SECRET COMMUNICATIONS

Sharing Concealed Messages

CURRICULAR OBJECTIVES and BACKGROUND INFORMATION

Curricular Objectives

Secret Communications: Sharing Concealed Messages **presents learners with examples of various encryption methods. Opportunities abound to use inquiry as an approach to get into the mind of the code writer in order to decipher messages encrypted in various fashions.**

Exposure to such examples empowers learners with the capacity to transfer and extend their knowledge of logical schemes and rules to different and novel situations. This ability is an earmark of genuine understanding.

Students striving to derive the greatest benefits of this curriculum will:

- **become more aware of different reasons for encrypting information**
- **apply their knowledge of mathematical systems to encrypt and decipher messages**
- **apply their knowledge of language systems to encrypt and decipher messages**
- **learn mathematical relationships that underlie coding and encryption methods**
- **experiment with different means of communicating concealed messages**
- **develop the habits of mind of persistence and tenacity in deciphering coded messages**
- **gain an understanding of the role of creativity and insight by encrypting and deciphering concealed messages**

Regardez . . . Ce n'est pas un message crypté

Logistics

Class Size: 30 Middle Level 6 – 8 students

Location: Most activities are completed in a classroom. An open area is preferred for *Locking Onto an Idea: Considering the Possibilities* and *Digitized Message Transmission*

Time: This unit is designed for 32 content hours. Each unit will take approximately 2 – 3 hours. Refer to each lesson for more specific time breakdowns.

Background Information

Throughout history people have needed to share information in ways so that certain others are prevented from obtaining it. Cryptology is the science of secure communication. The most obvious examples come from the arena of military conflict. Critical information concerning the placement and/or movement of forces, strategic plans, and other sensitive material needs to be kept secret.

Other areas that need information protection include the business and financial industries. Credit card information, bank account numbers, social security numbers, and other personal information falling into the hands of unscrupulous people can result in serious problems in terms of business operations as well as the financial status of individuals. While these issues may seem like modern day problems, such information protection has been going on for centuries.
This unit will explore various ways in which information can be encrypted and shared. Cryptography is the science of concealing a message's meaning rather than its existence. It can be subdivided into *codes* and *ciphers*.

One point needs to be brought forward regarding messages that are not understandable. Just because a message cannot be understood does not make it a coded message. For English speaking individuals, information written in languages other than English is not necessarily an encrypted message. Foreign languages are not necessarily codes, as the subtitle of this section, **Regardez ..... Ce n'est pas un message crypté, (Look ..... This is not an encrypted message),** exemplifies.

Codes are devices that are purposely intended to prevent information from being shared. Only those individuals who know the "code" are supposed to be able to "decode" and understand the message.

Next Generation Science Standards

MS-LS1 From Molecules to Organisms: Structures and Processes
MS.LS1-8 Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

MS-PS4 Waves and their Applications in Technologies for Information Transfer
MS.PS4.C Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information. (MS-PS4-3) Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals.

PS-Physical Science, MS-PS2 Motion and Stability:Forces and Interactions
MS.PS2.B. Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (MS-PS2-3) Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

HS-LS1 From Molecules to Organisms: Structures and Processes
HS-LS1.A All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. (HS-LS-1) Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.

4-PS3 Energy
4PS3-4 Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

Next Generation Science Standards Reference:
NGSS Lead States. 2013. *Next Generation Science Standards: For States, By State*s. Washington, DC: The National Academies Press.

Mathematics Common Core Standards

CCSS.MATH.CONTENT.6.RP.A.3 *Understand ratio concepts and use ratio reasoning to solve problems. Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalent ratios, tape diagrams, double number line diagrams, or equations.*

CCSS.MATH.CONTENT.6.NS.B.4 *Compute fluently with multi-digit numbers and find common factors and multiples. Find the greatest common factor of two whole numbers less than or equal to 100 and the least common multiple of two whole numbers less than or equal to 12. Use the distributive property to express a sum of two whole numbers 1–100 with a common factor as a multiple of a sum of two whole numbers with no common factor. For example, express 36 + 8 as 4 (9 + 2).*

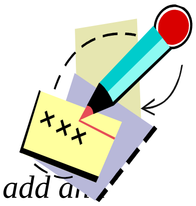
CCSS.MATH.CONTENT.6.EE.A.1 *Apply and extend previous understandings of arithmetic to algebraic expressions. Write and evaluate numerical expressions involving whole-number exponents.*

CCSS.MATH.CONTENT.6.EE.A.2C *Evaluate expressions at specific values for their variables. Include expressions that arise from formulas in real-world problems. Perform arithmetic operations, including those involving whole-number exponents, in the conventional order when there are no parentheses to specify a particular order (Order of Operations). For example, use the formulas* $V = s^3$ *and* $A = 6 s^2$ *to find the volume and surface area of a cube with sides of length* $s = 1/2$.

CCSS.MATH.CONTENT.6.EEC.9 *Represent and analyze quantitative relationships between dependent and independent variables. Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation. For example, in a problem involving motion at constant speed, list and graph ordered pairs of distances and times, and write the equation* $d = 65t$ *to represent the relationship between distance and time.*

CCSS.MATH.CONTENT.6.SP.B.5C *Summarize and describe distributions. Summarize numerical data sets in relation to their context, such as by:-- c. Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data was gathered.*

CCSS.MATH.CONTENT.7.NS.A.1B *Understand p + q as the number located a distance |q| from p, in the positive or negative direction depending on whether q is positive or negative. Show that a number and its opposite have a sum of 0 (are additive inverses). Interpret sums of rational numbers by describing real-world contexts.*



CCSS.MATH.CONTENT.7.NS.A.1D *Apply properties of operations as strategies to add an subtract rational numbers.*

CCSS.MATH.CONTENT.7.NS.A.3 *Apply and extend previous understandings of operations with fractions to add, subtract, multiply, and divide rational numbers. Solve real-world and mathematical problems involving the four operations with rational numbers. (Computations with rational numbers extend the rules for manipulating fractions to complex fractions.)*

CCSS.MATH.CONTENT.7.EE.A.1 *Use properties of operations to generate equivalent expressions. Apply properties of operations as strategies to add, subtract, factor, and expand linear expressions with rational coefficients.*

CCSS.MATH.CONTENT.7.EE.B.4 *Solve real-life and mathematical problems using numerical and algebraic expressions and equations. Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.*

CCSS.MATH.CONTENT.7.SP.A.1 *Use random sampling to draw inferences about a population. Understand that statistics can be used to gain information about a population by examining a sample of the population; generalizations about a population from a sample are valid only if the sample is representative of that population. Understand that random sampling tends to produce representative samples and support valid inferences.*

CCSS.MATH.CONTENT.7.SP.C.8B *Represent sample spaces for compound events using methods such as organized lists, tables and tree diagrams. For an event described in everyday language (e.g., "rolling double sixes"), identify the outcomes in the sample space which compose the event.*

CCSS.MATH.CONTENT.8.F.A.1 *Define, evaluate, and compare functions. Understand that a function is a rule that assigns to each input exactly one output. The graph of a function is the set of ordered pairs consisting of an input and the corresponding output. (Function notation is not required in Grade 8.)*

CCSS.MATH.CONTENT.8.G.B.8 *Understand and apply the Pythagorean Theorem. Apply the Pythagorean Theorem to find the distance between two points in a coordinate system.*

CCSS.MATH.CONTENT.HSA.REI.C.6 *Solve systems of equations. Solve systems of linear equations exactly and approximately (e.g., with graphs), focusing on pairs of linear equations in two variables.*

CCSS.MATH.CONTENT.HSS.CP.B.9 *Use the rules of probability to compute probabilities of compound events in a uniform probability model. Use permutations and combinations to compute probabilities of compound events and solve problems.*

Mathematical Practices

CCSS.MATH.PRACTICE.MP1 *Make sense of problems and persevere in solving them*

CCSS.MATH.PRACTICE.MP2 *Reason abstractly and quantitatively*

CCSS.MATH.PRACTICE.MP3 *Construct viable arguments and critique the reasoning of others*

CCSS.MATH.PRACTICE.MP4 *Model with mathematics*

CCSS.MATH.PRACTICE.MP5 *Use appropriate tools strategically*

CCSS.MATH.PRACTICE.MP6 *Attend to precision*

CCSS.MATH.PRACTICE.MP7 *Look for and make use of structure*

CCSS.MATH.PRACTICE.MP8 *Look for and express regularity in repeated reasoning*

Common Core English Language Arts (ELA) Standards

CCSS.ELA-LITERACY.RI.6.7: *Integrate information presented in different media or formats (e.g., visually, quantitatively) as well as in words to develop a coherent understanding of a topic or issue.*

CCSS.ELA-LITERACY.RI.7.7: *Compare and contrast a text to an audio, video, or multimedia version of the text, analyzing each medium's portrayal of the subject (e.g., how the delivery of a speech affects the impact of the words).*

CCSS.ELA-LITERACY.RI.8.7: *Evaluate the advantages and disadvantages of using different mediums (e.g., print or digital text, video, multimedia) to present a particular topic or idea.*

CCSS.ELA-LITERACY.SL.6-8.1: *Engage effectively in a range of collaborative discussions with diverse partners on grade 6-8 topics, texts, and issues, building on others' ideas and expressing their own clearly.*

CCSS.ELA-LITERACY.SL.6.2: *Interpret information presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how it contributes to a topic, text, or issue under discussion.*

CCSS.ELA-LITERACY.SL.8.2: *Analyze the purpose of information presented in diverse media formats and evaluate the motives behind its presentation.*

<u>**CCSS.ELA-LITERACY.RST.6-8.1**</u>: *Cite specific textual evidence to support analysis of science and technical texts.*

<u>**CCSS.ELA-LITERACY.RST.6-8.3**</u>: *Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.*

<u>**CCSS.ELA-LITERACY.RST.6-8.7**</u>: *Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).*

Common Core Mathematics and ELA Standards Reference

Authors: National Governors Association Center for Best Practices, Council of Chief State School Officers Title: Common Core State Standards (insert specific content area if you are using only one) Publisher: National Governors Association Center for Best Practices, Council of Chief State School Officers, Washington D.C. Copyright Date: 2010

Unit Summaries

As an introduction to the ideas explored in this curriculum, the first unit, **"Guess and Check"** provides students with "secret messages" that they are challenged to decipher. During the process they will use their knowledge of the English language to employ strategies that will allow them to make progress in reading the message. They will come to learn that solid background knowledge coupled with committed persistence and tenacity can lead to successful results.

One of the simplest encryption methods involves the substitution of letters of the alphabet to match them with different letters of the alphabet or the numbers 1 – 26 by sliding them from their usual position to a slot that is a given number of characters removed from the original position. Such an encryption is the **"Caesar's Cipher".** Students will construct a tool and use team strategies to enable them to decipher and create messages based upon **"Caesar's Cipher".**

Some ciphers require a "Key" in order to decode the message. **"Finding the Right Route"** taps students' ability to make careful observations that help suggest the transposition key that leads to deciphering the secret message. The role that the teacher plays in guiding and suggesting pathways of inquiry is critical in this unit.

The ability to describe or identify something quantitatively allows us to rank order things, use statistics and probability to assist in decision making, and to make predictions based upon previously gathered information. Using numbers is also a strategy to encode secret messages. Most people are familiar with our base-10 number system but there are other number base systems that are useful as well. The base-2 number system can be used to write numbers as is done in the base-10 system. An advantage of the base-2 system that uses combinations of "Yes" or "No" or, alternatively, "On" or "Off" conditions is that we can use a variety of physical situations to represent these conditions. Students will use the "North" or "South" properties of magnetism to decipher and encrypt numerical messages written in the base-2 number system while working through the unit **"On or Off: Reading the Code"**.

Not all concealed messages use the alphabet or numbers as encryption characters. The **"Symbolic Encryption"** unit employs symbols as encryption characters. Upon being presented with a mysterious message, students engage in an inquiry that requires teamwork and guidance in order to construct a template and rule that allows them to decipher the message and create messages of their own using the newly discovered code.

Codes can also be used to prevent entry into places that are intended only for those who know the code. The familiar "combination" lock will be investigated to learn the difference between combinations and permutations. **"Locking onto an Idea: Considering the possibilities"** leads students through a series of tasks that bring out the possibilities embedded in different systems.

The benefits of choosing Morse code as the mechanism of communication lie chiefly in the many modes in which it can be transmitted. Once the character representations for the letters of the alphabet are known messages can be both encrypted and deciphered with relative ease.

"Digitized Message Transmission" first introduces the elements of Morse code to students and then explores various ways to transmit the messages.

Some secret messages are not as explicit as others. While "would be" code crackers might be able to see an encoded message they may not be able to decipher it. A more clandestine procedure is to prepare the message so that it cannot even be seen. Invisible messages can be hidden in readable narratives or combined with unintelligibly encrypted communications. Students will be forced to think in new ways in order to discover this encryption approach in, "**Seeing is Believing"**.

In the unit **"Tag Team Secret Messages"** students form teams and choose an encryption method from previous units to encrypt a list of phrases thus creating a "key". Keeping the method a secret, they pass their coded list of phrases to another team to decipher. A variety of strategies will be used by the teams to uncover the method of encryption.

Today's secure internet protocols are derived from a system known as "public key encryption" which makes use of one-way functions. In "**Who Holds the Key**?" students will be introduced to an asymmetric cipher and will learn the reasoning behind using an asymmetric cipher. Then, students will use graph theory and the idea of one-way functions to construct a Perfect Code public key cryptosystem for other teams to try and crack.

"**Secret Codon: A Genetic Cipher**" explores the way the human body uses DNA codes to build the various proteins that make each human unique. An internet-based animation will allow students to observe the processes of transcription and translation which allows protein synthesis to occur in the cells. Students will encode a message using a table of DNA codons, send the complementary codons to a partner to be transcribed into mRNA, and then use an mRNA Secret Codon Wheel to decode the message.

"The Final Challenge" is an integration of the knowledge gained of some basic encryption approaches with the creativity, tenacity, and persistence needed to follow a trail of encrypted messages that lead the teams to a final goal. This unit requires teamwork and advanced inquiry techniques as students race to complete the challenge and reach the goal so that they can assist others in the task.

The curriculum **"Secret Communications-Sharing Concealed Messages"** introduces some basic coding and encrypting strategies. Far more sophisticated and complicated approaches remain for students to explore as they continue to develop their understanding of mathematics and language. For now, the researchers and investigators pursuing the activities in this curriculum can apply their skills, talents, and knowledge to achieve success in getting "into the mind" of the agents attempting to get their messages across without being read and understood.

Good luck to all!

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Unit Objectives

GUESS AND CHECK
The students will:
- learn the frequency of letters used in the English alphabet
- use frequency analysis to help decode monoalphabetic substitution ciphers
- gain insights into decryption strategies

CAESAR'S CIPHER
The students will:
- recognize alpha-numeric means of coding messages
- discover patterns embedded in coded messages
- employ mathematical strategies in order to decipher certain types of codes
- learn to decipher alpha-numeric messages encrypted in various ways

FINDING THE RIGHT ROUTE
The students will:
- use a Route Transposition Template to decipher a message
- learn how to use a Route Transposition Template to encrypt a message
- create their own Route Transposition Templates and use them to encrypt and send messages to others

ON OR OFF: READING THE CODE
The students will:
- find ways to identify On / Off settings
- learn how different On / Off settings can be used to write numbers
- practice using base-2 number representations to write familiar base-10 numbers
- create their own encrypted messages using base-2 code

SYMBOLIC ENCRYPTION
The students will:
- learn how to use symbols to represent letters of the alphabet
- practice using the "Pig Pen" cipher to decode messages
- create their own encrypted messages using the "Pig Pen" cipher

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LOCKING ONTO AN IDEA: CONSIDERING THE POSSIBILITIES
The students will:
- demonstrate understanding of the difference between combinations and permutations of items
- devise strategies that help decipher combinations and permutations
- use a cryptex/bicycle lock to investigate possibilities for password encryptions
- investigate the importance of order

DIGITIZED MESSAGE TRANSMISSION
The students will:
- learn how dots and dashes are used to communicate
- read and interpret messages written in Morse Code
- create and send messages written in Morse Code
- use different means to send and receive Morse Code messages

SEEING IS BELIEVING
The students will:
- use their experience with different codes to read a secret message
- learn new strategies for revealing secret messages
- send others secret messages using invisible ink

TAG TEAM SECRET MESSAGES
The students will:
- use their experience with different codes to decide on one to use to encode a list of phrases
- determine the code used for the coded phrases of others
- decode the set of coded phrases

WHO HOLDS THE KEY?
The students will:
- compare/contrast symmetric and asymmetric ciphers
- encrypt a message using a public key
- decrypt a message using a private key
- create their own public and private keys to encrypt/decrypt messages

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SECRET CODON: A GENETIC CIPHER
The students will:
- understand that information within a DNA molecule is divided into genes that contain the code used to assemble a unique protein
- use technology to explore the two-step process of transcription and translation that results in the creation of a protein
- encode a secret message using the DNA codons, write a complementary DNA strand to be transcribed by a partner, and use the mRNA codons to decode the message

THE FINAL CHALLENGE
The students will:
- employ teamwork to decode secret messages
- become expert at decoding certain types of codes and encryptions
- engage in an exploration that uses differently coded messages to locate the ultimate treasure