**Indiana Academic Standards for Chemistry**

**Standards Resource Guide Document**

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| This Teacher Resource Guide has been developed to provide supporting materials to help educators successfully implement the Indiana Academic Standards for Chemistry 1. These resources are provided to help you in your work to ensure all students meet the rigorous learning expectations set by the Academic Standards. Use of these resources is optional – teachers should decide which resource will work best in their school for their students. |
| This resource document is a living document and will be frequently updated.  Please send any suggested links and report broken links to:  Jarred Corwin  Secondary Science Specialist  [jcorwin@doe.in.gov](mailto:jcorwin@doe.in.gov) |
| The resources, clarifying statements, and vocabulary in this document are for illustrative purposes only, to promote a base of clarity and common understanding. Each item illustrates a standard but please note that the resources, clarifying statements, and vocabulary are not intended to limit interpretation or classroom applications of the standards. |
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| **Standard 1: Properties and States of Matter** | | | |
| **Indiana Academic Standard** | **Clarifying Statement** | **Highlighted Vocabulary Words from the Standard Defined** | **Crosscutting Concept** |
| C.1.1 Differentiate between pure substances and mixtures based on physical and chemical properties. | Identify and explain why a sample that has multiple elements (water) can be pure (depending on the sample, not tap water).  Students are able to identify physical and chemical properties in the laboratory.  Separate mixtures using physical and chemical properties. | Pure substance – composed of only one type of particle (compound or element)  Mixture – sample of two or more pure substances where each material maintains its own properties  Physical property – aspect of matter that can be observed or measured without changing the chemical composition of the sample  Chemical property – any property of matter that may only be observed and measured by performing a chemical change or chemical reaction. | Patterns  Structure and Function |
| C.1.2 Use chemical properties, extensive, and intensive physical properties to identify substances. | Identifying various compounds and elements based on their chemical properties (flammable, oxidizer, etc.) extensive (mass, volume, etc.) and intensive physical properties (density, hardness, color, melting point, odor, etc.).  Extensive properties of mass and volume can be used to calculate density (intensive) to help identify the substance.  Extensive properties alone are not useful in the identification of a substance. | Chemical properties – any property of matter that may only be observed and measured by performing a chemical change or chemical reaction.  Extensive properties – dependent on the amount of matter that is present in a sample  Intensive properties – do not depend on the amount of matter present in a sample  Physical properties – aspect of matter that can be observed or measured without changing the chemical composition of the sample  Substances – a material with a definite chemical composition | Patterns  Structure and Function |
| C.1.3 Recognize observable macroscopic indicators of chemical changes. | Use the indicators of energy released/absorbed during a reaction(heat, light, sound), gas production, precipitate formation, or color change to justify whether a chemical reaction occurred or if there was just a physical change. | macroscopic indicators – observations made by the naked eye  chemical changes – the making and/or breaking of chemical bonds resulting in the formation of new chemical substances | Energy and matter |
| C.1.4 Describe physical and chemical changes at the particle level. | Students examine and build models of what samples look like at the microscopic level. Manipulate atoms/particles to see that chemical changes rearrange particles and break/form new bonds. | Physical changes – any change that does not change the chemical identity of a substance  Chemical changes – the making and/or breaking of chemical bonds resulting in the formation of new chemical substances  Particle – smallest individual units of a sample (formula units, molecules, atoms) | Structure and function  Energy and Matter |
| C.1.5 Describe the characteristics of solids, liquids, and gases and changes in state at the macroscopic and microscopic levels. | Students look at defining characteristic of each state of matter.  Students make/examine models of particles at the microscopic/macroscopic levels and how these particles behave in each of the states of matter. | Solid – state of matter characterized by structural rigidity and resistance to changes of shape or volume  Liquid – state of matter characterized by nearly constant volume independent of pressure and conforms to the shape of its container.  Gas – state of matter that expands freely to fill any space available  Change in state – transition from one state of matter to another state of matter  Macroscopic – visible to the naked eye/large scale  Microscopic – visible only with a microscope or various technology/small scale/particle level | Cause and Effect  Scale, proportion, and quantity  Energy and Matter |
| C.1.6 Demonstrate an understanding of the law of conservation of mass through the use of particle diagrams and mathematical models. | Modeling a chemical reaction through diagrams, manipulatives so that as a chemical reaction occurs, the matter/atoms that make the reactants equal that in the final products, just rearranged and bonds formed/broke | Law of conservation of mass – matter can be changed from one form into another, but the total amount of mass remains the same  Particle diagrams – visual depiction in which atoms and molecules are drawn as dots/circles  Mathematical models – description of a system using equations | Patterns  Scale, Proportion, and Quantity |
| C.1.7 Perform calculations involving density and distinguish among materials based on densities. | Identify density as an intensive property derived from two extensive properties. Identify unknown substance by calculating density and comparing to known values of various samples. Identify and use correct units for density. Calculate volume, mass, and density when two of the three values are known. | Density – mass per unit volume  Material – sample of matter. | Scale, Proportion, and Quantity |

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| **Standard 2: Atomic Structure and the Periodic Table** | | | |
| **Indiana Academic Standard** | **Clarifying Statement** | **Highlighted Vocabulary Words from the Standard Defined** | **Crosscutting Concept** |
| C.2.1 Using available experimental data, explain how and why models of atomic structure have changed over time. |  | Experimental data – quantities obtained through laboratory investigations  Model – representation of a more complex item/relationship  Atomic structure – the particles, amounts, and position of particles within an atom | Systems and System Models  Structure and Function  Stability and Change |
| C.2.2 Determine the number of protons, neutrons, and electrons in isotopes and calculate the average atomic mass from isotopic abundance data. |  | Protons – an elementary particle that is identical with the nucleus of the hydrogen atom, that along with the neutron is a constituent of all other atomic nuclei, that carries a positive charge numerically equal to the charge of an electron  Neutron – an uncharged elementary particle that has a mass nearly equal to that of the proton and is present in all known atomic nuclei except the hydrogen nucleus  Electron – a very small particle of matter that has a negative charge of electricity and that travels around the nucleus of an atom  Isotopes – any of two or more species of atoms of a chemical element with the same atomic number and nearly identical chemical behavior but with differing atomic mass or mass number and different physical properties  Average atomic mass – sum of the masse of its isotopes, each multiplied by the natural abundance of each  Isotopic abundance data – relative number of atoms of different isotopes of one chemical element usually expressed as a percentage of all the long – lived isotopes of that element. | Structure and Function  Scale, proportion, and quantity |
| C.2.3 Write the full and noble gas electron configuration of an element, determine its valence electrons, and relate this to its position on the periodic table. |  | Full electron configuration – distribution of electrons of a neutral atom  Noble gas electron configuration – the loss or gain of electrons to achieve the stable electron configuration of a noble gas  Element – smallest unit of matter that maintains its unique properties  Valence electrons – electrons in the outer shell of an atom that often are involved in bonding.  Periodic table – arrangement of all known elements in order of atomic number so that elements with similar atomic structure and properties appear in vertical columns | Pattern  Cause and Effect  System and system models |
| C.2.4 Use the periodic table as a model to predict the relative properties of elements based on the pattern of valence electrons and periodic trends. | Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, electronegativity, atomic radius, ionization energy, and reactions with oxygen | Periodic table – arrangement of all known elements in order of atomic number so that elements with similar atomic structure and properties appear in vertical columns  Model – representation of a more complex item/relationship  Properties – an attribute, quality, or characteristic of something  Element – smallest unit of matter that maintains its unique properties  Valence electrons – electrons in the outer shell of an atom that often are involved in bonding.  Periodic trends – specific patterns that are present in the periodic table that illustrate different properties. | Pattern  Cause and effect  Structure and Function |
| C.2.5 Compare and contrast nuclear reactions with chemical reactions | Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations. | Nuclear reactions – change in the energy or structure of an atomic nucleus (fission, fusion, or radioactive decay)  Chemical reactions – process of rearrangement of the molecular or ionic structure of a substance (making or breaking chemical bonds), as opposed to change in physical form or a nuclear reaction | Energy and Matter  Stability and change |
| C.2.6 Describe nuclear changes in matter, including fission, fusion, transmutations, and decays. | Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations. | Nuclear changes – change in the number of protons or neutrons in the nucleus of an atom  Matter – thing that has mass and takes up space  Fission – splitting of a nucleus of an atom into two nuclei of lighter atoms and the release of energy  Fusion – nuclei of light atoms join to form nuclei of heavier atoms  Transmutation – the conversion of one element or nucleide into another either naturally or artificially  Decay – nucleus of an unstable atom loses energy by emitting radiation | Energy and matter  Stability and change  Structure and function |
| C.2.7 Perform half-life calculations when given the appropriate information about the isotope. | Perform sample calculations and graph half-life to find time that has passed, original mass, final mass, and calculate half-life based on experimental data. | Half-life – the time it takes for half of a radioactive sample to decay to a more stable isotope  Isotope – any of two or more species of atoms of a chemical element with the same atomic number and nearly identical chemical behavior but with differing atomic mass or mass number and different physical properties | Patterns  Scale, proportion, and quantity |

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| **Standard 3: Bonding and Molecular Structure** | | | |
| **Indiana Academic Standard** | **Clarifying Statement** | **Highlighted Vocabulary Words from the Standard Defined** | **Crosscutting Concept** |
| C.3.1 Investigate the observable characteristics of elements, ionic, and covalent compounds. | Examine conductivity, solubility, melting point, boiling point, etc. using lab data and observations | Elements – smallest unit of matter that maintains its unique properties  Ionic compounds – chemical compound comprised of ions held together by electrostatic forces  Covalent compounds – two or more nonmetal atoms bonded by sharing valence electrons | Patterns  Structure and function |
| C.3.2 Compare and contrast how ionic and covalent compounds form. |  | Ionic compounds – chemical compound comprised of ions held together by electrostatic forces  Covalent compounds – two or more nonmetal atoms bonded by sharing valence electrons | Structure and function  Systems and system models |
| C.3.3 Draw structural formulas for simple molecules and determine their molecular shape. | Introduction to drawing structural formulas and simple molecular shapes emphasizing three dimensional molecules (water is bent because of lone pairs of electrons) | Structural formulas – a formula that shows the arrangement of atoms in the molecule of a compound  Molecules – group of atoms held together by chemical bonds  Molecular shape – three dimensional arrangement of the atoms bonded in a molecule | System and system models |
| C.3.4 Write chemical formulas for ionic compounds and covalent compounds given their names and vice versa. | Writing formulas and naming compounds for simple binary ionic and binary covalent compounds | Chemical formula – set of chemical symbols showing the elements present in a compound and their relative proportions | Patterns  System and system models |
| C.3.5 Use laboratory observations and data to compare and contrast ionic, covalent, network, metallic, polar, and non-polar substances with respect to constituent particles, strength of bonds, melting and boiling points, and conductivity; provide examples of each type. | Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] | Data – facts and statistics collected together for reference and analysis  Ionic –  Covalent –  Network –  Metallic – attraction between positively charged atomic nuclei of metal atoms and delocalized electrons  Polar substances– compound in which the electric charge is not symmetrically distributed to where there is a separation of charge or partial charge  Non-polar substances – compound composed of molecules that possess symmetric distribution of charge  Constituent particles –  Strength of bonds – strength with which a chemical bond holds two atoms together, measured in the amount of energy, kilocalories/mole, required to break the bond  Melting point – temperature at which a solid transitions to a liquid at atmospheric pressure  Boiling point – temperature at which a liquid transitions to a gas at atmospheric pressure  Conductivity – degree to which a specified material conducts electricity | Cause and effect  Structure and function  Stability and change |
| C.3.6 Use structural formulas of hydrocarbons to illustrate carbon's ability to form single and multiple bonds within a molecule. | Introducing organic compounds and the formation of long chains, rings, double, and triple bonding between carbon | Structural formulas - – a formula that shows the arrangement of atoms in the molecule of a compound  Hydrocarbons – simplest organic compounds containing only carbon and hydrogen  Single bonds – a chemical bond in which one pair of electrons is shared between two atoms.  Multiple bonds – a chemical bond in which two or more pairs of electrons are shared between two atoms  Molecule - group of atoms held together by chemical bonds | Structure and function  System and system model |

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| **Standard 4: Reactions and Stoichiometry** | | | |
| **Indiana Academic Standard** | **Clarifying Statement** | **Highlighted Vocabulary Words from the Standard Defined** | **Crosscutting Concept** |
| C.4.1 Describe, classify, and give examples of various kinds of reactions: synthesis (i.e., combination), decomposition, single displacement, double displacement, acid/base, and combustion. | Extension: Electrochemistry | Synthesis – two or more simple substances combine to form a more complex product  Decomposition – separation of a chemical compound into elements or simpler compounds  Single displacement – an element or ion moves out of one compound and replaced by another  Double displacement – two compounds react and the cation and anion of the two reactants switch to form two new compounds  Acid/base – exchange of one or more hydrogen ions between species  Combustion – oxygen reacts with another compound, usually a hydrocarbon | Patterns  Cause and effect  System and system models  Energy and matter |
| C.4.2 Predict products of simple reactions as listed in C.4.1. | When given two compounds/reactants, students can predict products by classifying the type of reaction | Products – new compounds formed in a chemical reaction | Stability and change  Patterns |
| C.4.3 Balance chemical equations and use the law of conservation of mass to explain why this must be true. | Extension: Identify REDOX reactions/Balance REDOX reactions | Balance – using coefficients to ensure that each type of atom and the total charge of reactants matches the total number of atoms and charge of products.  Law of conservation of mass – mass in an isolated system is neither created nor destroyed by chemical reactions or physical transformations. | Scale, proportion, and quantity |
| C.4.4 Apply the mole concept to determine the mass, moles, number of particles or volume of a gas at STP, in any given sample, for an element or compound. | Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale | Mole – a chemical unit defined to be 6.022 x 10^23 molecules, atoms, or some other unit  Mass – measure of the amount of matter in an object  Number of particles – molecules, formula units, atoms  Volume – quantity of three-dimensional space occupied by a solid, liquid, or gas  STP – standard temperature and pressure, 273.15 K and a pressure of 1 atm  Element – atoms that all have the same number of protons  Compound – two or more elements chemically bonded together | Scale, proportion, and quantity  Energy and matter |
| C.4.5 Use a balanced chemical equation to calculate the quantities of reactants needed and products made in a chemical reaction that goes to completion. | Examining limiting reagents, excess reagents, and left-over materials. Extension can be when the reaction does not go to equilibrium(examining equilibrium constants) | Balanced chemical equation – using coefficients to ensure that each type of atom and the total charge of reactants matches the total number of atoms and charge of products to reflect the law of conservation of mass  Reactant – substances initially present in a chemical reaction  Product – new compounds formed in a chemical reaction  Chemical reaction – process of rearrangement of the molecular or ionic structure of a substance (making or breaking chemical bonds), as opposed to change in physical form or a nuclear reaction  Completion – a reaction in which essentially all of the reactants react to form products | Scale, proportion, and quantity |
| C.4.6 Perform calculations to determine the composition of a compound or mixture when given the necessary information. | % composition by mass for each element in a compound when given the formula, % composition by mass of various compounds/elements in a mixture | Composition – proportions of various elements/compounds in a sample  Compound – substance formed when two or more elements are chemically bonded together  Mixture – sample of two or more pure substances where each material maintains its own properties | Scale, proportion, and quantity  Structure and function |
| C.4.7 Apply lab data to determine the empirical and molecular formula of a compound. | Use percent composition data to calculate the empirical formula and with the molar mass, find the molecular formula | Empirical formula– simplest whole number ratio of a chemical formula  Molecular formula– expression of the number and type of atoms that are present in a molecule of a substance (can be a multiple of an empirical formula)  Compound – substance formed when two or more elements are chemically bonded together | Scale, proportion, and quantity  Structure and function |

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| **Standard 5: Behavior of Gases** | | | |
| **Indiana Academic Standard** | **Clarifying Statement** | **Highlighted Vocabulary Words from the Standard Defined** | **Crosscutting Concept** |
| C.5.1 Use the kinetic molecular theory with the combined and ideal gas laws to explain changes in volume, pressure, moles and temperature of a gas. |  | Kinetic molecular theory – individual gas particles interact with one another and relates microscopic gas to macroscopic gas behavior  Combined gas law – combination of Charles’s, Boyle’s, and Gay-Lussac’s law relating pressure, volume, and temperature  Ideal gas law –relationship of variables in a hypothetical ideal gas, combination of Boyle’s, Charles’s, and Avogadro’s law.  Volume – quantity of three-dimensional space occupied by a solid, liquid, or gas  Pressure – force exerted by the substance per unit area on another substance  Moles - a chemical unit defined to be 6.022 x 10^23 molecules, atoms, or some other unit  Temperature - measure of thermal energy  Gas - state of matter that expands freely to fill any space available | Scale, proportion, and quantity  Cause and effect |
| C.5.2 Apply the ideal gas equation (PV = nRT) to calculate the change in one variable when another variable is changed and the others are held constant. |  | Ideal gas equation – equation that equates the product of the pressure and the volume of a gas to the product of the number of moles of gas, the temperature, and gas constant  Variable – factor, trait, or condition that can exist in differing amounts or types  Constant – a fixed value, non-varying | Scale, proportion, and quantity  Cause and effect |
| C.5.3 Use lab data and a balanced chemical equation to calculate volume of a gas at STP and non STP conditions, assuming that the reaction goes to completion and the ideal gas law holds. |  | Balanced chemical equation – using coefficients to ensure that each type of atom and the total charge of reactants matches the total number of atoms and charge of products to reflect the law of conservation of mass | Scale, proportion, and quantity  Systems and system models |

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| **Standard 6: Thermochemistry** | | | |
| **Indiana Academic Standard** | **Clarifying Statement** | **Highlighted Vocabulary Words from the Standard Defined** | **Crosscutting Concept** |
| C.6.1 Explain that atoms and molecules are in constant motion and that this motion increases as thermal energy increases. |  | Motion –moving or changing place or position  Thermal energy – internal energy of an object due to kinetic energy of its atoms and/or molecules | Scale, proportion, and quantity  Cause and effect |
| C.6.2 Distinguish between the concepts of temperature and heat flow in macroscopic and microscopic terms. |  | Temperature – measure of thermal energy  Heat flow – process whereby heat moves from one body or substance to another by radiation, conduction, convection, or a combination of these methods  Macroscopic – visible to the naked eye/large scale  Microscopic – visible only with a microscope or various technology/small scale/particle level | Scale, proportion, and quantity  Energy and matter |
| C.6.3 Classify chemical reactions and phase changes as exothermic or endothermic based on enthalpy values. Use a graphical representation to illustrate the energy changes involved | Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved | Phase changes – transition between solid, liquid, and gaseous phases  Exothermic – accompanied by the release of heat  Endothermic – accompanied by or requiring the absorption of heat  Enthalpy – measure of energy in a thermodynamic system | Energy and matter |
| C.6.4 Perform calculations involving heat flow, temperature changes, and phase changes by using known values of specific heat, phase change constants, or both. |  | Specific heat – thermal energy required to raise the temperature of one gram of a given substance by one degree Celsius  Phase change constants – rate of energy required to change a mass of sample from one state to another(heat of fusion, heat of vaporization) | Scale, proportion, and quantity  Energy and matter |

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| **Standard 7: Solutions** | | | |
| **Indiana Academic Standard** | **Clarifying Statement** | **Highlighted Vocabulary Words from the Standard Defined** | **Crosscutting Concept** |
| C.7.1 Describe the composition and properties of solutions. |  | Composition – proportions of various elements/compounds in a sample  Property – characteristic of a substance  Solution- homogenous mixture composed of two or more substances | Scale, proportion, and quantity |
| C.7.2 Explain how temperature, pressure, and polarity of the solvent affect the solubility of a solute. |  | Pressure – force exerted by the substance per unit area on another substance  Polarity – separation of electric charge leading to a molecule having a electric dipole or multipole moment  Solubility – chemical property referring to the ability for a given substance, solute, to dissolve in a solvent  Solute – substance dissolved in another substance, known as a solvent | Cause and effect |
| C.7.3 Describe the concentration of solutes in a solution in terms of molarity. Perform calculations using molarity, mass, and volume. Prepare a sample of given molarity provided a known solute. |  | Concentration – ratio of solute per total volume of a mixture  Molarity – moles of solute per liter of solution | Scale, proportion, and quantity |

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| **Standard 8: Acids and Bases** | | | |
| **Indiana Academic Standard** | **Clarifying Statement** | **Highlighted Vocabulary Words from the Standard Defined** | **Crosscutting Concept** |
| C.8.1 Classify solutions as acids or bases and describe their characteristic properties. |  | Acid – chemical substance whose aqueous solutions are characterized by a sour taste, turn blue litmus red, and react with bases to form salts  Base – chemical substance that in aqueous solution are slippery to the touch, taste bitter, change red litmus paper blue, and react with acids to form salts  Characteristic properties – chemical or physical property that helps identify and classify substances | Patterns  Systems and system models |
| C.8.2 Compare and contrast the strength of acids and bases in solutions. | Examine household chemicals and a variety of stock laboratory chemicals | Strength – concentration of ions in solution | Structure and function |
| C.8.3 Given the hydronium ion and/or the hydroxide ion concentration, calculate the pH and/or the pOH of a solution. Explain the meanings of these values. | Extension: Titrations, finding the concentration/molarity of an unknown acid/base  Extension: Buffers | Hydronium ion – hydrogen ion bonded to a molecule of water found in aqueous systems  Hydroxide ion – diatomic anion with an oxygen and hydrogen covalently bonded and carries a negative charge  pH – figure expressing the acidity or alkalinity based on hydrogen ion concentration of a solution on a logarithmic scale on which 7 is neutral, lower acidic, and higher basic  pOH – figure expressing the acidity or alkalinity based on hydroxide ion concentration of a solution on a logarithmic scale on which 7 is neutral, higher acidic, and lower basic | Scale, proportion, and quantity  Stability and change |

Crosscutting Concepts

1. *Patterns.* Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

2. *Cause and effect: Mechanism and explanation*. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

3. *Scale, proportion, and quantity.* In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system’s structure or performance.

4. *Systems and system models.* Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.

5. *Energy and matter: Flows, cycles, and conservation.* Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems’ possibilities and limitations.

6. *Structure and function.* The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

7. *Stability and change.* For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.