Supplemental Material

CBE—Life Sciences Education

Roche Allred *et al*.

Supporting Material

"Big Ideas" of the Introductory Chemistry and Biology Courses and the Connections Between Them

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The following document includes:

S.1 Demographic Information

Table S.1A Students who participated in the interviews

Students	Spring '14 (N = 14)	Spring '15 (N = 14)
Gender	*n* = 6 Females *n* = 8 Males	*n* = 9 Females *n* = 5 Males
Course GPAs	*GC 1*	*GC 1*
	Mean: 3.73 Median: 4.00 Minimum: 2.50 Maximum: 4.00	Mean:3.82 Median: 4.00 Minimum:3.00 Maximum:4.00
	GC 2	*GC 2*
	Mean: 3.23 Median: 3.50 Minimum: 2.00 Maximum: 4.00	Mean: 3.54 Median:3.50 Minimum:2.00 Maximum:4.00
	B1	*B1*
	Mean:3.38 Median: 4.00 Minimum:1.50 Maximum:4.00	Mean:3.42 Median: 3.47 Minimum: 2.00 Maximum: 4.00

Table S.1B Students who participated in the survey

Students	Registered in GC2 (N = 815)	Completed Survey (N = 109)
Gender	*n* = 457 Females *n* = 358 Males	*n* = 70 Females *n* = 39 Males
Performance:	Mean: 2.99** Median: 3.50 S.D.: 1.17 Minimum: 0.00 Maximum: 4.00	Mean: 3.17** Median: 3.00 S.D.: 1.01 Minimum: 0.00 Maximum: 4.00

** U = 41260.50, z = - 1.24, p = 0.214

S.2 Survey Summary

Questions:

1. HS Science Courses

2. General Chemistry
   a. Please provide a description of what you learned in your college general chemistry 1 lecture course.
   b. Do you feel that taking general chemistry 1 in college was a worthwhile experience? Please describe why or why not.

3. Other Course (Repeated for Biology, Physics and Other Science Courses as selected by the students) [Below questions are referring to the biology courses due to the nature of the paper]
   a. Please provide a description of what you learned in your college cell and molecular biology lecture course.
   b. Do you feel that taking cell and molecular biology in college was a worthwhile experience? Please describe why or why not.

4. Relationship Questions
   a. Please describe the ways in which you see the concepts in your college general chemistry 1 and cell and molecular biology courses as being connected.
   b. Do you think you benefited from taking you college general chemistry 1 and cell and molecular biology courses at the same time? Please describe why or why not.
   c. Please describe any ideas or topics that you covered in your general chemistry 1 course that you found useful for thinking about cell and molecular biology.
      i. Why do you think these ideas or topics were useful?
   d. Please describe any ideas or topics that you covered in your cell and molecular biology course that you found useful for thinking about general chemistry 1.
      i. Why do you think these ideas or topics were useful?
   e. Many colleges require that students take some chemistry as a prerequisite for biology. Why do you think this is the case?
   f. In your opinion, should some chemistry be a pre-requirement, co-requirement, or not required prior to taking biology? Please explain.

S.3 List for the "Things" Learned & Big Ideas in Chemistry: Codebook and Counts from the Interviews

As a reminder A represents "Things" Learned in the Course, B represents Big Ideas Listed or Stated, and C represents "Both: "Things" Learned in the Course & Big Ideas Listed and Stated.

Things Learned & Big Ideas	Descriptions*	A	B	C	Total
*To stay true to students' ideas, their language was used to generate each description, therefore, these are not always scientifically accurate.					
Interactions	Student talks about intermolecular forces, interactions, or attractions. Student may or may not provide one or more examples of intermolecular forces such as Dipole-dipole, London dispersions, hydrogen bonding.	9	1	12	22
Reactions	Student provides a general description of reactions. Student may or may not provide examples of reactions such as Acid-Base Reactions, Redox Reactions, etc.	8	4	8	20
Type of bonds	Student talks about bonds/bonding or types of bonds as a chemistry idea. As examples the student may or may not list different types of bonding such as covalent, ionic, metallic bonding, pi bonding, sigma bonding.	9	1	5	15
Structures	Student describes drawing structures of molecules or having a symbol in the center and dots representing the number of valence electrons to determine the number of bonds the element can form. Student also may or may not refer to the characteristics that can be identified from a molecule by looking at a Lewis structure such as: polarity, bond angles, shape.	7	0	7	14
Acids and bases	Student simply talks about acids and bases without specifying types of acids or bases. The student may or may not mention pK_a and K_a as part of their description of acids and bases.	9	2	1	12
Energy	Student talks about energy as a chemistry idea. The student may or may not talk about types of energy such as potential and kinetic energy and even potential energy curve.	7	1	3	11

Periodic trends	Student talks about trends associated to how elements are organized such as electronegativity, ionization energy, atomic radius, electron affinity, etc.	6	0	5	11
Gibbs free energy	Student explicitly mentions Gibbs free energy or free energy. This does not include a student mentioning Gibbs free energy as a description or an example of what s/he thinks thermodynamics is. It does not include a student talking about how a reaction depends on entropy and enthalpy unless they are explicit about how these relate to Gibbs free energy.	8	1	1	10
Reaction equilibrium	Student refers to the K and Q of an equation and how the calculations resulting from that determined what needed to be added to restore equilibrium. Student may also state that it equals the rate of forward over the backwards rate of a reactions.	6	1	3	10
Reaction rate	Student talks about the rate of reactions. The student may talk about energy curves, reaction coordinate diagrams or activation energy to describe what s/he means by reaction rate.	9	1	0	10
Enthalpy	Student talks about changes in enthalpy of a reaction as a chemistry idea. Student could simply list or mention delta H as an idea. This does not include a student mentioning enthalpy as a description or an example of what s/he thinks thermodynamics is.	7	2	0	9
Entropy	Student talks about changes in entropy of a reaction as a chemistry idea. Student could simply list or mention delta S as an idea. This does not include a student mentioning enthalpy as a description or an example of what s/he thinks thermodynamics is.	7	2	0	9

pH	Student talks about pH calculations and may or may not talk about pk_a, k_a and different types of concentrations of ions found in solutions to aid in calculating pH. Student may also mention the existence of a pH scale.	8	1	0	9
Stoichiometry	Student talks about stoichiometry as an import idea in chemistry. As examples student may mention balancing equations, conversions from moles to grams or vice versa, and the use of Avogadro's number for equations.	5	1	3	9
Molarity	Student talks about the stoichiometry of a solution or the concentration of a solution as an important concept in chemistry.	6	0	0	6
Atom	Student describes atoms as the entity that "everything is made of." The student could have also described the atom as the "building block" or "unit" of matter.	4	1	0	5
Atomic structure/theory	Student talks about the electronic structure of the atom and how in the center of the atom is made of protons and neutrons or nucleus. The student did not specify an atomic model and did not describe a specific atomic model.	3	1	1	5
Endothermic/ exothermic	Student talks about how reactions process that either absorb or release energy.	3	0	2	5
Thermodynamics	Student explicitly talks about thermodynamics, s/he can talk about heat, specific heat, temperature changes, entropy, enthalpy, heat capacity, systems, and surroundings as part of their descriptions or examples. This code does not include students that mentioned, entropy, enthalpy or Gibbs free energy.	4	0	1	5

Atomic models	Student talks about how the models of the electronic structure of the atom have evolved over time (History of the atomic models). Some students provided example of different models such as the Plum pudding model.	3	0	1	4
Molecular geometry	Student talks about 3D shapes, molecule shapes, etc. but does not explicitly mention any type of bonding or type of structure. Use this if the student does not mention any type of bonding theory.	4	0	0	4
Periodic table	Student talks about how the elements are organized, what kind of information can be obtained from the periodic table and the type of elements (Atomic numbers, atomic weight, group names, family names).	4	0	0	4
Bond strength	Student talks about the relative strength of bonds. A student might talk about factors that can affect the bond strength of a molecule, such as structure and polarity.	2	1	0	3
Hybridization	Student talks about the "mixing of atomic orbitals" and may or may not refer to this as hybridization of atomic orbitals.	2	0	1	3
Structure determines properties	Student describes how the structures of molecules determines the properties of molecules.	0	3	0	3
Bonding energy	Student specifically talks about the energy associated with bonds.	2	0	0	2

Buffers	Student talks about the composition of buffers, as being made of a weak acid and conjugate base. Student may or may not refer to the carbonic anhydrase system in the blood as a type of buffer as well as the equation needed to calculate pH for buffers - Henderson-Hasselback.	2	0	0	2
Electron orbital/ atomic orbital	Student describes the region of space where an electron is found as an electron/atomic orbital or just orbital.	2	0	0	2
Factors affecting reaction rates	Student talks about "things" that could affect reaction rates. Student mentions temperature, pressure and changes in concentrations.	2	0	0	2
Formal charges	Student talks about how they learned to determine the formal charges in the class.	2	0	0	2
Light particle	Students talks about light "existing" as packets or photons.	2	0	0	2
Molecular orbital	Student implicitly or explicitly mentions molecular orbitals.	2	0	0	2
Origins of the universe	Student talks about how the universe originated through the big bang theory as an important idea in chemistry.	2	0	0	2
Polarity	Student talks about the polarity of molecules, or the electronegativity associated with atoms within a molecule.	2	0	0	2
Properties of water	Student talks about the importance of water, and some properties associated to water.	1	1	0	2
Valence/outer orbitals	Student describes valence orbitals as the outermost shell or orbitals where electrons could be found.	2	0	0	2

Don't Know	Students talked about how they didn’t know what the big ideas of the course were.	0	2	0	2
Algorithmic problem	Student refers to using the correct formula to solve a problem.	0	1	0	1
Charged Molecule	Student talks about molecules having or “holding” either a positive or negative charge.	1	0	0	1
Chemical and physical foundations of life	Student says that the big idea of chemistry was to describe the “chemical and physical foundations of life” without providing more details.	1	0	0	1
Chemical vs. physical changes	Student talks about differences in chemical and physical changes.	1	0	0	1
Electron configuration	Student mentions electron configuration as a big idea of chemistry. Student may or may not talk about quantum numbers to talk about electron configuration.	1	0	0	1
Enzyme	Student talks about how there are proteins or enzymes that assist or help speed up reactions in the cell.	1	0	0	1
Equilibrium constant	Students mentions how reactions have an equilibrium constant and this value shows the point at which the forward and backward reaction rates are equal.	1	0	0	1
Forces	Student talks about how forces are important to understand in the course.	0	0	1	1
Ions	Student describes charged molecules or atoms as important ideas in chemistry.	0	1	0	1
Matter	Student talks about how everything is made out of matter.	0	1	0	1

Mixture and solutions	Student talks about how an important concept in chemistry is to be able to differentiate between mixtures and solutions.	1	0	0	1
Nucleophiles and electrophiles	Student talks about nucleophiles and electrophiles in terms of their reactivity/interactions with one another.	1	0	0	1
Quantum model	Student talks about the quantum theory and describes it in term of wavelength, frequency and how it relates to light particles.	1	0	0	1
Rate law	Student speaks about order of reactions. The student may mention the order of a reaction.	1	0	0	1
Rate order	Student talks about how the rate orders of reactions are related to how fast concentration of the reactants change.	1	0	0	1
Solubility	Student talks about how “things” dissolve.	1	0	0	1
Solutions	Student talks about solutions as an important concept in chemistry.	0	1	0	1
Type of systems	Student talks about closed and open systems independently of thermodynamics.	1	0	0	1
Valence electrons	Student talks about the outermost electrons in the atom.	1	0	0	1
VSEPR	Student specifically mentions VSEPR as an important chemistry idea and describe the structure of a molecule.	1	0	0	1
Wavelength	Student talks about learning about wavelength.	1	0	0	1

S.4 List for the "Things" Learned & Big Ideas in Biology: Codebook and Counts from the Interviews

Things Learned & Big Ideas	Descriptions*	A	B	C	Total
*To stay true to students' ideas, their language was used to generate each description, therefore, these are not always scientifically accurate.					
DNA replication	Student describes how DNA is replicated in the cell. The student could talk about templates or DNA strands.	16	1	5	22
Cell respiration	Student could talk about glycolysis or the production of ATP; Energy cycles, suggesting that energy is neither created nor destroyed. Students spoke about other processes involved in cellular respiration such as citric acid cycle/Krebs cycle.	9	1	7	17
DNA	Students talks about the importance of DNA. Student could describe the composition of DNA, referring to its double helix and the nucleotides and different nitrogenous bases.	10	4	2	16
Macromolecules	Student talks about how there are different types of macromolecules or biomolecules, their different structures, and mentioned carbohydrates, lipids, nucleic acids, and proteins.	11	0	4	15
Photosynthesis	Student describes this process as how energy comes from the sun and it cycles in plants, suggesting that energy is neither created nor destroyed.	11	0	4	15
Cell organelles	Student talks about the different "parts" of the cells. The student could refer to these parts as organelles or even list some of these organelles.	8	2	4	14
Structure-Function Relationship	Student describes or talks about how the structures of molecules/organelle determines its function.	1	8	2	11
Translation	Students talks about how mRNA is decoded in the ribosome to "get" proteins from individual amino acids.	7	3	1	11
Cell division	Student either mentions cell division or mentions meiosis and/or mitosis. Student could also refer to this as cell reproduction.	5	3	2	10
Transcriptions	Student describes how RNA is synthesized	7	2	1	10

	from the DNA.				
Mutation	Student talks about changes in genetic material and expression of proteins like Trisomy 21. Student may talk about mutations leading to the constant revision of vaccines and the production of cancer cells as a result of genetic changes.	9	0	0	9
Functional group	Student talks about different functional groups including Hydroxyl groups; phosphate groups, amino groups, methyl group, acetyl group.	6	0	1	7
Enzyme	Student talks about how there are proteins or enzymes that assist or help speed up reactions in the cell.	6	0	0	6
Genes	Traits expressed, genetic instructions for organisms. Students used a variety of terms to talk about genes and how these led to different genetic traits. The example of Punnett Squares as a form to predict possible inherited traits was used. How genes are expressed and how different states such as methylation affect gene expression.	4	1	1	6
Cellular signaling	Student talks about how cells have "ways" or process by which they communicate within and outside of the cell.	2	0	3	5
Types of cells: Eukaryotic & Prokaryotic	Student talks about how there are different type of cells such as animal and plant cells; differences between prokaryotic and eukaryotic cells.	4	0	1	5
Central dogma	Student is explicitly mentioning the Central dogma and describes it as the process by which DNA goes to RNA which goes to proteins.	2	1	1	4
Energy	Student talks about energy as a biology idea. The student may or may not talk about types of energy such as potential and kinetic energy and even potential energy curve.	3	1	0	4
Evolution	Student talks about the history of organisms and the different components that played a role into the development of organisms, such as mutations and environmental effects. Student could provide examples of phylogenies trees, the difference between eukaryotic and prokaryotic and animal versus	0	2	2	4

	plant cells, and tree thinking.				
ATP	Student talks about ATP as the "energy source" in the cell.	2	1	0	3
Membranes	Student talks about cell membrane and some properties of membranes such as their permeability.	2	0	1	3
Polarity	Student talks about the polarity of molecules, or the electronegativity associated with atoms within a molecule.	2	1	0	3
RNA	Single stranded genetic code used to "create proteins." Student did not say transcription or translation.	2	0	1	3
Types of cells: Animal & Plants	Student talks about how there are different type of cells such as animal and plant cells; differences between prokaryotic and eukaryotic cells.	2	0	1	3
Atoms	Student describes atoms as the entity that "everything is made of." The student could have also described the atom as the "building block" or "unit" of matter.	0	1	1	2
Calvin cycle	Student specifically mentions the Calvin cycle instead of photosynthesis.	2	0	0	2
Cell	Student mentions studying the cell as a whole. For example, how cells functions.	0	2	0	2
Cell cycle	Student talks about lifecycle of the cell and how it's broken into three phases: G1, the S phase, and G2.	1	1	0	2
Cellular processes	Student refers to it as the metabolic and inner functions of the organelles within a cell, mentioning the role of ribosomes and other organelles. This could also be referred to as function of organelles.	1	1	0	2
Chemical and Physical foundations of Life	Student says that the big idea of chemistry was to describe the "chemical and physical foundations of life" without providing more details.	0	1	1	2
Fermentation	Student talks about cellular processes that create energy in the absence of oxygen, creates lactic acid or ethanol depending on the nature of the cell.	2	0	0	2
Function of cell organelle	Student talks about the function or how different "parts" of the cells work. The student could refer to these parts as organelles or even	1	1	0	2

	list some of these organelles.				
Glycolysis	Student specifically mentions glycolysis without referring to the cell respiration process.	2	0	0	2
Hydrophobicity	Student talks about the level of hydrophobicity of molecules as an example the student may talk about the distinct characteristic of the phospholipid bilayer with polar heads and nonpolar tails.	2	0	0	2
Interactions	Student talks about intermolecular forces, interactions or attractions. Student may or may not provide one or more examples of intermolecular forces such as Dipole-dipole, London dispersions, hydrogen bonding.	2	0	0	2
Properties of water	Student talks about the importance of water, and some properties associate to water.	1	0	1	2
Thermodynamics	Student explicitly talks about thermodynamics, s/he can talk about heat, specific heat, temperature changes, entropy, enthalpy, heat capacity, systems, and surroundings as part of their descriptions or examples. This code does not include students that simply mentioned, entropy, enthalpy or Gibbs free energy.	2	0	0	2
Types of bonds	Student talks about bonds/bonding or types of bonds as a chemistry idea. As examples the student may or may not list different types of bonding such as covalent, ionic, metallic bonding, pi bonding, sigma bonding.	2	0	0	2
Virus	Student talks about the development of different viruses has given rise to the creation and the research of vaccines. Student could talk about different viruses like HIV, and flu.	0	2	0	2
Atomic theory	Student talks about the electronic structure of the atom and how in the center of the atom is made of protons and neutrons or nucleus. The student did not specify an atomic model and did not describe a specific atomic model.	1	0	0	1
Cancer	Student talks about how cancer cells grow and metabolize in the body.	1	0	0	1
Data interpretation	Students speaks about learning the skill of understanding data sets to answer questions in class.	0	0	1	1

Drug	Student mentions learning about how drugs affect cellular processes.	1	0	0	1
Electron transport	Student simply mentions that s/he learned about electron transport.	1	0	0	1
Fluid mosaic model	Student talks about the proteins and other biomolecules embedded on the cell membrane.	1	0	0	1
Gene regulation	Student talks about how genes are regulated in the cells.	1	0	0	1
Hydrolysis	Student simply mentions learning about hydrolysis in the course.	0	0	1	1
Living systems	Student talks about living systems as being important for biology.	1	0	0	1
Matter	Student talks about how everything is made out of matter.	0	1	0	1
Operon	Student talks about operons and their functions. As an example, the student talks about prokaryotic operons.	1	0	0	1
Phylogenies	Student talks about the diagram of a phylogenetic tree-diagram used to show differences in genetic traits.	1	0	0	1
Proteins	Student talks about structures and different structural features of proteins.	1	0	0	1
Signaling cascades	Student talks about signaling cascades that happen in the body, such as hormones.	0	0	1	1

S.5 List for the "Things" Learned & Big Ideas in Chemistry: Codebook and Counts from the Survey

"Things" Learned & Big Ideas	Descriptions*	GC1	GC2	Both	Total
*To stay true to students' ideas, their language was used to generate each description, therefore, these are not always scientifically accurate					
Reactions	Student provides a general description of reactions. Student may or may not provide examples of reactions such as Acid-Base Reactions, Redox Reactions, Coupled Reactions, etc. Student may also mention heat and work transfer during reactions.	10	39	15	64
Interactions	Student talks about intermolecular forces, interactions, or attractions. Student may or may not provide one or more examples of intermolecular forces such as Dipole-dipole, London dispersions, hydrogen bonding.	44	2	10	56
Reaction Rate	Student talks about the rate of reactions. The student may talk about reaction rate in terms of how fast and far a reaction will go.	2	27	2	31
Acids & Bases	Student talks about acids and bases. Student may or may not mention how acids and bases interact/react with each other.	4	26	0	30
Atoms	Student describes atoms as the entity that "everything is made of." The student could have also mentioned atomic models.	24	0	0	24
Thermodynamics	Student explicitly talks about thermodynamics, s/he can talk about systems as part of their descriptions or examples. This code does not include students that mentioned, entropy, enthalpy or Gibbs free energy.	7	10	3	20
pH	Student talks about pH calculations and may or may not talk about pKa, Ka and different types of concentrations of ions found in solutions to aid in calculating pH.	1	16	2	19
Structures	Student talks about atomic, molecular, and chemical structure. This code does not include Lewis structures.	17	1	1	19

No Specific Idea(s) Provided	Student did not provide a topic.	7	8	2	17
Molecules	Students talks about molecules. Some mention how molecules are formed.	15	0	0	15
Reaction Equilibrium	Student refers to the K of an equation and some students may provide examples of equilibrium such as dynamic equilibrium.	4	11	1	16
Types of bonds	Student talks about bonds/bonding or types of bonds as a chemistry idea. Students may mention the breaking and forming of bonds. This code does not include the energy associated with bonds.	11	1	2	14
Entropy	Student explicitly mentions entropy.	4	8	1	13
Energy	Student talks about energy as a chemistry idea. The student may or may not talk about types of energy such as potential and kinetic, energy changes, transfer of energy, and where energy goes in a system. Student may also mention how the transfer of energy is due to collisions.	6	0	4	10
Element	Student talks about elements as a basic idea in chemistry.	9	0	0	9
Enthalpy	Student explicitly mentions enthalpy.	2	6	1	9
Gibbs Free Energy	Student explicitly mentions Gibbs free energy.	2	5	1	9
Buffer	Student talks about buffers. Student may also mention how acids and bases can act as buffers.	1	7	0	8
Stoichiometry	Student talks about stoichiometry. Student may also mention how stoichiometry is used to convert between grams and moles.	6	2	0	8
Periodic trends	Student talks about periodic trends.	5	1	0	6
Periodic table	Student talks about the periodic table. Students may mention that they learned how to interpret the periodic table.	5	0	0	5
Reaction Mechanisms	Student talks about reaction mechanisms.	0	5	0	5

Solutions	Student talks about solutions. Student may mention acids and bases as examples of solutions and may also mention the way solutions interact.	0	5	0	5
Activation Energy	Student talks about activation energy.	0	3	0	3
Concentration	Students talk about the concentration of a solution.	1	2	0	3
Ions	Student talks about ions.	3	0	0	3
Rate Laws	Student talks about rate equations	0	2	1	3
Bonding Energy	Student specifically talks about the energy associated with bonds. Student may mention bond breaking and forming in relation to energy.	2	0	0	2
Catalysts	Student talks about catalysts	0	2	0	2
Hybridization	Students mention hybridization without providing any more details.	2	0	0	2
Kinetics	Student talks about kinetics of reactions.	0	2	0	2
Subatomic Particles	Students talk about protons, neutrons, electrons. This code does not include valence electrons.	2	0	0	2
Spectra	Student talks about spectra. Student may mention examples such as the electromagnetic spectrum and spectroscopy.	2	0	0	2
Types of Systems	Student talks about closed systems independently of thermodynamics.	1	1	0	2
Chemical & physical foundation of life	Student mentioned that chemistry relates to life without providing any more details.	1	0	0	1
Collisions	Student talks about collisions.	0	1	0	1
Enzymes	Student talks about enzymes.	0	1	0	1
Half Life	Student talks about half life.	0	1	0	1
Light	Student talks about light as a particle and wave.	1	0	0	1
Limiting Reactant	Student talks about limiting reactant problems.	1	0	0	1

Matter	Student talks about states of matter.	1	0	0	1
Melting point	Student talks about melting point.	1	0	0	1
Oxidation Numbers	Student talks about oxidation numbers.	1	0	0	1
Particle-wave theory	Student talks about learning about particle wave theory.	1	0	0	1
Phase changes	Student talks about phase changes and properties of phase changes.	1	0	0	1
Photon	Student talks about learning about photons.	1	0	0	1
Physical properties	Student talks about physical properties as being a result of interactions between atoms, molecules, and ions.	1	0	0	1
Reactants	Student talks about reactants.	0	1	0	1
Compound	Student talks about compounds.	1	0	0	1
Reaction Diagram	Student talks about reaction diagrams.	0	1	0	1
Regulation	Student talks about regulation.	1	0	0	1
Structure determines Property	Student describes how the structures of molecules determines the properties of molecules.	0	1	0	1
Universe	Student talks about fundamentals of the universe.	1	0	0	1
Valence electrons	Student talks about the outermost electrons in the atom.	1	0	0	1
Waves	Student talks about learning about waves.	1	0	0	1
Weight	Student mentioned how weight is determined when reactions are taking place.	1	0	0	1

S.6 List for the "Things" Learned & Big Ideas in Biology: Codebook and Counts from the Survey

"Things" Learned & Big Ideas	Descriptions*	No. of Students
*To stay true to students' ideas, their language was used to generate each description, therefore, these are not always scientifically accurate		
Cells/Cell Structure	Student mentions studying the cell or its structure as a whole. For example, how cells functions.	54
Cellular Respiration	Student talks about cellular respiration. Student may or may not have mentioned parts of cellular respiration such as glycolysis, Krebs's cycle, and electron transport chain.	25
Photosynthesis	Student talks about photosynthesis.	25
Genes	Student talks about genes. Student may or may not talk about gene expression and inheritance.	22
Transcription/Translation	Student explicitly mentions transcription and translation	19
Cell Cycle	Student talks about cell cycle. May refer to the cell cycle as cell replication.	18
DNA Replication	Student talks about DNA replication. Student may also refer to DNA replication as "copying DNA"	17
DNA	Student talks about DNA. Student may or may not also mention their structures.	14
RNA	Student talks about RNA. Student may or may not also mention their structures.	14
Cell Division	Student talks about cell division. May refer to the cell division in terms of mitosis and meiosis.	13
Macromolecules	Student talks about how there are different types of macromolecules and mentioned carbohydrates, lipids, nucleic acids, and proteins.	10
Molecules	Student talks about molecules. Student may mention how molecules are created and talk about molecules as having a function in the cell.	10
Human Body	Student talks about the human body. Student may or may not mention the processes of the human body, the systems in the human body, etc.	10
Cell Signaling	Student talks about cell signaling. Student may refer to cell signaling as cell communication.	9
Proteins/Protein Structure	Student talks about proteins. Student may or may not mention protein structure, how proteins are made, and even RNA translation to describe what they mean by how proteins are made.	9

No Specific Topic Provided	Student did not provide a specific topic learned.	7
Genetics	Student talks about genetics. Student may mention RNA's role in genetics.	6
Structure-Function	Student talks about structure-function relationships. Student may mention structure-function of cells, macromolecules, proteins, etc. and talk about how these maintain an organism.	6
Structure	Student talks about structure. Student may or may not provide examples of structure such as structure of plant, animal, and bacterial cells, macromolecules, atoms, molecules, etc.	5
Types of Cells: Eukaryotes/Prokaryotes	Student talks about prokaryotes and eukaryotes. Student may or may not also mention their structures, mechanisms, and how these cells compare and differ.	5
Interactions	Student talks about interactions between cells, molecules, and atoms.	4
Amino Acids	Student talks about amino acids.	3
Cell Organelles	Student talks about cell organelles.	3
Cellular Processes	Student talks about cellular processes. This can also be referred to as function of organelles.	3
Organisms	Student talks about organisms. Student may or may not also talk about organisms at the cellular level and how cells affect organisms.	3
Central Dogma	Student talks about the central dogma. Student may or may not also talk about the central dogma as "how DNA is made into proteins". This code does not include transcription and translation.	2
Cancer/Diseases	Student talks about cancer and disease biology.	2
Membranes	Student talks about the cell membrane.	2
Metabolism	Student talks about metabolism. Student may or may not refer to metabolism as a life process.	2
Mutations	Student talks about mutations.	2
Reactions	Student may talk about the reactions that take place within cells or the human body.	2
ATP	Student talks about ATP production.	1
Biological Systems	Student talks about biological systems.	1
Calvin Cycle	Student talks about the Calvin Cycle.	1

Energy	Student talks about processes that convert water air and energy to glucose and back.	1
Organic Compounds	Student talks about organic compounds.	1
Phenotype	Student talks about phenotype.	1
Scientific Model	Student talks about how the most important thing they learned in cell and molecular biology was how to make a model of a scientific process.	1
Temperature	Student talks about temperature.	1
Thermodynamics	Student talks about thermodynamics.	1
Virus	Student talks about virus.	1

S.7 Comparing the Lists of "Things" Learned & Big Ideas in Chemistry: Counts from the Interview and Survey

"Things" Learned & Big Ideas	Interview Data (No. of Students	Survey Data (No. of Students)
Acids & Bases	12	30
Activation Energy	0	3
Algorithmic problem	1	0
Atom	5	24
Atomic models	4	0
Atomic structure/theory	5	0
Bond strength	3	0
Bonding energy	2	2
Buffer	2	8
Catalysts	0	2
Charged Molecule	1	0
Chemical & physical foundation of life	1	1
Chemical vs. Physical changes	1	0
Collisions	0	1
Compound	0	1
Concentration	0	3
Electron configuration	1	0
Electron orbital/ Atomic orbital	2	0
Element	0	9
Endergonic/Exergonic	0	1
Endothermic/ Exothermic	5	0
Energy	11	10
Enthalpy	9	9
Entropy	9	13
Enzyme	1	0
Equilibrium	10	16
Equilibrium constant	1	0
Exothermic/Endothermic Process	0	1
Factors affecting reactions	2	0
Forces	1	0
Formal charges	2	0
Gibbs Free Energy	10	9

Half Life	0	1
Hybridization	3	2
Interactions	22	56
Ions	1	3
Kinetics	0	2
Light	0	1
Light particle	2	0
Limiting Reactant	0	1
Matter	1	1
Melting point	0	1
Mixture and solutions	1	0
Molarity	6	0
Molecular geometry	4	0
Molecular orbital	2	0
Molecules	0	15
No topic Provided	2	17
Nucleophiles and electrophiles	1	0
Origins of the Universe	2	0
Oxidation Numbers	0	1
Particle-wave theory	0	1
Periodic table	4	5
Periodic trends	11	6
pH	9	19
Phase changes	0	1
Photon	0	1
Physical properties	0	1
Polarity	2	0
Pressure	0	1
Properties of water	2	0
Quantum model	1	0
Rate Laws	1	3
Rate order	1	0
Reactants	0	1
Reaction Diagram	0	1
Reaction Mechanisms	0	5
Reaction Rate	10	31
Reactions	20	64

Regulation	0	1
Solubility	1	0
Solutions	1	5
Spectra	0	2
Stoichiometry	9	8
Structure determines properties	3	1
Structures	14	19
Subatomic particles	0	2
Thermodynamics	5	20
Type of bonds	15	14
Type of systems	1	2
Universe	0	1
Valence electrons	1	1
Valence/Outer orbitals	2	0
VSEPR	1	0
Wavelength	1	0
Waves	0	1
Weight	0	1

S.8 Comparing the Lists of "Things" Learned & Big Ideas in Biology: Counts from the Interview and Survey

"Things" Learned & Big Ideas	Interview Data (No. of Students	Survey Data (No. of Students)
Amino Acids	0	3
Atomic theory	1	0
Atoms	2	0
ATP	3	1
Biological Systems	0	1
Calvin Cycle	2	1
Cancer/Diseases	1	2
Cell cycle	2	19
Cell division	10	13
Cell organelles	14	3
Cell signaling	0	11
Cells/Cell Structure	2	54
Cellular processes	2	3
Cellular/Cell respiration	17	26
Central dogma	4	3
Chemical and Physical foundations of Life	2	0
Data interpretation	1	0
DNA	16	16
DNA replication	22	19
Drug	1	0
Electron transport	1	0
Energy	4	1
Enzyme	6	0
Evolution	4	0
Exothermic/Endothermic	0	1
Fermentation	2	0
Fluid mosaic model	1	0
Function of cell organelle	2	0
Functional group	7	0
Gene regulation	1	0
Genes	6	23
Genetics	0	6
Glycolysis	2	0

Human Body	0	10
Hydrolysis	1	0
Hydrophobicity	2	0
Interactions	2	4
Living systems	1	0
Macromolecules	15	13
Matter	1	0
Membranes	3	2
Metabolism	0	2
Molecules	0	10
Mutation	9	2
No Topic Provided	0	7
Operon	1	0
Organic compounds	0	1
Organisms	0	3
Phenotype	0	1
Photosynthesis	15	25
Phylogenies	1	0
Polarity	3	0
Properties of water	2	0
Proteins/ Protein Structures	0	9
Reactions	0	2
RNA	3	16
Scientific Model	0	1
Signaling cascades	1	0
Structure	0	5
Structure-Functions	11	6
Temperature	0	1
Thermodynamics	2	1
Transcription	10	20
Translation	11	20
Types of bonds	2	0
Types of cells: Animal & Plants	3	0
Types of cells: Eukaryotic & Prokaryotic	5	5
Virus	2	1

S.9 Summary of the "Things" Learned & Big Ideas from the Chemistry & Biology Courses

The interview data revealed a total of 57 unique ideas listed or mentioned by students for the combination of the "things" learned and big ideas lists for the GC1/GC2 course with an average of six to seven "things" learned (A) in their GC1/GC2 course with one or two big ideas (B) or both (C) per student (see Table S.9). The students in B1 course listed a total of 53 unique ideas in the interviews where each student listed on average 5 or 6 topics or ideas as part of the "things" learned list from B1 and only one or two big ideas (Table S.9). The survey data produced a similar size list of unique ideas for students' chemistry courses (56 topics/ideas) and a lesser amount for their biology course (40 topics/ideas). This difference may stem from students in the survey being less specific with their ideas. For example, in both the interviews and surveys students listed ideas related to cells. In the interviews students tended to be more specific by talking about individual organelles, while in the survey students were broader and simply listed the cell as a "thing" learned in the course. The differences in the lists' sizes, broadness and specificity of unique ideas were also observed for chemistry. For example, in Figure 3 (in Main Text) with Galen's list, he included entropy and enthalpy separately while another student might consider them under the larger idea of thermodynamics. Therefore, it was important to further explore how students were thinking about their ideas mentioned.

Table S.9: Interview and Survey Data

Interview Data (No. of Topics/Ideas)	Average	Range	Survey Data (No. of Topics/Ideas)	Average	Range
Chemistry Ideas (GC1/GC2)			**Chemistry Ideas (GC1/GC2)**		
Topics/Ideas learned (A)	6-7	1-16	Topics/Ideas learned	4-5	0-13
Big ideas (B)	1-2	0-5	-	-	-
Both (C)	1-2	0-5	-	-	-
Biology Ideas (B1)			**Biology Ideas (B1)**		
Topics/Ideas learned (A)	5-6	0-14	Topics/Ideas learned	2-3	0-8
Big ideas (B)	1-2	0-8	-	-	-
Both (C)	1-2	0-7	-	-	-
Overlapping Ideas	2-3	1-8	**Overlapping Ideas**		
	-	-	GC1/GC2 to B1	1-2	0-8
	-	-	B1 to GC1/GC2	1-2	0-5

Figures S.9A & S.9B show the results from the students' lists created during the interviews when asked to identify the "things" and big ideas learned for their GC1/GC2 and B1 respectively. Both figures show ideas listed or stated by 25% or more of the students interviewed.

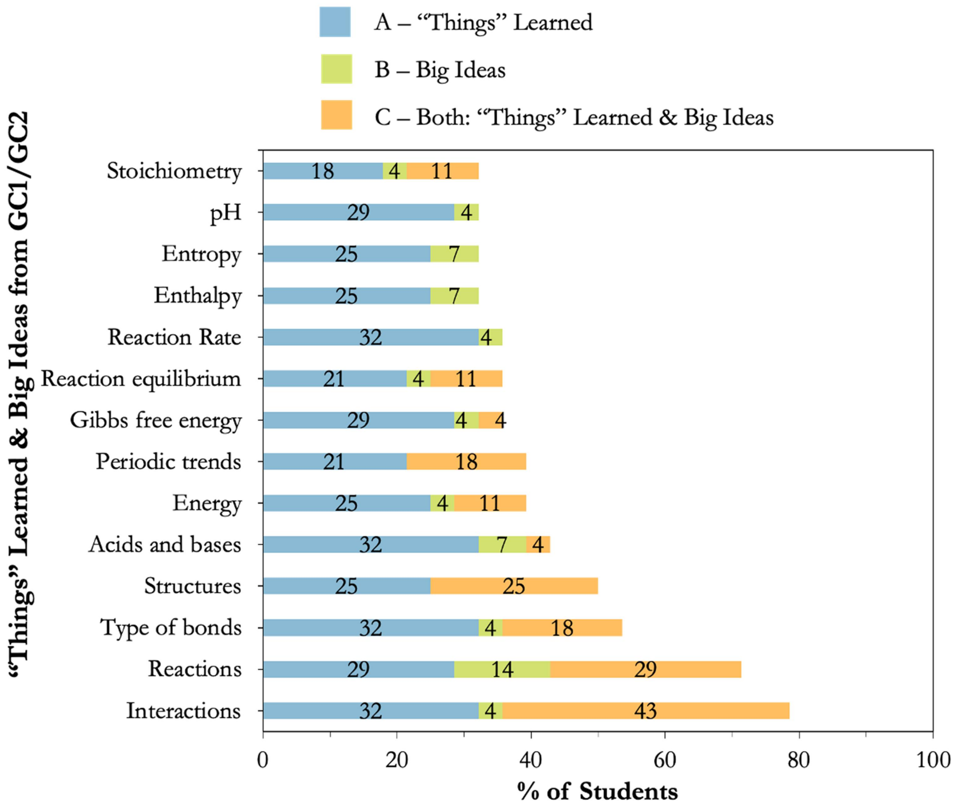

Figure S.9A: *"Things" learned and big ideas listed or stated by 25% or more of the students for their GC1/GC2 course during the interview.*

When compared to survey results, similar "things" learned and big ideas were observed. On both the interview and the survey, students identified *reactions* (in survey 59%, n = 64) and *interactions* (in survey 51%, n = 56) as the two most important key ideas. While similar "things" and ideas are observed on what students perceived to be important in their chemistry course such as acids & bases (in survey 28%, n = 30), pH (in survey 17%, n = 19), and types of bonds (in survey 13%, n = 14), the percentage of students mentioning these individual ideas differed between the interview and the survey (see S.3 and S.5). Even though in the survey students could move at their own pace to reflect on what they had learned in each course, the probing questions during the interviews most likely pushed students to be more reflective on what they considered to be important in the course. Overall, it can be observed that the surveyed students wrote a broader list of "things" and ideas with some overlap between the two (see full lists in S.3-S.8).

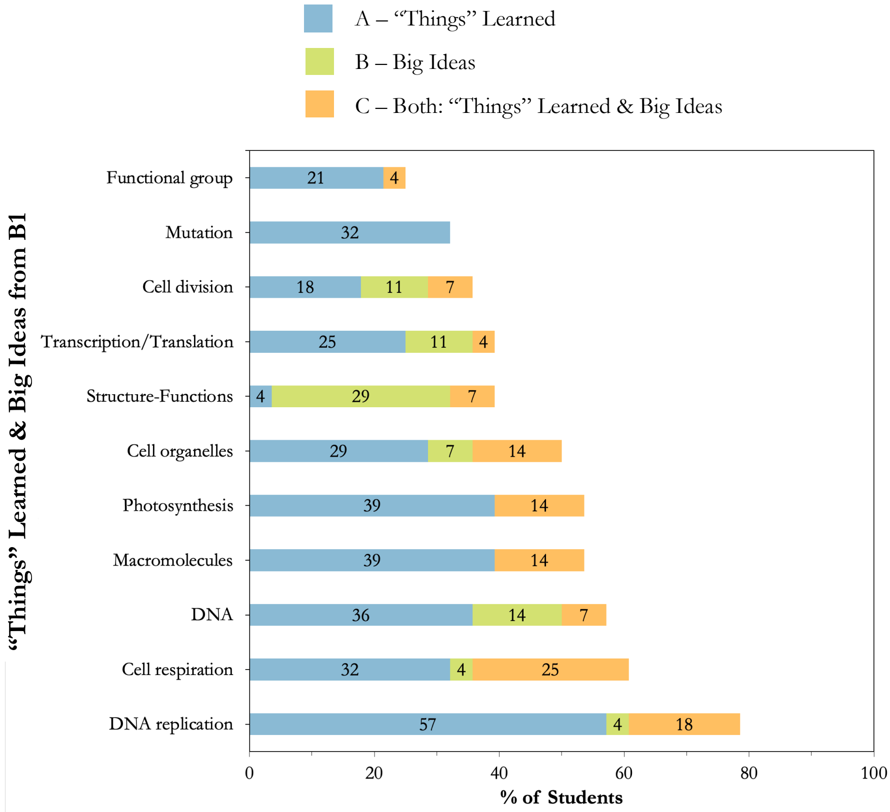

Figure S.9B: *"Things" learned and big ideas listed or stated by 25% or more of the students for their B1 course during the interview.*

When comparing the interview and survey results, it can be observed that both sets of students considered the idea of cell/cellular respiration (Interview 61% n = 17, Survey 43% n = 26) to be important for the B1 course. However, major differences were observed among the ideas students considered to be important for the B1 course. While a very small number of the students interviewed talked about cell/cell structure (7%, n = 2) as an important idea in the course, this idea was listed by the surveyed students the most (47%, n = 54). Another difference is between the percent of students who considered structure-function to be a big idea in the course, while this was the most common big idea among the ideas listed during the interview, only 5% (n = 6) of the surveyed students listed this as an "thing" learned in their B1 course. Despite these differences observed between the interview and survey data, there were also some overlaps on what students considered to be important for the course such as the topics of photosynthesis, DNA replication, and genes.

S.10 Reasoning Codebook from the Interviews

Codes Chemistry	Description	Examples
Time Spent on idea(s)	Student mentions having spent a lot of time, most of the time or a large amount of time of the course or the semester talking/using these topics/ideas/concepts.	"Just because I feel that we talked about it the whole first semester." – Galen
Re-occurring idea(s)	Student talks about how these concepts/ideas/topics "kept" coming back to everything they do (homework, activities, exams).	"The properties of water and bonds thing because it comes up in—it's repetitive, it comes up in a lot of my classes." – Aaron
Encompasses a large amount of ideas ("umbrella")	Student talks about how these concepts/ideas/topics helped them understand a lot of "smaller" ideas that were "under" these concepts/ideas/topics.	"Like I said I think everything is built upon those so if you understand that, you understand a bunch of the little concepts in the class. So if you were to take home one big idea it would be to understand those and know what goes on in them." – Joseph
Basis of the subject	Student talks about how these concepts/ideas/topics are the basis/building blocks/or is related to everything s/he learned in the course. This could also be described as the "key organizing principles" of the subject in the language of the *Framework (National Research Council, 2012b)*.	"Because they're like the building blocks for everything else, I guess because they're like — I lost my train of thought. (pause) They make that substance, or atom— so if it's small and it's electronegative and then that's going to affect how it's going to react with a different atom that's big and polar— if that makes sense?" – Priyah
Personal experience	Student says these concepts/ideas/topics are big ideas because these are connected to the students' life and experiences.	"Probably because I never really had experience in understanding periodic trends. So that was one of the highlights of the course for me because now I really understand them." – Zoe

Need to know/understand/learn	Student talks about how these topics/concepts/ ideas/skill needed to be understood or know how to do it in order to move on with the subject; Student could talk about it as this is what the instructor had tried to "drill down" into the student's head.	"It's a lot of what we've been focusing on. I don't know. It seems like what he's/she's trying to drill into our heads, is like more of what we really need to know to move on." – Clarice
Remembered the most	Student mentions that these are topics/concepts/idea that s/he considered as big because that's what s/he remembered the most from the course.	"That's like what I remember most, but that could also be affected by what we've been learning this semester as opposed to like…I don't know. I probably could have given different answers if I thought about it way more, but my mind just doesn't seem to be working." – Tamara
Progression of ideas	Student talks about the big ideas as the concepts/topics/ideas that help her/him to start with a "small" idea and progress to more complex ideas/concepts	"You progress through them [big ideas]. First, [the instructor] taught us - I think he/she spent a good third of the first semester in [general chemistry 1] teaching us about atomic theory because it is just really important to learn about. And then he/she went to stoichiometry and then electron orbitals. And then I think electron orbitals and geometry kind of overlapped but I learned mostly about geometry in [general biology 1]." – Felix
Explanatory and predictive power	Student talks about how these ideas/concepts/topics help them explain the how and why, and/or make a prediction/guess other concepts/phenomena in the course	"Because these things all have got to come together to interact in a certain way to produce – like interact with the solution of water or with water in solution to make like acid and its conjugate base or base and it's conjugate acid and things like that. Like everything. Like if I didn't know about these interactions, it would be a lot harder for me to understand why atoms are getting rearranged in the ways they are. I guess that would be the

		biggest help from like [instructor's name] style of teaching, just because I guess I could just straight up memorize – sure this atom is going to switch off with this atom. The beryllium's going to fly off and the sodium's going to jump on there and something like that. But if I can think about what properties do these atoms have like where they sit on the periodic table or what type of electronegativity or effective nuclear charge they have and things like that, you can predict stuff a little bit better in what your course is. I should think it's your general goal in the end. I guess." – Karl
Memorized Facts	Student says that these concepts/topics/ideas are big because these are what she had done in the class and most of the class was very factual and consisted of memorization	"Because those are the main things that we've done I guess. Yeah, I don't know, I feel like it's a little bit different of an approach than chemistry. I feel like chemistry is very conceptual, and then Bio is more just like factual. I mean chemistry is too, but like the approaches of how they've been taught. Like I feel like chemistry is more like why does this happen, why does this happen? Whereas in Bio I feel like it's just like once you get to this other level it's like, 'Oh, the helicase unwinds the DNA.' Like just fact. It doesn't ask why, because then that gets into chemistry, like chemically why does this happen, like why does— We don't do that. So it's more like— I guess Bio, it just seems more factual to me. Like he/she kind of lectures, has us do a bunch of stuff in class to

		try to keep us engaged, and then we just memorize. And then chemistry it's more like understanding along with memorizing." – Lida
Development of Scientific Practices	Student talks about how these ideas/concepts/topics were a focused of the course because the professor wanted them to be "well-rounded science students."	"Well, I mean interpreting data, I think is because they want us to be more well-rounded science students and know how to make a claim and make sure we know how to make a claim and how to support it with evidence." – Lacy
Identified by the instructor	Student says that these concepts/topics/ideas are the ones identified/talked about by their instructor at the beginning or during the course semester.	"That structure determines function, and that— What was it? chemical properties are like the basis of life, I think was another one. We also have talked about— (sighs) (pause) I just thought of one and then I forgot it. (pause) I think it's gone yeah. But a big one was structure determines function, because if you mess with the structure, function is gone. (laughs) Yeah yeah. The two that I listed. Oh, it was the chemical and physical properties of life, yes. And then there is more, but I can't remember them, but yes they were from my professor" – Ruth
No reasoning	Student was not asked about his/her reasoning.	

S.11 Reasons-Counts from the Interviews

Reasoning	*Chemistry*	*Biology*	*Total No. of Students*
Re-occurring topics/ideas	12	10	22
Explanatory and/or predictive power	12	2	14
Time spent on topics/ideas	9	5	14
Basis of the course	4	7	11
Encompasses/Important for other concepts	3	7	10
Identified by the instructor	0	7	7
Progression of ideas	5	1	6
Personal experience	3	0	3
Need to know	2	0	2
Remembered the most	1	0	1
Memorized facts	0	1	1
Development of scientific practices	0	1	1

S.12 List of Overlapping Ideas: Codebook and Counts from the Interviews

Overlapping Ideas	Descriptions*	Total
*To stay true to students' ideas, their language was used to generate each description, therefore, these are not always scientifically accurate		
Type of Bonds	Student talks about bonds/bonding or types of bonds as a chemistry idea. As examples the student may or may not list different types of bonding such as covalent, ionic, metallic bonding, pi-bonding, sigma bonding.	7
Interactions	Student talks about intermolecular forces, interactions or attractions. Student may or may not provide one or more examples of intermolecular forces such as Dipole-dipole, London dispersions, hydrogen bonding.	7
Chemistry is the basis of biology	Student talks about how chemistry "drives" or is the basis of everything in biology.	6
Polarity	Student talks about the polarity of molecules or the electronegativity associated with atoms within a molecule.	6
Structures	Student makes a connection between what chemistry and biology by listing the kind of structures they have talked about and drawn in both courses.	6
Energy	Student talks about energy as a chemistry idea. The student may or may not talk about types of energy such as potential and kinetic and even potential energy curve.	4
Reactions	Student speaks about different reactions seen in chemistry and biology.	4
Heat	Student believes heat is involved and drives reactions in both disciplines.	4
Functional groups	Student talks about different functional groups that characterize molecules, compounds and even macromolecules.	3
Macromolecules	Student talks about how there are different types of macromolecules or biomolecules, their different structures, and mentioned carbohydrates, lipids, nucleic acids, and proteins.	3
pH	Student talks about how pH affects multiple "things" in both chemistry and biology.	3
Structure-Property Relationship/Structure-Function Relationship	Student talks about how both courses talk about related ideas such as structure-properties and structure-function.	3
Courses are complementary	Student talks about how the courses are complementary to each other.	2
Micelles	Student mentions having covered concepts related to	2

	micelles in both chemistry and biology.	
Periodic table	Student uses the periodic table to interpret the characteristics (atomic size, charge) of biological systems (i.e., plasma membrane).	2
Reactivity	Student talks about how atoms and molecules interact with each other.	2
No connections stated	Student does not mention any connections between the courses.	2
Atoms	Student talks about both courses being related to atoms.	1
Acids & Bases	Student mentions that acids and bases are in both courses.	1
Atomic structure	Student talks about how s/he talks about the structure of atoms in both courses.	1
Catalysts	Student mentions catalysts/enzymes are talked about in both courses.	1
Endothermic/Exothermic process	Student talks about how reactions process either absorb or release energy.	1
Lipid bilayer	Student mentions talking about lipid bilayers in both courses.	1
Molecules	Student talks about how both courses "dealt" with molecules.	1
Mutation	Student remembers talking about mutations in both courses.	1
Origins of the universe	Student speaks about how the universe originated through the Big Bang theory and how this is related to both courses.	1
Oxidation-reduction	Student talks about how in both chemistry and biology they encountered oxidation-reduction reactions.	1
Periodic trends	Student talks about how learning about periodic trends were useful in both courses.	1
Light particles	Student talks about light "existing" as packets or photons.	1
Photosynthesis	Student talks about how reactions from chemistry power photosynthesis which is a biology concept.	1
Properties of water	Student sees the importance of knowing the properties of water in both subjects.	1
Relevant for Upper-level courses	Student talks about how he/she thought both courses were relevant to upper-level courses.	1

S.13 List of Overlapping Ideas: Codebook and Counts from the Survey

Overlapping Ideas	Descriptions*	GC1/GC2 to B1	B1 to GC1/GC2
*To stay true to students' ideas, their language was used to generate each description, therefore, these are not always scientifically accurate			
No Specific Idea(s) Provided	Students states not finding any topics/ideas to be helpful when thinking about the other course	15	51
Interactions	Student talks about intermolecular forces, interactions or attractions. Student may or may not provide one or more examples of intermolecular forces such as dipole-dipole, London dispersions, hydrogen bonding.	49	5
Reactions	Student speaks about different reactions seen in chemistry and biology.	37	15
Types of Bonds	Student talks about bonds/bonding or types of bonds as a chemistry idea. As examples the student may or may not list different types of bonding such as covalent, ionic, metallic bonding, pi-bonding, sigma bonding.	24	5
Gibbs free energy	Student explicitly mentions Gibbs free energy or free energy. This does not include a student mentioning Gibbs free energy as a description or an example of what s/he thinks thermodynamics is. It does not include a student talking about how a reaction depends on entropy and enthalpy unless they are explicit about how these relate to Gibbs free energy.	12	7
Enzyme	Student talks about how there are proteins or enzymes that assist or help speed up reactions in the cell.	7	11
Energy	Student talks about energy as a chemistry idea. The student may talk about types of energy such as potential and kinetic.	12	3

pH	Student talks about pH calculations and may or may not talk about pKa, Ka, and different types of concentrations of ions found in solutions to aid in calculating pH. Student may also mention the existence of a pH scale.	7	8
ATP	Student talks about ATP as the "energy source" in the cell.	3	11
Structures	Student makes a connection between what chemistry and biology by listing the kind of structures they have talked about and drawn in both courses.	9	2
Atom	Student talks about both courses being related to atoms.	9	2
Acids & Bases	Student mentions that acids and bases are taught in both courses.	6	3
Coupled reaction	Student talks about how coupled reactions were common in both courses or how the idea of coupled reaction was introduced in one of the courses and found it to be important for the other course.	2	7
Polarity	Student talks about the polarity of molecules, or the electronegativity associated with atoms within a molecule.	7	2
Buffer	Student talks about the composition of buffers, as being made of a weak acid and conjugate base. Student may or may not refer to the carbonic anhydrase system in the blood as a type of buffer as well as the equation needed to calculate pH for buffers - Henderson-Hasselback.	5	3
Endergonic/Exergonic reaction	Student talks about reactions being endergonic and/or exergonic, or simply talks about the likeliness a reaction would occur, student may bring up the idea of reactions being spontaneous.	3	5
Hydrolysis	Student simply states learning about hydrolysis and may talk about it in terms of water formation.	3	5
Thermodynamics	Student explicitly talks about	5	3

	thermodynamics, s/he can talk about heat, specific heat, temperature changes, entropy, enthalpy, heat capacity, systems, and surroundings as part of their descriptions or examples. This code does not include students that simply mentioned entropy, enthalpy or Gibbs free energy.		
Rate of Reaction	Student talks about the rate of reactions. The student may talk about energy curves, reaction coordinate diagrams or activation energy to describe what s/he means by reaction rate.	6	0
Structure-Function	Student describes or talks about how the structures of molecules/organelle determines its function.	0	6
Amino acids	Student talks about how amino acids link to form proteins or how proteins are made of amino acids.	0	5
Bond energy	Student specifically talks about the energy associated with breaking or forming a bond.	4	1
Catalyst	Student mentions catalysts/enzymes being talked about in both courses.	3	2
Cell/Cell structure	Students mentions studying the cell as a whole. For example, how cells functions.	0	5
Charge	Student talks about molecules/atoms having or “holding” either a positive or negative charge.	5	0
Endothermic/Exothermic reaction	Student talks about reactions or processes that either absorb or release energy.	2	3
Molecules	Student talks about learning about different types of molecules.	2	3
Proteins	Student talks about structures and different structural features of proteins.	1	4
Reaction mechanisms	Student talks about knowing the way reactions occur.	4	1
System	Student talks about closed and open systems independently of thermodynamics.	4	2

DNA/RNA	Student talks about the structure, formation, and/ or function of DNA and/or RNA.	0	5
Element	Student simply mentions learning about different to types of elements.	2	2
Formal charge	Student talks about how they learn to determine the formal charges in the class.	2	2
Hydrophilic/Hydrophobic	Student talks about entities either being hydrophilic or hydrophobic.	2	3
Lipids	Student talks about having learned about different type of lipids and how these were also important when thinking about the cell membrane.	0	4
Oxidation-Reduction	Student talks about how in both chemistry and biology they encountered oxidation-reduction reactions.	3	1
Solution	Student talks about solutions as an important concept in the courses.	4	0
Carbon dating	Student talks about how carbon dating was useful for them to understand other ideas in the courses.	1	2
Forces	Student talks about how forces are important to understand in the course.	3	0
Functional group	Students talks about how different functional groups that characterize molecules, compounds and even macromolecules.	2	1
Photosynthesis	Student describes this process as how energy comes from the sun is “processed” by the plants, suggesting that energy is neither created nor destroyed.	1	2
Structure-Property Relationship	Student describes how the structures of molecules determines the properties of molecules.	2	1
Cell respiration	Student could talk about glycolysis or the production of ATP; Energy cycles, suggesting that energy is neither created nor destroyed. Student speaks about other processes involved in cellular respiration such as citric acid	1	1

	cycle/Krebs cycle.		
Enthalpy	Student talks about changes in enthalpy of a reaction as a chemistry idea. Student could simply list or mention delta *H* as an idea. This does not include a student mentioning enthalpy as a description or an example of what s/he thinks thermodynamics is.	2	0
Entropy	Student talks about changes in entropy of a reaction as a chemistry idea. Student could simply list or mention delta S as an idea. This does not include a student mentioning enthalpy as a description or an example of what s/he thinks thermodynamics is.	2	0
Macromolecules	Student talks about how there are different types of macromolecules or biomolecules, their different structures, and mentioned carbohydrates, lipids, nucleic acids, and proteins.	0	2
Activation energy	Student talks about the minimum about of energy required for a reaction to take place.	1	0
Atomic structure	Student talks about the electronic structure of the atom and how in the center of the atom is made of protons and neutrons or nucleus. The student did not specify an atomic model and did not describe a specific atomic model.	1	0
Cell communication/signaling	Student talks about how cells have "ways" or process by which they communicate within and outside of the cell.	0	1
Cell cycle/division	Student talks about lifecycle of the cell and how it's broken into three phases: G1, the S phase, and G2.	0	1
Cell membrane	Student talks about cell membrane and some properties of membranes such as their permeability.	0	1
Environment	Student mentions how learning about multiple environments was important to	1	0

	for biology.		
Equilibrium	Student talks about reactions having or reaching equilibrium. Student may also state that it equals to the rate of forward over the backwards rate of a reactions.	1	0
Ester linkages	Student simply states that learning about ester linkages in biology was useful when thinking about chemistry.	0	1
Types of cells: Eukaryotic & Prokaryotic	Student talks about how there are different type of cells such as animal and plant cells, differences between prokaryotic and eukaryotic cells.	0	1
Heat	Students believes heat is involved and drives reactions in both disciplines.	1	0
Homeostasis	Student simply states how learning about homeostasis in chemistry was important for biology.	1	0
Kinetics	Student talks about how learning about kinetics was useful for biology.	1	0
Law of matter	Student talks about how the "*law of matter*" was important when thinking about biology.	1	0
Le Chatelier's Principle	Student talks about how learning about Le Chatelier's principle is important for the other course.	0	1
Sub-atomic particles	Student talks about how having an understand of subatomic particles like protons, electrons, and neutrons is important for biology.	1	0
Orbitals	Student simply states that learning about orbitals was useful when thinking about biology.	1	0
Structure modifications	Student talks about how modifying a structure could lead to differences in "behavior."	1	0