Supplemental Material

CBE—Life Sciences Education

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Appendix A

Categories Defined

Category	Definition
Assessment (A)	This bin collects any strategies that helps the teacher evaluate students' knowledge/achievement in the class via feedback.
Conceptual Class Design (C)	This bin collects any strategies that concern how a teacher designed their class and values they hope to project. This bin focuses primarily on long-term methods of affecting the classroom.
Discussion (D)	This bin collects any strategies that include people talking to one another.
Games (G)	This bin collects any strategies that are "a form of play or sport, especially a competitive one played according to rules and decided by skill or luck" (Merriam Webster, 2019).
Group Work (W)	This bin collects any strategies that involve 2-6 students working together (Miller & Tanner, 2015).
Live-action Visuals (V)	This bin collects any strategies used in class for student observation.
Meta-Cognition (M)	According to Flavel ("Metacognition and cognitive monitoring" 1979), the mental process of acquiring knowledge and understanding of cognitive phenomena through thought, experience, and the senses. i.e. oral communication of info, oral persuasion, oral comprehension, reading comprehension, writing, language acquisition, attention, memory, problem solving, social cognition, various types of self-control and self- instruction.
Paperwork (K)	This bin collects any strategies that involve distributed handouts to be filled out by the student(s) that are not assumed to be graded.
Practicing Core Competencies	This bin collects any strategies that fall under one or more of the six core competencies put forward by *Vision and Change*: (1) Apply the Process of Science (PPS); (2) Use quantitative reasoning (PQR); (3) Use Modeling and Simulation (PMS); (4) Interdisciplinary Nature (PIN); (5) Communicate and Collaborate (PCC); and/or (6) Relate Science and Society (PSS; AAAS, 2010).

Appendix B – Active Learning Strategy Guide

2 minute essays | M | A brief active-learning strategy that provides a mechanism for students to stop, think, and write during or at the end of a class period. The goal is to provide a momentary break during which students can capture their thoughts or questions (Miller & Tanner, 2015). *Synonyms: Minute papers, Notecards, & One-minute papers*

5-E learning cycle | C | "This module provides a built-in structure for creating a constructivist classroom: the 5E Instructional Model. The 5E model sequences learning experiences so that students have the opportunity to construct their understanding of a concept over time. The model leads students through five phases of learning that are easily described using words that begin with the letter E: Engage, Explore, Explain, Elaborate, and Evaluate"(Inquiry, the Learning Cycle, & the 5E Instructional Model, NIH).

ABCs of Learning | C | A book presenting a new science of learning so that educators can creatively translate the science into exceptional practice. With everyday language, engaging examples, a sense of humor and solid evidence, it describes 26 unique ways that students learn (Schwartz, Tsang, & Blair, 2016).

Act out chromosome movements during meiosis | V, A | Pretending to be a chromosome during the process of meiosis to explain meiotic processes. Found in Newman and Wright (2017).

Active listening | M | Active listening means fully concentrating on what is being said rather than just passively 'hearing' the message of the speaker.

Active reading | M | Active reading is a process or technique of actively engaging with the text being read.

Analyses/presentation of literature | PCC | Students performing detailed examination/presentation of the elements or structure of primary literature. Found in Hoskins et al (2011).

Analyze data | PQR | Detailed examination/presentation of the elements or structure of data. Found in Escobar et al. (2019); Schultheis & Kjelvik (2015).

Annotating figures | M, PCC | Asking students to explain or comment on a figure. Found in Round & Campbell (2013).

Application of science and reasoning skills | PPS | An activity that focuses on having students apply scientific concepts and reasoning skills.

Applying knowledge of other subjects | PIN | An activity that focuses on having students apply their knowledge in other disciplines to a scientific problem. Found in Kohn et al. (2018).

Assessments | A | Assessments are any activity that gives feedback to the teacher about the student(s) understanding and mastery of material. Depending on the instructional goals, classroom assessment techniques (CATs) can employ closed-ended assessment questions, open-ended assessment questions, and questions at a variety of Bloom's taxonomy levels (Miller & Tanner, 2015). *Synonyms: CAT Scans*

Audience response questions | A | A classroom response system is a set of hardware and software that facilitates teaching activities by collecting student answers and giving real time feedback to the teacher. Found in Caldwell (2007); Knight et al. (2013); Smith et al. (2009); Smith et al. (2011).
Synonyms: Student Response Systems, Clicker Questions, Personal Response System, iClicker, Classpulse, Classroom Polling, Electronic Polling, & Live Polling

Bingo | G | Review game in which students try to answer questions on a game board similar to non-academic versions of the game. Found in Tinsley (2019).
Brainstorming | M | Idea generation focused on a topic or question.
Break down scientific arguments | PPS, M | Analyzing and understanding a scientific argument.
Building models | PMS | Conceptually devise a representation of a system, object, or phenomenon. Not assumed to be a physical task. Found in Wilson et al. (2020).
Canvas collaboration | W, D | Use of the online classroom system Canvas for collaborative work.
Card sorts | A, D, M | This strategy gives students the opportunity to work with vocabulary, terms, and concepts. Students sort cards with the terms and concepts into categories based on meaning. Sorting the cards gives students a structure to talk meaningfully with one another about content and helps teachers check for understanding (Smith et al., 2013).
Carousel graffiti | D, M | A Carousel Activity is a communicative and interactive opportunity for participants/students to get up and move around a room in a circular fashion (much like a real carousel might do), stopping intermittingly to comment, discuss, or respond (verbally or in writing) to probing headings/ questions/topics/themes posted by a facilitator/teacher that is related to a given topic/theme.
Case studies | PSS | Case-based learning begins with a situation or scenario that poses one or more issues the students need to address. Importantly, both case-based and problem-based learning usually involve students working in structured groups in which they collaboratively identify questions and confusions and seek out additional information to expand their understanding of concepts related to the problem or case (Miller & Tanner, 2015). Found in Allen & Tanner (2005); Emtage et al. (2016); Herreid (1994); Stowell & Martin (2016).
Circulate to check for understanding | A, C | Activities pursued by teachers to keep track of student learning for purposes of making instructional decisions and providing feedback to students on their progress.
Class activities | O | Classroom activities are those done by student inside the class as part of applying or doing the practical part of the lesson after listening to the theoretical part which is presented by an instructor.
Class discussion | D | A classroom discussion is a sustained exchange between and among teachers and their students with the purpose of developing students' capabilities or skills and/or expanding students' understanding—both shared and individual—of a specific concept or instructional goal.
Cold call | A | Calling on a student whose hand is not raised. Freeman. also Knight et al. 2013.
Collaboration | PCC | Science is, by nature, a collaborative endeavor, and all scientific careers to which undergraduate students aspire will require extensive skills in working collaboratively. Group work, also referred to as cooperative learning, is a term that refers to activities that require students to engage in active learning with others, during which they work together toward a common outcome and practice improving their collaborative skills (Johnson et al., 1998). Group work and cooperative learning is often assumed to include more than two students, but usually no more than six (Miller & Tanner, 2015).
Collecting data | PPS | The collection of data through experimentation and/or observation. Found in Parrotta et al. (2019).
Compare & contrast | D, M | Teacher and student(s) comparing and contrasting concepts or scenarios to fuel discussion.

Competitive quizzes | A, G | A game-like function to increase student engagement while reviewing.
Complete exercises | O | Completion of exercises.
Completing charts | PQR | Teacher and students completing charts.
Completing supporting activities when assessments reveal a problem area | C | Completing supporting activities when assessments reveal a problem area.
Computer-based summative measure of student performance for each objective | A | Computer based summative measure of student performance for each objective.
Concept maps | M, V | Drawings or diagrams showing the mental connections that students make between a major concept the instructor focuses on and other concepts they have learned (Angelo & Cross, 2012).
Construct phylogenetic trees | M | Students constructing phylogenetic trees. Used in Ballen & Greene (2017); Eddy et al. (2013); Karimi et al. (2017).
Counter stereotypical scientist activity | M | Metacognitive assignments to help traditionally underserved students persist and succeed in science. Found in Schultheis & Kjelvik (2015); Schinske et al. (2016); Project Biodiversify: www.projectbiodiversify.org.
Creating skits | V | Skits to help understand and demonstrate content.
Creative activities | M | Activities to help understand content and generate higher level thinking.
Critical thinking exercises | M | Exercises that involve critical thinking about course material. Found in Styers et al. (2018).
Crossword puzzles | G | Games to help remember content and build verbiage familiarity.
Dancing | V | Dancing for learning purposes.
Data activities | PQR | Using data from experimentation/observation in an activity. Found in Schultheis & Kjelvik (2015).
Data collection | PPS | Collecting data from an experiment/observation. Found in Hanauer et al. (2017).
Debates | D | A regulated discussion of a proposition between two matched sides. Found in Vandegrift & Dawson (2016).
Debrief | M | To carefully review upon completion for the purpose of building greater understanding
Demonstrations | V | An act, process, or means of demonstrating knowledge; an outward expression or display.
Design experiments | PPS | Designing an experiment to test a hypothesis.
Designing vignettes | V | Creating a picture or sketch.
Development of physical props | V | Developing props to better explain content.
Diagramming | M, V | Creation of a diagram.
Discuss literature | D, PCC | Discussion of primary literature.
Discussion questions | D | Questions to spark discussion.
Discussions | D | Consideration of a question in open and usually informal debate.
Dissections | PPS, V | Dissecting an animal in a lab setting.
Drawing | V | Illustrating concepts visually in an informal, non-schematic representation.
Essay outlines | M | Creating the basic outline of an essay, helping to organize ideas.
Ethical stakeholder activities | PSS | Activities demonstrating how your decisions and desires as a stakeholder have implications. Found in Larson & Wong (2019).
Evaluate data | PPS | An activity in which students are asked to draw conclusions from a data set.

Exam redux | M | Review of exam material after the exam has been taken.
Exam Wrappers | M | Exam wrappers are short activities that direct students to review their performance (and the instructor\'s feedback) on an exam with an eye toward adapting their future learning. Exam wrappers ask students three kinds of questions: How did they prepare for the exam? What kind of errors did they make on the exam? What could they do differently next time? Each of the question types is discussed next (Carnegie Mellon University, 2020). Found in Smith et al. (2019).
Exercises that lead students to draw their own conclusions | M | Exercises that lead students to draw their own conclusions.
Exit tickets | A | Before students leave, they hand the teacher a ticket filled out with an answer to a question, a solution to a problem, or a response to what they've learned. (Lansing Community College Web Management, 2008)
Experimental design | PPS | Taking the time and effort to organize the experiment properly to ensure that the right type of data, and enough of it, is available to answer the questions of interest as clearly and efficiently as possible
Experiments | PPS | A scientific procedure undertaken to make a discovery, test a hypothesis, or demonstrate a known fact.
Explanations | O | Making known or understandable.
Family feud | G | Review game loosely following the same structure as the television show of the same name.
Feedback | A | The transmission of evaluative or corrective information about an action, event, or process to the original or controlling source.
Field trips | V | Often significantly enhance the content of a course by providing information that is difficult to convey in a laboratory or classroom setting.
Fix the scenario | M | Student(s) work to identify problems and propose solutions to a scenario given by the teacher.
Flipped classroom | C | Students gain first-exposure learning prior to class and focus on the processing part of learning (synthesizing, analyzing, problem-solving, etc.) in class (Tucker, 2012). Found in Jensen et al. (2015); van Vliet et al. (2015).
Flow charts | M, V | A diagram that represents a process or chain of thought.
Follow instructions | C | Following instructions.
Formative assessment | A | This diagnostic use of assessment to provide feedback to teachers and students over the course of instruction is called formative assessment (Boston, 2002).
Gallery walk | D, W | This discussion technique allows students to be actively engages as they walk in team throughout the classroom. They work together in small groups to share ideas and respond to meaningful questions, documents, images, problem-solving situations or texts (Francek, 2006).
Games | G | Review activities designed to help students learn or retain material in an engaging and fun way.
Garage demos | V | Based on experience of students in introductory physics, where large-scale in-class demonstrations had been very effective in solidifying understanding and ability to recall basic principles, teachers use common items to create models and demonstrations to engage students.
Grant proposals | PPS, PSS, PCC | A formal proposal submitted to a government or civilian entity that outlines a proposed project and shows budgetary requirements and requests monetary assistance in the form of a grant

Graphic organizers/worksheets | M, V | A visual representation of knowledge, a way of structuring information, and of arranging essential aspects of an idea or a topic into a pattern using labels.
Graphing | PQR | Creating graphs based on data.
Group activities | W, D | Science is, by nature, a collaborative endeavor, and all scientific careers to which undergraduate students aspire will require extensive skills in working collaboratively. Group work, also referred to as cooperative learning, is a term that refers to activities that require students to engage in active learning with others, during which they work together toward a common outcome and practice improving their collaborative skills (Johnson et al., 1998). Group work and cooperative learning is often assumed to include more than two students, but usually no more than six (Miller & Tanner, 2015). Synonyms: Cooperative Learning Activities
Group assignments | GW, D | Group work, also referred to as cooperative learning, is a term that refers to activities that require students to engage in active learning with others, during which they work together toward a common outcome and practice improving their collaborative skills (Johnson et al., 1998). Group work and cooperative learning is often assumed to include more than two students, but usually no more than six (Miller & Tanner, 2015).
Group brainstorming | W, M | Working together in a group of 2-6 students to propose solutions to a problem or to answer a question
Group discussion | GW, D | Discussion in a group of 2-6 students (Miller & Tanner, 2015).
Group discussion questions | W, D, A | Discussion in a group of 2-6 students aimed at providing a solution to a question (Miller & Tanner, 2015).
Group exams | W, D, A | Collaboration on an exam in a group of 2-6 students (Miller & Tanner, 2015). Found in Cortright et al. (2003).
Group learning | W, D | Science is, by nature, a collaborative endeavor, and all scientific careers to which undergraduate students aspire will require extensive skills in working collaboratively. Group work, also referred to as cooperative learning, is a term that refers to activities that require students to engage in active learning with others, during which they work together toward a common outcome and practice improving their collaborative skills (Johnson et al., 1998). Group work and cooperative learning is often assumed to include more than two students, but usually no more than six (Miller & Tanner, 2015).
Synonyms: Cooperative Learning
Group problems | W, D | Working on a problem as a group of 2-6 students.
Group projects | W, D, A, M | Science is, by nature, a collaborative endeavor, and all scientific careers to which undergraduate students aspire will require extensive skills in working collaboratively. Group work, also referred to as cooperative learning, is a term that refers to activities that require students to engage in active learning with others, during which they work together toward a common outcome and practice improving their collaborative skills (Johnson et al., 1998). Group work and cooperative learning is often assumed to include more than two students, but usually no more than six (Miller & Tanner, 2015).
Group random call | W, D, A | A group of 2-6 students are randomly selected to answer a question/problem posed by the teacher. Found in Knight et al. (2013).
Group work | W, D | Science is, by nature, a collaborative endeavor, and all scientific careers to which undergraduate students aspire will require extensive skills in working collaboratively. Group work, also referred to as cooperative learning, is a term that refers to activities that require students to engage in active learning with others, during which they work together toward a

common outcome and practice improving their collaborative skills (Johnson et al., 1998). Group work and cooperative learning is often assumed to include more than two students, but usually no more than six (Miller & Tanner, 2015).
Group work with worksheets | W, D, K | Work given to a group of 2-6 students that includes or centers around worksheets (Miller & Tanner, 2015).
Groups Develop Hypothesis | W, D, PPS | To work out the possibilities of a tentative assumption made in order to draw out and test its logical or empirical consequences as a group.
Guest Lectures | C | A discourse given before an audience or class especially for instruction presented by someone who is not the assigned lecturer.
Guided Self-Directed Learning | C | Directed for or by oneself knowledge acquisition that is exhibited and explained to highlight points of interest.
Hands-on Activities | M | Characterized by active personal involvement an educational procedure designed to stimulate learning by firsthand experience
Hands-on Computer work | M, PMS | To perform or carry through a task requiring sustained effort or continuous repeated operations on a computer characterized by active personal involvement.
Hands-on laboratory experiments | M, PMS | An operation or procedure carried out under controlled conditions in order to discover an unknown effect or law, to test or establish a hypothesis, or to illustrate a known law characterized by active personal involvement.
Homework Assignments | A | To appoint as a task preparatory reading or research.
Hybrid CURE | C, PPS | Course-based undergraduate research experiences that involve whole classes of students in addressing a research question or problem that is of interest to the scientific community blended with more traditional lecture design.
Hypothesis Generation | PPS | To bring into existence a tentative assumption made in order to draw out and test its logical or empirical consequences.
Identifying Students' Misconceptions | M | To establish the distinguishing character of a wrong or inaccurate idea held by students.
iFAT | A | Immediate Feedback Assessment Technique: Students take a multiple-choice test in which they can immediately see if the answer they gave was right or wrong (Smith, J. A. 2013). Found in Cotner et al. (2008).
Synonyms: iRAT
In-class work | M | To perform or carry through a task requiring sustained effort or continuous repeated operations in the period during which such a body meets.
In-class writing assignments | M | Assignments given in class that serve to have students think and write about some aspect of the course.
Inclusive teaching | C | To conduct instruction regularly, allowing and accommodating for people who have historically been excluded (as because of their race, gender, sexuality, or ability). Found in Dewsbury & Brame (2019).
Index card activity | A, D, M | An educational procedure designed to stimulate learning by having students write questions they have about the course material on index cards, some of which will be discussed at the end of class.
Individual brainstorming | M | The mulling over of ideas by one person in an attempt to devise or find a solution to a problem.
Individual problem sets | M, A | Intended for one person, a group of a specific number of repetitions of a particular exercise, questions raised for inquiry, consideration, or solution.

Individual projects | A, M | Intended for one person, a task or problem engaged in usually by a group of students to supplement and apply classroom studies.
Individual reflections | M | Intended for one person, a period of consideration of some subject matter, idea, or purpose.
Individual work | M | To perform or carry through a task requiring sustained effort or continuous repeated operations intended for one person.
Individual writing | M | A written composition intended for one person to complete.
Inquiry | M | A systematic investigation and an examination into facts or principles. Found in Allen & Tanner (2005); Frisch et al. (2018); National Research Council (1996); Uno (1990).
Interactive and constructive activities | C | A mutually or reciprocally active educational procedure designed to stimulate learning by firsthand experience that promotes improvement or development.
Interactive games | G | Any mutually or reciprocally active activity undertaken or regarded as a contest involving rivalry, strategy, or struggle.
Interactive lectures | D | A mutually or reciprocally active discourse given before an audience or class especially for instruction.
Interactive tutorials | V | A mutually or reciprocally active paper, book, film, or computer program that provides practical information about a specific subject.
Interactive videos | V, D | A mutually or reciprocally active recording of a motion picture.
Interpret data | PPS | To explain or tell the meaning of or to present in understandable terms the factual information (such as measurements or statistics) used as a basis for reasoning, discussion, or calculation.
Interpret figures/graphs | PPS | To explain or tell the meaning of or to present in understandable terms a diagram or pictorial illustration of textual matter or a diagram that represents the variation of a variable in comparison with that of one or more other variables.
Jeopardy! | G, A | A quiz competition in which contestants are presented with clues in the form of answers and must phrase their responses in the form of questions (BenekRivera & Mathews, 2004).
Jigsaw | W, D, M | Divide students into small groups, giving each group a problem. Ask students to work to formulate effective ways of teaching problem-solving strategies for that kind of problem to another group of students. After students have had a chance to master their problem, bring the groups back together so that each group has an expert in each problem type (Collaborative Learning Techniques). Found in Theobald et al. (2017); Wiggins et al. (2017).
Journal club | W, D, M | An association of persons usually meeting periodically sharing records of experiences, ideas, or reflections.
Just-in-time telling | C | Also known as Just-in-time teaching, is a teaching and learning strategy comprised of both classroom activities that promote active learning and webbased resources that are used to enhance the classroom activities (Novak et al., 1999). Found in Marrs & Novak (2004).
Kahoot | G, A | Kahoot! is a game-based learning platform, used as educational technology in schools and other educational institutions. Its learning games, "Kahoots", are multiple-choice quizzes that allow user generation and can be accessed via a web browser or the Kahoot app (Kahoot!, 2013)
Knowledge checks | A, M | To compare with a source, original, or authority a student's acquaintance with or understanding of a science, art, or technique.
Lab | PPS | An academic period set aside for laboratory work.

Lab notebook | M | A book for notes or memoranda detailing experiences and knowledge gained in a place equipped for experimental study in a science or for testing and analysis.
Learning Catalytics | W, D, A, M | Engage your students in team-based and group learning activities with this interactive student response tool (Pearson, 2011).
Learning Goals | A, M | Setting goals for students to work toward that will give them a chance to think on their understanding of the material and show their progress. Found in Allen & Tanner (2006).
Literature review | M | An activity that uses critical evaluation of the body of writings on a particular subject.
Low risk pre lecture quizzes | A | A short oral or written test not likely to result in failure, harm, or injury administered before the period of instruction. Found in Ballen et al. (2017); Casper et al. (2019); Moravec et al. (2010).
Make graphs | PPS | To put together from components a diagram (such as a series of one or more points, lines, line segments, curves, or areas) that represents the variation of a variable in comparison with that of one or more other variables.
Make predictions | M | To lay out and construct a foretelling on the basis of observation, experience, or scientific reason.
Making models | PPS | To lay out and construct a system of postulates, data, and inferences presented as a mathematical description of an entity or state of affairs.
Making quiz questions | M | An activity where students create short oral or written test questions.
Manipulables | V | Items that a student can move, arrange, operate, or control with their hands or another body part or by mechanical means, especially in a skillful manner (Krech, 2000).
Many hands, many voices | A | After asking a question, ask for multiple hands and multiple voices to respond to any question posed during class time to broaden participation and increase the breadth of ideas flowing from students to instructors (Tanner, 2013).
Synonyms: "Multiple hands, multiple voices"
Metacognition activities | M | An educational procedure designed to stimulate awareness or analysis of one's own learning or thinking processes by firsthand experience. Found in Dye & Stanton (2017); Flavell (1979); Sabel et al. (2017); Tanner (2012).
Mini lectures | C | Lectures that last 15 min or less to clarify concepts and highlight terminology from the textbook Found in Walker et al. (2008).
Model building | PPS | The formation and subsequent development of mental models by a learner (Buckley, 2012).
Model-based learning | M | The formation and subsequent development of mental models by a learner (Buckley, 2012).
Synonyms: Models
Module | C | An educational unit which covers a single subject or topic
Muddiest point | M | The technique consists of asking students to jot down a quick response to one question: "What was the muddiest point in [the lecture, discussion, homework assignment, film, etc.]?" The term "muddiest" means "most unclear" or "most confusing" (Mcdaniel, 2018).
Multiple choice conceptual questions | A | Examination into an abstract or generic idea generalized from instances with more than one pre-written answer to select from.
Normalize error | C | Make it clear to students that incorrect answers are just as fundamental to education as correct answers and are completely normal (Puryear, 2014).
Not Lecture | C | Not a discourse given before an audience or class especially for instruction

Note-checking | M, W, D | Students to compare their notes with a partner. This exercise allows students to see how other students take notes, and it also gives students the quick opportunity to reconsider what was important in the material.
Observing Cellular Mechanisms | PMS | To come to realize or know especially through consideration of noted facts.
Online learning modules | C | An educational unit which covers a single subject or topic available on the internet. Found in Goff et al. (2017).
Online quizzes | A | A short oral or written test administered online. Found in Brown et al. (2015); Pan et al. (2019).
Online textbook | C | A textbook available on the internet.
Open-ended questions | D, A, M | Permit spontaneous and unguided responses.
Synonyms: Oral questions; Open-ended questions about potential complications related to research, Short answer discussion questions
Pair discussions | W, D | Consideration of a question in open and usually informal debate by two or more students.
Paper discussions | D | Consideration of a question in open and usually informal debate on published work.
Participatory projects | W, D | A task or problem engaged in usually by a group of students to supplement and apply classroom studies.
Pause and recall | D, W, M | Short pauses built into lectures in which students are given a chance to recall what they had learned so far in lecture and to review it with their peers (Harrington, 2014).
Peer discussion | W, D | Consideration of a question in open and usually informal debate between students.
Peer evaluation | A | Determination of the value, nature, character, or quality of one's work by another student. Found in Smith et al. (2009).
Peer instruction | C, W, D | Students teach each other (Rubin & Hebert, 1998). Found in Snyder et al. (2016).
Synonyms: Peer teaching
Peer review | A | The active learning strategy of peer review was used to enhance student understanding and engagement in the critique process. This active learning strategy involved small groups of students who worked together as a team to evaluate the work of other student groups using a critique-rubric (Odom, Glenn, Sanner, & Cannella, 2009).
Perform analyses | PQR | A detailed examination of anything complex in order to understand its nature or to determine its essential features: a thorough study.
Plays and videos | V | (1) the stage representation of an action or story; (2) being, relating to, or involving images on a television screen or computer display.
POGIL | W, D, N, C | POGIL is an acronym for Process Oriented Guided Inquiry Learning. Because POGIL is a student-centered instructional approach, in a typical POGIL classroom or laboratory, students work in small teams with the instructor acting as a facilitator. The student teams use specially designed activities that generally follow a learning cycle paradigm. These activities are designed to have three characteristics (POGIL, 1994). Found in Murray (2014); Roller & Zori (2017).
Poll everywhere | A | A website where an instructor can pose a question and students respond simultaneously from the privacy of their tablets or other devices. Since feedback is anonymous,

everyone can focus on what is said rather than who said it. All students have an equal opportunity to be heard (Poll Everywhere, 2007).
Poster presentation | D, A, PCC | A poster presentation is the presentation of research information in the form of a paper poster that conference participants may view (Purrington, 2010).
Practice exams | M | To perform an exercise designed to examine progress or test qualification or knowledge repeatedly so as to become proficient.
Practice questions | M | An interrogative expression often used to test knowledge to perform at repeatedly so as to become proficient.
Practicing skills | PPS | To perform the ability to use one's knowledge effectively and readily in execution or performance repeatedly so as to become proficient.
Praise effort | C | Verbally validate student effort (Tennessee Behavior Supports Project at Vanderbilt, 2016).
Praise improvement | C | Explicitly recognizing and praising student growth (Becker et al., 2017).
Pre-class reading and writing | C | Reading and writing assignments to be done by students prior to the material being covered in class.
Pre-class tasks | C | A piece of work to be finished before the next class period.
Synonyms: Student preparation before class
Preceptors | C | Tutors.
Synonyms: Tutors
Predict-explain-observe | PPS | POE is a strategy often used in science. It works best with demonstrations that allow immediate observations and suits Physical and Material World contexts. A similar strategy also works well in mathematics, particularly in statistics. It can be used for: finding out students' initial ideas, providing teachers with information about students' thinking, generating discussion, motivating students to want to explore the concept, generating investigations (White & Gunstone, 1992).
Predicting cellular mechanisms | PPS | To declare or indicate in advance; hypothesize how they work.
Presentation to Class | A, M | Asking students to present material to their peers (with their peers involved in the assessment) would alert all the students to: 'what makes a good presentation'; increase their subjectspecific knowledge; and reinforce their immediate (and the wider) group's identity (Dart, 2006). Found in Allen & Tanner (2005); Eisen (1998).
Problem-based learning | C, W, M | Student learning is promoted by the introduction of complex, real-world problems (Woods, 1985). Found in Allen & Tanner (2003); Tatner & Tierney (2016).
Problem sequences | M | A continuous or connected series of questions raised for inquiry, consideration, or solution.
Synonyms: problem sets
Problem solving | M | To find a solution, explanation, or answer for questions raised for inquiry, consideration, or solution.
Synonyms: Solving problems
Project-based learning | C, M | A model that organizes learning around projects. Projects are complex tasks, based on challenging questions or problems, that involve students in design, problem-solving, decision making, or investigative activities; give students the opportunity to work relatively autonomously over extended periods of time; and culminate in realistic products

or presentations (Thomas, Mergendoller, & Michaelson, 1999). Found in Wright & Boggs (2002); Zwick (2018).
Projects | A, M | A planned piece of work that has a specific purpose (such as to find information or to make something new) and that usually requires a lot of time. : a task or problem in school that requires careful work over a long period of time.
Propose further research | PPS | To set forth studious inquiry or examination for acceptance or rejection.
Puzzles | G | A question, problem, or contrivance designed for testing ingenuity.
Quantitative problems | PPS | As for a quantitative problem, it requires the student to manipulate a formula or work through an algorithm to find a numerical solution to the problem (Nakhleh, 1993). Found in Aikens & Dolan (2014); Andrews et al. (2017); Bray et al. (2016); Goldstein & Flynn (2011).
Question & answer | D, A | a period of time when people can have their questions answered. *Synonyms: Students answering questions*
Questioning prior knowledge | M | To subject the range of one's information or understanding to analysis.
Quiz | A | A short oral or written test.
Quiz bowl | A, G | Quiz bowl is a game in which two teams compete head-to-head to answer questions from all areas of knowledge (National Academic Quiz Tournaments, LLC, 2019).
Random call | A | The instructor may select students from the class to participate in specific activities. For smaller- sized courses, students may be selected from a cup holding popsicle sticks labeled with each student's name. For larger course class sizes, instructors can choose index cards, labeled with each student's name, out of a stack student (Tanner, 2012). Found in Ballen et al. (2019); Eddy et al. (2014). Knight et al 2013.
Reading | M | To learn from what one has seen or found in writing or printing.
Reading and evaluating scientific literature | M | To learn from what one has seen or found in writing or printing and to determine or fix the value of it. Found in Colosi & Zales (1998); Murray (2014).
Reading assignments | M, PPS | The reading of a passage assigned by the teacher.
Reading graphs | PPS, M | The interpretation of a visual representation of data/results (Tairab & Khalaf Al-Naqbi, 2004).
Redistribution of point allocation | C | The instructor reworks their grading system to reward group work and ongoing preparation rather than exam performance exclusively (Ballen, Wieman, Salehi, Searle, & Zamudio, 2017).
Reflect on experience | M | Consideration of some subject matter, idea, or purpose. *Synonyms: reflections, reflecting on the effectiveness of your study habit, reflecting on cellular mechanisms, reflective pauses, reflective writing*
Reflective index cards | M | Students write out one to three ideas on an index card that capture their initial thoughts on how to answer a question posed by the instructor. The act of writing itself may lead students to discover points of confusion or key insights. If collected, this writing can hold students accountable in thinking and recording their ideas (Tanner, 2013).
Reflective journals | M | Prior to class, students complete assigned readings and then write about what they learned (e.g. key points, summary, understanding, discovery, and points of confusion). The students then participate in class activities that cover the topics from the readings. After class, the students revise the preclass reflective journal in another color font and submit it for credit as the post-class reflective journal (Long, Su, & Waugh, 2013).

Relating scientific concepts to everyday phenomena or human experiences | PSS | The relation of the biological concepts learned in class to the real world (AAAS, 2010).
Synonyms: Think of science within the context of society
Reporting cellular mechanisms | PCC |
Research projects | PPS | A scientific investigation, usually using scientific methods, to achieve defined objectives. Found in Bakshi et al. (2019); Cotner & Hebert 2016.
Research skills | PPS | Developed aptitude or ability for diligent searching.
Researching information | PPS | Careful or diligent search.
Respond to instructor questions | A | To say something in return.
Results generation | PPS | Something obtained by calculation or investigation.
Retaking exams | A | A chance for students to take an assessment again.
Reviewing exam questions | M | The instructor explains assessment questions to the class. By recognizing their errors, each student can gain a better understanding (Hassan, 2011).
Role-playing | V | To represent in action.
Running simulations | PMS | The imitative representation of the functioning of one system or process by means of the functioning of another. Found in Bergan-Roller et al. (2017).
Synonyms: Simulations
Science argumentation | PCC | Students form persuasive exchanges to construct knowledge about the natural world and science (Munford, 2002). Found in Lacum et al. (2014).
Science skills | PCC ALL | A variety of developed attributes that aid in the processes or understanding of science. According to AAAS (2010), there are six core competencies every undergraduate biology student should practice and hone.
Self-directed learning | M | The overt management of the external learning environment (Pilling-Cormick & Garrison, 2007).
Self-reflections | M | An examination of one's own thoughts and feelings.
Sentence sorts | W, M | Below are three different ways to use sentence strips in BrainPOP ELL lessons. They all involve cognitive skills – putting items on a continuum, sequencing events from the movie, and matching sentence halves. Using manipulative is always good because students are actively engaged in the activity. Do them as partner activities, so students are using the target vocabulary and concepts as they share ideas and communicate with each other.
Sequence reconstructions | M | "Analyze and depict graphically a series of events, actions, roles or decisions. Useful for understanding processes, cause and effect, and chronological series, and organizing information in an orderly, coherent progression" (Barkley, Cross, & Major, 2005 p. 206).
Set up an experiment | PPS |
Synonyms: Set up and maintain their own aquaria
Share prior knowledge | D, PCC | Students reveal their current understanding of a particular topic (Meyrick, 2011). *Synonyms: Sharing info*
Skits | V | Either (1) a satirical or humorous story or sketch or (2) a short serious dramatic piece especially one done by amateurs.
Snowball responses | M, D, W | Learning cooperative with snowball throwing method to train students to be more responsive independently and enable more intensive interaction occur both in asking questions and opinions with other students in one group in the form of a snowball made of paper (Marlena, 2016).
Socratic discussion | M, D | The act of teaching did not consist in transmitting information from "teacher" to "student," but was an exercise in helping students to cease their reliance on

perceptual knowledge of the imperfect material world, and stimulating them to introspectively discover true knowledge through logic and reasoning. prompting students, through cross-examination, into acknowledging their own fallacies and then asking them provocative questions to steer them towards realizing true knowledge via introspection (Stoddard & O'Dell, 2016).
Synonyms: Socratic method, Socratic questioning, Thought questions

Sorting steps | M, W | Below are three different ways to use sentence strips in BrainPOP ELL lessons. They all involve cognitive skills – putting items on a continuum, sequencing events from the movie, and matching sentence halves. Using manipulative is always good because students are actively engaged in the activity. Do them as partner activities, so students are using the target vocabulary and concepts as they share ideas and communicate with each other.

Stand and shout outs | A | The instructor asks a question to which each individual student will respond. Each response is usually less than 30 seconds in length (Tanner, 2013).
Synonyms: Whip around

Statement corrections | K | The instructor provides statements, readings, proofs, or other material that contains errors. The students are charged with finding and correcting the errors. Concepts that students commonly misunderstand are well suited for this activity (The Derek Bok Center for Teaching and Learning at Harvard University, 2016)

Stretch-it questions | M | A technique in which the instructor asks additional questions, after asking an initial question, to extend the response and the learning even further. Often, questions such as, "How? and "Why?" are repeatedly asked (Lemov, 2010).

Strip sentences | M | The goal of this activity is for students to order a set of items, such as steps in a biological process or a series of historical events. As one strategy, the instructor provides students with a list of items written on strips of paper for the students to sort (Bhatt, 2007).
Synonyms: Strip sequences

Structured problems | M | Follow a structured format to solve problems. It is useful for "dividing problem-solving processes into manageable steps so that students don't feel overwhelmed and so that they learn to identify, analyze, and solve problems in an organized manner" (Barkley, Cross, & Major, 2005, p.171)

Student ownership | C | Students are charged with leading their learning journey, and the teacher becomes a guide to aid them on this journey (Weimer, 2002).
Synonyms: Student-centered; Supporting students working individually

Student-led discussion | D, M | Students enrolled in the class each take a turn in facilitating a discussion with a group of five to seven peers on an assigned article. The facilitator's responsibility is to review the article, prepare questions that he/she believes would spark discussion, and facilitate the group discussion. The role of the group members who are not facilitators that day is to read the article and come prepared with a typed sheet of three points that were of interest to them, and about which they are prepared to speak (McGlynnStewart, 2015).

Summarizing | M | Covering the main points succinctly.

Synthesis | M | The combining of often diverse concepts into one coherent concept.

Teachers answering questions | C | Teachers answering questions posed by the students

Team-based learning quizzes | W, A | The completion of a short oral or written test by a group of students.
Synonyms: Team quizzes, Team-based learning

Team challenges | W, M | The completion of a stimulating task or problem by a group of students.

Synonyms: Team activities, Small-group active-engagement (GAE) exercises
Team-based learning | C | Students use class concepts to solve problems within their groups. The students must be held accountable for their individual and group work and provided with frequent feedback. The assigned groups need to promote learning and team interdependence (Michaelsen & Sweet, 2008). Found in Haidet et al. (2014); Jeno et al. (2017).
Test feedback with discussion | D, M | Getting tests back, looking over answers, discussing them and what you got wrong and why.
Think out loud | M, W | Learners have opportunities to talk with their peers about their ideas, observations, and understanding. These opportunities are helpful because in expressing their thinking out loud, learners: (1) find out what they understand and don't understand; (2) make connections between new and existing knowledge; and (3) reflect on their own thinking.
Think-pair-share | W, D, M | Involves giving all students a minute or so to think (or write) about their ideas concerning a biological question. Students are then tasked with turning and talking with a neighboring student to compare ideas and identify points of agreement and misalignment (Tanner, 2013).
Synonyms: Turn and talk
Thinking time | M | An allotted period to use one's mind to produce thoughts.
Top hat | C | Top Hat's active learning technology helps professors engage students before, during, and after class. This engagement includes access to electronic textbooks, assessments, assignments, and in class feedback (Top Hat, 2009).
Troubleshoot | M | Troubleshooting exercises have been commonly included in the problem sections of recently published textbooks on electronics and circuit analysis. Such problems demand a minimum level of knowledge and comprehension that has to be applied before any conclusion(s) may be analyzed then synthesized in order to facilitate the evaluation of the resulting outcome(s) by the student (Banky & Wong, 2007).
Two-stage exams | W, A, M | Students take the same exam repeatedly. They first take it individually, then take it again working in pairs, and then finally take it for the last time while working in larger groups (Yuretich, Khan, Leckie, & Clement, 2001). This approach uses the exam itself not only for evaluation, but also as a learning tool (Zipp, 2007). Found in Wieman et al. (2014).
Using models | PMS | To utilize a representation of something.
Venn diagrams | M, V | A graph that employs circles to represent logical relations between the terms of propositions by the inclusion, exclusion, or intersection of the curves.
Verbal questions | A | A spoken interrogative expression often used to test knowledge.
Videos | V | A digital recording of an image or set of images (e.g. movie or animation).
Weekly review | C | A study of material previously studied, conducted once every sevenday period.
Working problems | M | The manner of functioning or operating a question raised for inquiry, consideration, or solution.
Working with models | PMS | The manner of functioning or operating a miniature representation of something.
Worksheets | K | A sheet of paper on which are printed exercises and problems to be solved by a student.
Writing | M | A letter, note, or notice used to communicate or record.
Synonyms: Writing exercises, writing prompts, writing time

Writing assignments | M, A | A specified task or amount of work assigned or undertaken as if assigned by authority.

The following strategies were not defined or categorized because we either (1) did not know what they meant or (2) they were vague: ASK, CREATE, Real science, Study learning, Talk to text, Throat vote, and White board activities.

Also, please note that synonyms were provided strategies that we lumped together with the defined term because they were so similar.

Appendix C – References Used to Define Active Learning Strategies in Appendix B

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Appendix D – Citations used by the articles that defined active learning using support from the literature.

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