIFFERENT LEVELS OF ACTIVE LEARNING?

When planning a lesson, it's important to realize that you don't need to implement a high level of active learning in your first instructional attempt. In fact, this would be a mistake. Start off slow. Table 3 presents different levels of example activities. Level I is the simplest to enact, while Level IV requires additional resources or instructional experience. The listed activities are just examples (there are many more) and they are grouped by how they are typically implemented in undergraduate classrooms. The example activities could certainly be implemented differently to achieve different active learning levels.

EXAMPLE LEVEL I - MATHEMATICS-CLICKERS

Dr. Campbell is introducing the concept of improper integrals in class. The lesson follows a series of discussions about techniques of integration and precedes a segment on numerical methods of integration. In planning the lesson, she has identified the instructional goal to be: students will be able to distinguish between convergent and divergent improper integrals. The lesson will begin with a lecture about the convergence of improper integrals and then she will provide several examples of convergent and divergent improper integrals. During the last 15 minutes of class, Dr. Campbell will give examples of improper integrals, which students will evaluate with clickers as being divergent or convergent.

In teaching the lesson, Dr. Campbell explains what an improper integral is and how it can be convergent or divergent. The lecture is well-planned, and the students are taking notes as the topic is presented. The last 15 minutes of class involves giving examples that students determine to be convergent or divergent. During the first example, a majority of the students correctly identify the improper integral as convergent. Dr. Campbell explained why the improper integral was indeed convergent. During the final two examples, which were divergent improper integrals, about 40% of the class incorrectly identified the integrals as convergent. Dr. Campbell explained why the integrals in both examples diverged.

After the lesson, Dr. Campbell realized that the students still did not understand how improper integrals could be divergent. She decided that the next lessons should just focus on divergent improper integrals, in order to help the students understand the concept.

EXAMPLE LEVEL II – CHEMISTRY – THINK-PAIR-SHARE

Dr. Garcia is planning to teach solubility to his introductory chemistry class. Dr. Garcia's class has just completed a series of lessons on intermolecular forces and he wants his students to apply what they have learned to the solubility of ionic and covalent compounds in water.

Dr. Garcia has the students work with the students who are next to them; thus, forming informal groups of two. He starts the class with a demonstration that shows 20 grams of table salt (non-iodized) and sugar (sucrose) dissolving in distilled water. He projects each demonstration on the screen behind him. As he does this, he asks the students to measure the dissolution time and look for changes in the solution.

When each demonstration is complete, Dr. Garcia asks the students to talk to their peers and indicate what they noticed during the demonstration. The students talk to one another. After about 5 minutes, Dr. Garcia provides five different observations on the overhead. Each group must select the observation that best matches their experience with one clicker. Several groups notice that the sodium chloride solution remains cloudy even after all the salt crystals have disappeared, while the sugar solution is clear immediately after the sugar crystals disappear. Dr. Garcia talks about why this observation is most likely what the students observed.

Dr. Garcia asks each student group to think about why the solutions appear different. Why is the salt solution cloudy, while the sugar solution is clear? Again, the students discuss their potential ideas, and then select an answer from the list provided by Dr. Garcia. After the students select their answers, Dr. Garcia discusses the correctness or incorrectness of each answer. The rest of the class continues in this format – question to think about (Think), discussion with a peer (Pair), sharing an answer (Share), and discussion of the answer by Dr. Garcia.

After class, Dr. Garcia looks at the student responses and determines that students are building an understanding of ionic and molecular compounds. Most of the student groups answered the questions correctly about these types of compounds. He feels the class can proceed to the next topic, which is about the strength of ionic bonds.

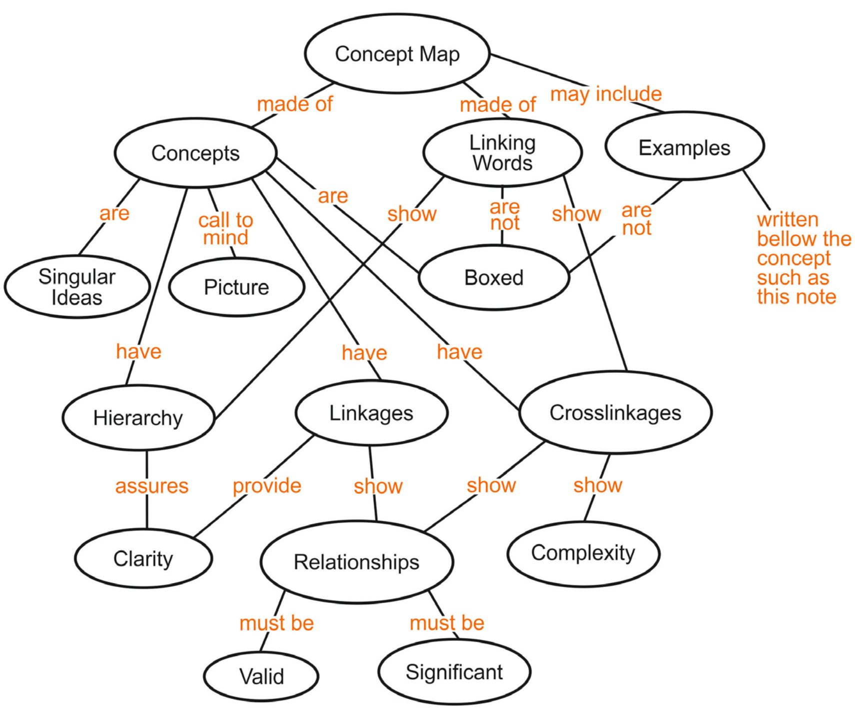


Figure 4. Example concept map format

EXAMPLE LEVEL III – ENGINEERING – CONCEPT MAPS

Dr. Richards teaches a large enrollment undergraduate design course for second-year mechanical engineering students. He has been teaching students about structural loads. In the lesson that will be taught, Dr. Richards wants to gauge how well students are making sense of the concepts in his course. In planning the lesson, Dr. Richards identifies the instructional goals: students will understand the relationship between loads, trusses, beams, and stress in relation to structural design. He plans to give a brief introduction to the content, before having student groups construct concept maps to make their understandings of these relationships explicit.

Dr. Richards uses a demonstration to illustrate stresses, loads, beams and trusses. During the demonstration, Dr. Richards highlights different terms that are represented. After about 30 minutes of demonstration, the students are asked to work in groups to create one concept map using the 10 terms provided in class and with an additional 10 terms of their choosing. Over the last two weeks, Dr. Richards has been teaching students how to use concept maps. He has used online videos, and dedicated time in his previous classes. In this lesson, Dr. Richards indicates that the concept maps must have a hierarchy, linking words, and cross links (see Kinchin, Hay, Adams, 2000).

Students work together in groups to draw concept maps that illustrate the relationships between the different terms (see Figure 4). While students are working, Dr. Richards guides student groups who are struggling to think about the relationship of the content in new ways.

After the lesson, Dr. Richards uses the students' concepts maps to analyze how students viewed the relationships between the information presented in class. He notices that several groups have a common misconception about load and stress. He decides this will have to be the starting point in the next class.

EXAMPLE LEVEL IV – BIOLOGY – CASE-BASED AND PEER INSTRUCTION

Dr. Green teaches a biochemistry course for 2nd and 3rd year undergraduate students. She teaches about 200 students in an amphitheater-style room, and recruits about 15 senior undergraduate students each semester to volunteer as peer mentors during instruction. The content of the class is taught through cases, which are based on incidents in the popular media or science news.

Her current lesson is meant to introduce metabolism and is situated within a series of lessons about the increase in diabetes and high fructose corn syrup use in the US. Previously, students engaged in a lesson about the different structures of carbohydrates. The series of lessons focus on metabolic processes.

Dr. Green enters the class 10 minutes early, in order to have a short meeting with the peer mentors. When the class formally starts, she makes a series of announcements while the peer mentors collect the homework and pass out the case that will be used in class. Each case has a series of data charts that illustrate specific points. The students work in groups to look at the data and to make conclusions, which build towards an understanding of the basic metabolism. The peer mentors and Dr. Green move throughout the class, examining the conclusions that students are making.

With about 15 minutes left to class, Dr. Green reviews some of the analyzed data and the conclusions offered by the students. The topics she covers are the areas that students struggled with during class. This review session involves the use of clickers, with Dr. Green and the students providing explanations about the clicker questions. At times, the students debate one another about the meaning of the data.

After class, Dr. Green reviews the responses from the homework and of the clicker questions. She feels that most of the students are starting to understand some components of metabolism and the importance of homeostasis in the human body. She thinks that her next step will involve looking at specific pathways in order to understand how systems change.

ONWARD TO ACTIVE LEARNING

This booklet is a starting place. It offers faculty who are new to active learning, basic information about student learning and suggests simple ways to create an active learning environment. For faculty who pursue active learning, it is important to remember to start slow and that learning to teach in an active format will take time. There will be mistakes and there be accomplishments along the way. These are experiences to learn from, and they will ultimately provide students with an education that focuses on their learning.

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LINGO OF LEARNING

24/7 summary – Students write a 24-word summary of a concept or lesson. They then create a descriptive title of no more than 7 words.

Active learning – Any instructional method that engages students in the learning process. In short, active learning requires students to do meaningful learning activities and think about what they are doing (Prince, 2004).

Assessment – The process of collecting data from students in order to determine what they have learned during instruction. Assessment occurs before, during and after instruction.

Case-based instruction – A series of activities that are about a specific topic, or local or national event. The activities illustrate a concept and are prepared by the instructor. Students study the cases in and/or outside of class, and discuss their emerging understandings with their peers.

Clickers – Devices that allow students to respond to a question posed by the instructor. The personal responses of all students are collected and examined by the instructor in class.

Concept – A representation of a phenomena or event that is defined by some term.

Concept maps – A visual way to link ideas together. Concept maps have linking words, cross-links, and a hierarchy. Developed initially by Novak and Gowin in 1984.

Conceptual change – A theory of learning that states that students have understandings about phenomena and these understandings need to be challenged. By challenging these ideas, students build more correct notions about the phenomena. Initially described by Posner, Strike, Hewson, and Gertzog (1982).

Cycle of instruction – The process of planning, instructing and reflecting upon a lesson.

Flipped classroom – An instructional strategy in which students receive content outside of the scheduled class meeting time (e.g., online, paper, experiment). Class instruction is then devoted to discussing, analyzing, and reinforcing the content acquired outside of normal class instruction. **http://flippedlearning.org**

Generating explanations – Data are presented in class. Students examine or analyze the data and generate an explanation from the data.

Generating questions – Events, data, or resources are examined and students suggest potential questions that are researchable and relevant to the data.

IF-AT (Immediate Feedback-Assessment Technique) *tests* – A "scratch-and-win-type" multiple choice answer sheet that is used following instruction. Students can work with peers or individually to select answers . IF-AT test demonstration: **https://www.youtube.com/watch?v=3Dqti9tz9sA** Website -**www.epsteineducation.com**

Ink shedding – Students provide a written response to a prompt that is provided by an instructor. The written response is passed along to another student, who writes a comment to the response. One to many students can comment on the original response. The instructor determines how long the process of providing written comments should continue. The initial response and all of the comments are returned to the original author for review.

Learning goals – What students are expected to know and be able to do at the end of a lesson, unit, or semester.

Minute papers – Students write the main idea, define, or discuss some aspect of a concept or a lesson in a minute. The objectives of minute papers are to rapidly assess student understanding and provide feedback to the instructor and/or the students at the conclusion of class.

Note check – Student pairs discuss the key points of their notes at certain times. They are ensuring they understand the key ideas, and have them recorded in their notes.

Peer teaching – Students who have prior experience with a course help with the instruction of the course. The experienced students are guided by the instructor and often receive additional training. **http://web.mit.edu/jbelcher/www/TEALref/Crouch_Mazur.pdf**

Predict-Observe-Explain (POE) – Prior to a demonstration, students are asked to predict the outcome. During the demonstration, observations are made by the students. Afterwards, the students offer an explanation about the event.

Prior knowledge – The knowledge that students have about a phenomena, topic, or area before formal instruction.

Scale-up classroom – A designed environment in which all students have access to technology (e.g., laptops, computers, SmartBoards) during the lesson, and in which students work together with peers or in groups. Instruction in these classrooms often consists of collaborative problem solving, interactive simulations, or working online. **http://scaleup.ncsu.edu/**

Schema – The mental framework that subsumes experiences and constructs meaning.

Think-pair-share – Students think and write their ideas quickly. They then discuss and refine ideas with a peer, and share their answers or results with the class.

Workshop – Students bring data or projects to class and work on these in groups.

RESOURCES – UNIVERSITY OF GEORGIA

Center for Teaching and Learning – **https://ctl.uga.edu/**

Chemical Education – **http://www.chem.uga.edu/research/chemical-education**

Department of Mathematics and Science Education – **http://coe.uga.edu/directory/departments/math-science-education**

Scientists Engaged in Educational Research (SEER) Center – **http://seercenter.uga.edu**

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