STEMulate Student Curriculum Manual

University *of* Hawaiʻi®

Maui College

Project STEMulate
August 2021

Project STEMulate

Project STEMulate utilizes a Problem-based Learning model and approach to stimulate STEM interest, knowledge and skills of Hawai'i's high school students. Specifically, providing a STEM curricula that actively engages students in real-world, technology-based problem solving and learning. Project STEMulate seeks to transform the learning experience for high school students to motivate and prepare them for the STEM careers of tomorrow by supporting today's teachers.

Funded through the National Science Foundation* ITEST (DRL# 1657625), Project STEMulate created, implemented, and iterated the design of a *Problem-based Learning in STEM Professional Development and Teacher Training.* Over the course of three-years (2018-2020), University of Hawaii Maui College Faculty and Staff iterated the curriculum design to support high school teachers in expanding their ideology and repertoire to include Problem-based Learning.

Project STEMulate TEAM

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Table of Contents

1. Preface
2. Introduction
3. STEMulate Student Curriculum
    - Creating your problem-based learning environment
    - Example Syllabus Template
        - Course Outline
    - STEMulate Modules
    - Module #1: Introduction to Logic
    - Module #2: Evaluating Arguments
    - Module #3: Introduction to the Scientific Method
    - Module #4: Steps of the Scientific Method
    - Module #5: Inductive Logic and Science
    - Module #6: Designing and Performing Experiments
    - Module #7: Deductive Logic and Computer Science
    - Module #8: Analysis and Presentation of Scientific Data
    - Module #9: Introduction to Communicating Results through Technical Writing
    - Module #10: Professional Presentation Skills
4. Next Steps

Preface

According to the 2018 Program for International Student Assessment[1], U.S. students ranked 37th out of 78 countries for math and 18th in science. Nationally, Hawai'i students test among the lowest in the nation in math and science with Maui students scoring lower than the state averages in math and science. Moreover, low-income students continue to score lower on achievement tests[2,3], with the achievement gap widening between low-income and high-income students[4]. Native Hawaiian families have higher rates of poverty (18.5% for Native Hawaiians compared to 9.8%; US Census Bureau, *S1701*, 2016) and Hawaiʻi holds the highest per capita of homeless persons (US HUD, 2017). Hope for the future lies in STEM jobs, which are projected to grow at nearly twice the rate of the U.S. labor force[5,6] with a growth of almost one million from 2018 to 2028[7]; in contrast, 2 million STEM jobs are estimated to be unfilled in 2025[8]. Hawaii is predicted to have 31,965 STEM positions by 2026[9].

In response to these needs and projections, the University of Hawaii Maui College (UHMC) has created the Project STEMulate - a STEM Problem-based Learning (PBL) approach designed to develop STEM interest and motivation among underserved and underrepresented high school students. Specifically designed for Native Hawaiian and other underrepresented, low-income, potential first generation-to-college high school students, Project STEMulate utilizes PBL as an avenue to honor student voice and culture alongside STEM learning outcomes. Early on, the Project STEMulate model acknowledged that in order to impact students, teachers need innovative teaching strategies and resources to connect science learning with students' lived experiences. Teachers play a key role in cultivating the PBL student-driven environment in which students thrive. Yet, implementing PBL and creating a student-driven environment goes beyond the traditional teaching skill set and requires teachers to look beyond the textbook.

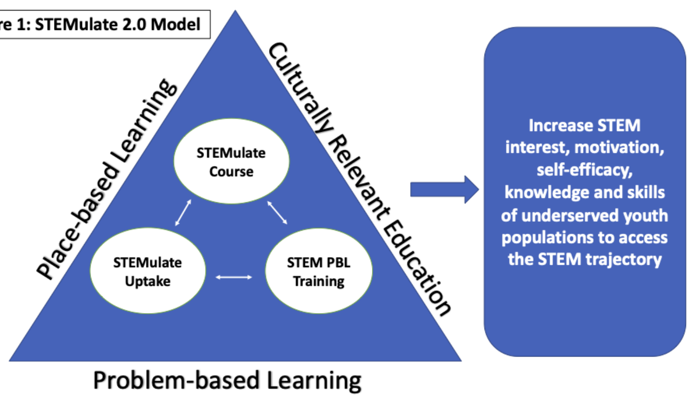
Funding provided by the National Science Foundation, allowed UHMC to further refine, implement, and research the effectiveness of Project STEMulate. Research findings revealed that students participating in the STEMulate PBL curriculum increased science motivation and self-efficacy, mathematics motivation and self-efficacy and STEM career interests. Project STEMulate found that through PBL training teacher dispositions improved in most dimensions, including teaching inquiry-based approaches, integrating technology, and STEM career knowledge and awareness.

This Teacher Training Guide provides teacher trainers, directors, program coordinators and others supporting teachers a sequence of activities used to shift teachers' mindset to include PBL approaches. Over the course of three years, the Project STEMulate team led by Dr. Amir Amiraslani and Mr. Derek Snyder iterated and evolved the *Problem-based Learning in STEM Professional Development and Teacher Training* to the set of activities provided in this guide.

Introduction

Project STEMulate proposes an innovative STEM Problem-based Learning Model that is multifaceted and multilayered aimed to connect students, teachers, STEM Industry, practitioners, institutions, and organizations (Figure 1). Problem-based Learning (PBL) is the foundation of the STEMulate Model and draws on Culturally Relevant Education (CRE) and Place-based Learning (PLBL) to create a community of support for underrepresented and underserved students towards STEM aspirations. The STEMulate Model leverages students' cultural identities and geographic locations as a foundation of strength and knowledge towards STEM self-efficacy and interest. By transforming students' experiences, teachers empower students to act and impact their surroundings and their place therein for the better (Nieto & Bode, 2007). The STEMulate Model uniquely combines the foundation of PBL with CRE and PLBL to broaden STEM participation to include Native/Indigenous, remote, and low-income students, while simultaneously engaging teachers and STEM Industry personnel in the learning process.

Figure 1: STEMulate 2.0 Model



Problem-based Learning (PBL). PBL is an innovative learning and instructional approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem (Savory, 2006). Essential tenets of PBL include: 1) student-driven and student-centered design; 2) real-world focus; 3) collaboration; 4) open-ended outcomes; and 5) interdisciplinary approach (Savory, 2006). In a PBL setting, students actively participate in their own learning to address real and relevant problems contributing to their own understanding and achievement outcomes (Barrows, 1985; Blumenfeld, Soloway, Marx, Krajik, Guzdial, & Palinscar, 1991; Gultek, 2005; Marx, Blumenfeld, Krajik, Soloway, 1997; Moursund, 1999).

Stalker, Cullen, and Kloesel (2015) found that Problem-based Learning (PBL) effectively engaged participants in exploring weather-related impacts. PBL is effective for teaching critical thinking, communication, collaboration, and applying knowledge to real-world situations

(Walker & Leary, 2009; Darling-Hammond, Barron, & Pearson, 2008; Strobel & Barneveld, 2009). Promising results of several high school studies indicate PBL is *as or more effective* than traditional teaching, especially with low-income students (Mergendoller, Maxwell, & Bellisimo, 2006, Strobel & Barneveld, 2009). Furthermore, adolescents are an ideal population for self-directed problem-solving curriculum (Halper, Heckman, & Larson, 2013). Yet, few opportunities exist for high school students to experience PBL curriculum (Atkinson & Mayo, 2010). Teachers with the skills to facilitate PBL, content knowledge in environmental science, and resources will provide students with meaningful learning experiences.

Teachers are a critical component in providing a PBL experience for students (Merritt, Rillero, & Kinach, 2017; Mergendoller, Maxwell, Bellisimo, 2006). Yet, studies point to teacher reluctance towards PBL due to curriculum standards, lack of PBL training, and discomfort with the unstructured PBL method (Subramaniam, 2014; Pagander & Read, 2014; Liu, Wivagg, Geurtz, Lee & Chang, 2012, Ertmer, 2010, Asgnar, Ellington, Rice, Johnson, & Prime, 2012; Nowak, 2017). Bound and Feletti (1997) stated that PBL fails to achieve anticipated learning outcomes when staff is not fully committed to PBL.

Culturally Relevant Education (CRE). CRE enables equal opportunities for students from diverse cultural backgrounds (Ladson-Billings, 1995) by creating meaningful connections between students' background knowledge (i.e., culture, language, and life experiences) and what they learn in class to increase relevancy towards academic success (Banks, 2017; Gay, 2010; Ladson-Billings, 1995). Aronson and Laughter (2016), draw from Gay and Ladson-Billing, to define CRE as teacher practice and disposition that 1) connects students' cultural references with academic skills and concepts, 2) engages students in critical reflection, 3) facilitates students' cultural competence to learn about their own and others' cultures, and 4) critiques discourses of power and finds opportunities to pursue social justice. Aligning with PBL, CRE demands student-centered instruction (Irvine & Armento, 2001) where teachers act as facilitators with high expectations of students and create a learning environment within the context of culture (Ladson-Billings, 1995). PBL strategies support students in recognizing, acknowledging, and applying their own cultural identities, strengths, backgrounds, and knowledge.

Place-based Learning (PLBL). PLBL is grounded in leveraging local structures and opportunities to contextualize the learning experience for students (Nadelson, Seifert, & McKinny, 2014). PLBL starts with vital community issues and links curriculum to students' lived experiences. By emphasizing the local community as one of the primary resources for learning, PLBL encourages learning that grounds students in their own history and culture (Sobel, 2004). According to Buxton (2010), "*When a topic of study is too far removed from our direct experience, it seems unlikely to inspire us to action. In contrast, topics that affect us physically, socially, and emotionally may call us to action and result in the need for new knowledge and skills*" (p. 125). Bennett (2016) found PLBL created a sense of relevancy among middle school students. Likewise, the extent students were connected to the material increased motivation and their ownership of learning (Appleton, Christenson, & Furlong, 2008; Hadre & Reeve, 2003).

STEM PBL Student Course Curriculum

This curriculum is a part of a larger NSF Funded project, entitled Project STEMulate. Project STEMulate aimed to build STEM motivation and interest among underserved and underrepresented (including low-income, first-generation-to-college, and Native Hawaiian) high school students through STEM Problem-based Learning (PBL). Problem-based Learning is characterized by the following core tenets: 1) real-world focus; 2) student-driven and student-centered design; 3) collaboration; 4) open-ended outcomes; and 5) interdisciplinary approach. The STEMulate Curriculum operationalized these tenets into an interactive and engaging experience for all learners. The STEMulate experience connected students, teachers, and STEM industry partners in an array of activities that constructs and reinforces the STEM workforce pipeline.

Highlighted in yellow are "**Teacher to Teacher**" comments on the rationale for the activities within the curriculum. This rationale will provide teachers with an opportunity to consider if the activity shared could be slightly altered for the specific context/audience to achieve the same learning outcomes.

Teacher to Teacher: Creating your STEM PBL Classroom Environment

Real World Focus

The cornerstone and anchor to the PBL process and Project STEMulate is the Real-World Focus. The guiding STEM-related Problem Topic Statement (PTS) is to be presented by the local industry (private, nonprofit, or other organization), known as the STEM Partner. The PTS is a written document of the Larger Topic. This is the macro-level thematic, ill-structured problem to be presented to students. The STEM Partner must be involved in the formation of the Problem Topic Statement. Coordinating staff contact and work with the local STEM Partner, before instructors are hired, developing relationships and starting the process to develop the Problem Topic Statement. Teachers that attend the Professional Development Training Course, are introduced to the STEM Partner and also work on developing the Problem Topic Statement. Once instructors are hired, they work with the STEM Partner (and Coordinating staff) on further developing the Problem Topic STatement for students in the Summer Course.

In addition to having the PTS as a written document, students will have access to the STEM-Partner as a primary central resource. During the first week of the Summer Course, the STEM partner provides an oral presentation of the Larger Topic. This oral presentation of the

Larger Topic can include an overview, working framework, related issues, possible problems and questions the STEM partner is currently working on related to the topic being investigated. During the Summer Course, the STEM Partner presents all related information to the students, provides mentorship (e.g., during site visits, expertise/mini-lectures, available to answer student questions along the way), provides feedback during mock/rehearsal presentations, and serves as a final symposium judge. The STEM Partner involvement may vary depending on the site. instructors must supplement the involvement of the STEM Partner

STEM Career Introduction. Prepare the STEM Partner/Guest Speakers/Field Trip Hosts to talk a little about their own career pathways and/or careers in the area. If the STEM Partner/Guest Speaker/Field Trip Host does not bring it up, be sure to ask them so the students can hear their response and be exposed to additional local STEM careers.

Student-Center/Student-Driven

The student-centered/student-driven approach is another cornerstone of PBL. The cornerstone of the STEMulate Summer Course is having students deconstruct the Larger Topic to Narrow Issues to select areas of interest and investigate and innovate around a specific problem throughout the summer. Deconstruction of the Problem includes:

Larger Topic> Narrow Issues > Specific Problem

As you guide students through the PBL process, continue to look for and self-reflect upon opportunities to let go of control and let your students drive.

Here are a few supports and tips along the way:

STEMulate Modules. The key to keeping your classroom a student centered/driven environment is the STEMulate Modules (modules). These modules do all the teaching for you! This means there is no need for you to prepare formal lessons. Rather, reinforce students' learning of the modules during class time. This also means you must view the module videos or read module transcripts prior to assigning modules (you do have prep time to do this). This will allow students to have ownership over lessons learned in the modules by asking them what they learned and how that needs to be incorporated into their problem projects.

There are a total of 10 consecutive modules that cover the topics of Scientific Method, Logic, and Technical Writing. The modules include: 1) Scientific Method covers the topics of Science, Western and Indigenous Ways of Knowing, and Experimental Methods 2) Logic covers the topic of integrated math to meet Upward Bound requirements; 3) Technical writing to support students as they write their reports and prepare for presentations. Modules include a video to watch, activities, and worksheets. These modules are to be assigned during time outside of the classroom (such as study hall) to support students in developing a hypothesis and critically thinking about the problem. The Course Syllabus outlines suggested days as to when modules should be assigned to students. Your role is to assign modules to students as homework, ensure that module activities and worksheets are completed, integrate module lessons into the classroom, and utilize report and presentation guidelines in the modules as grading standards.

Google Classroom. Google Classroom is a great way to assign and keep track of student work/progress and assign modules.

Authentic Learning Experience. Throughout the class, you will guide students to AUTHENTIC LEARNING EXPERIENCES (ALE) from experts, professionals, and related site visits/field trips. These ALE will be scheduled twice a week so that students can interact with the STEM Partner. Ideally, you'd work with the STEM partner to prepare lectures and/or tours in the first weeks of the program to help the students explore the complexities behind TOPIC, understand the multiple ISSUES within the presented framework, and help construct students' perspectives of his/her PROBLEM statement. During the final weeks, ask the STEM partner and/or other professionals you may have interacted with to consult with each group and give feedback on a mock/rehearsal presentation.

Coordinating staff typically do some scheduling before teachers are able to, but it is your responsibility to craft the experience as a whole for the student and fill in the blanks. You may have flexibility to schedule additional guest speakers or arrange field trips as you might see fit in helping your students explore the problem. Your students may have ideas too! Please ask them and attempt to accommodate reasonable ideas. Also, please check with your Upward Bound Director first. Each site varies in its ability to accommodate last minute travel. The more genuine the experience (i.e. in the actual learning environment, with professionals), the better.

Open-Ended Outcomes

As an instructor team, your main role is to create a learning environment that fosters student centered/driven learning that meets desired outcomes within the specified timeline. Support students to stay on task, ask questions to ensure they think critically, help the students support their project with data, guide them to valid sources of information (to include journal articles and experts), use technology, and prepare them to present. You may not know what students will be studying but you do have the framework to work within!

Course Syllabus. The course syllabus template has been created as a guide for your class and takes away some logistical stress. It provides you a baseline structure for your instructor team to start building your classroom. There are some aspects of the course that need to be standardized as all sites need common grading and student expectations. Your instructor team has flexibility and creativity within that framework to construct, instruct, and manage your classroom as your team sees fit.

Interdisciplinary Approach

The PBL Classroom is facilitated by an instructor team of 3 and a college mentor. The instructor team ideally consists of a math instructor, English instructor, and science instructor with one instructor having a knowledge of Hawaiian culture/values. Additionally, a college student is hired as a mentor to support student learning in the PBL Classroom and as students attend study hall to complete Modules. As an interdisciplinary team, the instructors and mentors work together to support student learning, help them process through the PBL process and integrate module lessons into student learning.

As part of the STEMulate Model, it is imperative that you all work as an instructor team (including the college mentor) and present a united front when working with students. Each of you come with strengths and content area expertise. Please ensure that your content area is explicit in each student's final product. This means that you will need to work with your fellow instructor on balancing the student workload and expectations. To support you in developing your instructor TEAM, you have been provided time within your daily schedule to meet to talk about your roles within the instructor team aside from content area such as how to split grading, give student feedback (ensuring you're not giving contradictory feedback), classroom management, monitor student progress, or classroom procedures. We encourage you to create a flexible outline of the day and set aside time at the end of the day to debrief how things went with possible ideas to evolve.

Native Hawaiian Cultural Perspective. Include discussions about Native Hawaiian perspectives and traditional ways of knowing. Native Hawaiians were biologists, astronomers, agriculture specialists, meteorologists, engineers, and more. How does your specific problem relate to traditional Native Hawaiian cultural ways of thinking and being? What are relevant cultural values and/or perspectives on the issue? Consult with the STEM partner, they may have Native Hawaiian Culture integrated into their site or program or they may have thoughts about how to make possible connections to culture. Another possibility is reaching out to cultural practitioners you may know to speak to students on the topic as a guest lecturer.

Hands on Application of Technology. Include at least one related technology that students can experience as part of their problem project. Consult with the STEM partner to explore possible technologies that can be integrated in the students' classroom experiences and/or problem project. Technology could be used to explore any aspect of a student's problem project from exploring the problem, conducting experiments toward possible solutions, or presenting outcomes. For example, some projects may use GIS Storymap (we have lesson plans available, please ask!) to gather information and present their final project. Other projects should use technology that is naturally included in the TOPIC (i.e. energy problems may use energy meters and generators; water-related problems may use water-quality testing kits and software packages, etc.). We want students to realize the technology around them as well as build self-efficacy to utilize technology to tell their stories, present their data, and use technology to their advantage. The Project STEMulate can purchase technology-related supplies as needed (e.g., energy meters, GIS receiver, etc.), please ask as soon as possible so we can order the supply (as the procurement process may take time).

Collaborative Group Work.

You will facilitate arranging students into groups of 4 students during the first week of classes. Groups should be arranged after the TOPIC has been presented by the STEM Partner. This is to allow students to have the opportunity to explore possible ISSUES of the TOPIC. A great activity to explore possible ISSUES of the TOPIC is the Sticky Note Exercise in which students brainstorm all the possible ISSUES and then categorize those ISSUES into clusters. This may be one way to identify multiple ISSUES that exist within that TOPIC and help students explore the ISSUE he/she is interested in. Students should form groups around the ISSUE that interests them. Please note: it is important, to the extent possible, to help students form groups that are integrated among grade levels (i.e. the students should not be all from one grade level in any given group). This is important to the students' learning and the competition. As the facilitator, you should pay attention to group dynamics to adjust groups as needed based on personalities or other factors.

STEM Symposium. Students will compete in a STEM Symposium providing their final presentation to a panel of 3-5 judges (see included scoring rubric sample). Judges should include the STEM Partner (or their designee), STEM Faculty, knowledgeable experts in the field, and/or relevant administration (i.e. the Chancellor or Vice Chancellor). Inviting relevant college administration as a Symposium Judge may be helpful in gaining support for STEMulate. Each program (i.e. the Upward Bound Directors) will need to help in identifying judges for the panel. Teachers can suggest judges too if you know of relevant people in the field. Additionally, you could ask sponsoring agencies for prizes to the winning group or find your own sponsors for possible prizes.

Example Syllabus Template

This example syllabus template and course outline was developed in partnership with University of Hawaii Maui College (UHMC) and Upward Bound programs. The syllabus was specifically designed as a UHMC credit course in which Upward Bound students enrolled in. Green Highlights indicate areas to insert or change information

University of Hawaii Maui College Science 114:
Introduction to Scientific Method and Laboratory

Course Description

This course exposes the students to the scientific method and reasoning as required in STEM disciplines through solving real-world problems. Introduces logic, problem-solving, evaluation process, lab methods, literature review, and technical writing.

Course Student Learning Outcomes and Competencies

Upon successful completion of this course, participants will:

1. Be able to solve problems utilizing inductive and deductive logic and following the steps of the scientific method, including ability to process, analyze, and critique the results of their own work while being familiarized with Native Hawaiian practices of science observation.
2. Be able to follow lab techniques and procedures, write lab reports, carry out experimental science, gather and analyze data in order to draw conclusions, find reliable sources of information and research, review current literature, write a technical report, and present the results of their work.
3. Gain specific science and math knowledge related to the content area of the question stimulus.

Course Format

Problem-based learning (PBL) is an instructional approach that has been used successfully for over 30 years, and continues to gain acceptance in multiple disciplines. PBL is an instructional learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem. Critical to the success of this approach is the selection of ill-structured (i.e., no particular, certain answer) interdisciplinary problems, and a teacher who guides the learning process and experience.

Course content will be delivered through:

- Online curriculum modules with worksheets and activities
- In-class and discussions
- Authentic Learning Experiences with community STEM partners
- Independent and group research

Students are expected to access the course website, obtain materials, and complete class activities on a regular basis.

Students must be familiar with using a computer and also have basic Internet skills (browsing, sending emails, saving/sending files).

Course Assignments & Grading

This course implements a flipped-classroom setting, where students will often follow instructional videos in Study Hall, and then use the skills learned in the videos to design and implement their PBL project. In this course, students will most likely need to dedicate approximately 16-20 hours every week to learn what is necessary. This includes class time, study hall, working on your own, and authentic learning experiences. Please build this time into your schedule and plan to complete Online Modules daily.

Grading will be comprised of the following assignments, assessments and activities:

1. Online Module Assignments (20%)
2. Scientific Report: 3-5 pages following Online Module Assignments. See attached rubric for expectations. (30%)
   a. Abstract
   b. Introduction
   c. Materials & Methods
   d. Results
   e. Discussion/Conclusion
   f. APA References
3. Presentation of Scientific Report: Presentation 10-15 minutes. See attached rubric for expectations. (30%)
4. Individual Participation: Self-Assessment and Teacher-Assessment Provided (10%)
5. Teamwork: Group Evaluation Provided (10%)

Grades will be based on the final total point score on an A-F scale (>90%A, 80-89%B, 70-79%C, 60-69%D, <60%F). Graded materials will be returned as quickly as possible, and you can ask your instructor for information about your grade at any point in time, so that you understand where your grade stands. Please make an appointment with the instructors if you have any issues. Don't wait until the end of the course to notify instructors of a problem, or it may not be fixable at that time. *If you find you are having any trouble understanding materials or have questions, contact the instructor immediately – it is easier to fix these issues earlier rather than later!*

Course Schedule Overview/Daily:

8:00-9:00am	Instructor Team Mtgs
9:00am-12:00pm	PBL work/ STEM partner site visits
12:00-1:00pm	Lunch
1:15-2:30pm	Study Hall (Modules)

Course Policies and Student Expectations

1. Attendance:

2. Field Trip and Site Visit Policies:

3. Homework and Late Policy:

4. (Add others here)

SCI 114: Introduction to Scientific Method and Laboratory
Course Schedule Summer XXXX

The course schedule is **subject to change**, depending on specific project and/or community partner requirements.

Wk	Day	Classroom 9am-12pm	Student Progress	Study Hall 1:15-2:30pm
1	1	Student Introduction, Ice Breakers, PBL Intro, Students introduced to Topic Statement, **STEMulate Research: Student Pre-Assessment**	Develop understanding of PBL	Module #1: Intro to Logic Video 1 Activity Worksheet
	2	Presentation of TOPIC by STEM Industry Partner (as well as overview of organization, related STEM careers and multiple example questions)	Individual students identify possible issues (using Module 1)	Module #2: Evaluating Arguments Video2 Activity Worksheet
	3	Student further discuss and refine possible ISSUES. Students form groups by interest around ISSUE (group discussions to refine possible ISSUES using Module 2)	Students form groups. In groups, students present & evaluate each other's arguments. Choose one ISSUE to focus on.	Module #3: The Scientific Method of Inquiry Video 3 Activity Worksheet
	4	Authentic Learning Experience - gain feedback and insight on ISSUE from site visit/guest speaker.	Refinement of ISSUE to Problem Statement.	Module #4: Steps of Scientific Method Video 4 Activity Worksheet
2	5	Problem Statement, hypothesis, scientific method identified	Problem statement & Hypothesis created	Module #5: Inductive Logic & Science Video 5 Activity Worksheet
	6	Authentic Learning Experience - gain feedback and insight on Problem Statement and possible experiments. Get contact information for experts as sources or leads to other sources.	Problem statement & Hypothesis refined; Identify reliable sources	Module #6: Designing & Performing Experiments Video 6 Activity Worksheet
	7	Designing & Performing Experiments	Work on Experiment; Materials & methods identified;	Module #7: Deductive Logic & Computer Science Video 7

			Outline due	Activity Worksheet
	8	Authentic Learning Experience - gain feedback and insight on Problem Statement and possible experiments. Get contact information for experts as sources or leads to other sources.	**Introduction due**	Module #8: Analysis and Presentation of Scientific Data Video 8 Activity Worksheet
3	9	Experiment/Data gathering	Work on Experiment	Module #9: Communicating Results through Technical Writing Video 9 Activity Worksheet
	10	Authentic Learning Experience - discussions with experts, data gathering from site visits, based on problem statements		Module #10: Professional Presentation Skills Video 10 Activity Worksheet
	11	Experiment/Data gathering executed	Data analysis	
	12	Authentic Learning Experience - discussions with experts, data gathering from site visits, based on problem statements		
4	13	PBL workday prepping presentation and technical report	**Draft Paper Due**	
	14	Authentic Learning Experience - Experts provide feedback on research/presentations	**Presentation Draft Due**	
	15	Practice Presentations (Class/Instructor feedback)	**2nd Draft of Paper Due**	
	16	STEM Partner feedback/PBL workday prepping presentation and technical report	**Presentation Revisions Due**	
5	17	MOCK SYMPOSIUM	Revisions on presentation and paper	
	18	PBL workday prepping presentation and technical report	**Final Presentation Due**	
	19	SYMPOSIUM	Revisions on paper	
	20	**STEMulate Research: Post-Assessments**	**Written Reports Due**	

Authentic Learning Experiences:

Throughout the course, students will learn from experts, professionals, and related site visits/field trips for you to interact with the STEM Partner. These Authentic Learning Experiences will provide you with real life information on the complexities behind TOPIC, understand the multiple ISSUES, and help construct your perspectives of his/her PROBLEM statement and solutions.

STEMulate Modules

STEMulate Modules were created to support teachers in creating and keeping a student-centered student-driven classroom environment. Modules consist of videos and assignments for students. Teachers were provided with a lesson plan for each module that included an overview, learning outcomes, materials, lesson objectives, video transcript, bridging activities (bridge module lessons to students problem-based learning projects), and forecasting what‘s next.

<table>
<tr><th colspan="2">Module 1: Introduction to Logic</th></tr>
<tr><td>Overview</td><td>In this module, students will learn how to structure a logical argument. They'll learn what logic is, why it's important, and how to use it. Students will apply this argument-structure to the PBL-problem by creating their own argument. This exercise should be thought of as a very preliminary step - just a way for students to show that they can come up with an argument consisting of a conclusion ("what" they want to persuade someone to believe) and supporting evidence (reasons "why" they think someone should believe their conclusion). Students shouldn't feel locked into the argument they come up with here. Future modules will further explore different types of logical arguments and how to create a "good" argument.</td></tr>
<tr><td>Learning Outcomes</td><td><table><tr><td>Student Learning Outcomes</td><td><u>Course SLO 1</u>
Participants will be able to solve problems utilizing inductive and deductive logic and following the steps of the scientific method, including ability to process, analyze, and critique results of their own work while being familiarized with Native Hawaiian practices of science observation.

<u>Course SLO 2</u>
Participants will be able to follow lab techniques and procedures, write lab reports, carry out experimental science, gather and analyze data in order to draw conclusions, find reliable sources of information and research, review current literature, write a technical report, and present results of their work.</td></tr></table></td></tr>
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	<u>Course SLO 3</u> Participants will gain specific science and math knowledge related to the content area of the question stimulus.
Program Learning Outcomes (LIBERAL ARTS)	1. Demonstrate an understanding of theories, practices, histories, and key issues of a field of study using essential terminology and concepts of the discipline. (SLO1) 2. Use theories, concepts, and practices of a field of study to analyze evidence, artifacts, and/or texts and produce interpretations, hypotheses, evaluations, or conclusions. (SLO2) 3. Apply theories and/or methods of a field of study to perform practical, scholarly, and/or creative tasks that respond to social, cultural, environmental, or economic issues. (SLO3)
Course Competencies	At the completion of the course, students will be able to: a. Apply Logic, and steps of the Scientific Method to any problem solving situation. b. Observe and learn about Native Hawaiian perspective of observation. c. Carry out lab assignments confidently. d. Write technical lab reports. e. Learn to locate reliable sources, read, and interpret research journal articles. f. Learn to write a technical report and professional present results. g. Learn the Math and Science content knowledge related to the STEM Industry Partner.

Materials

Video	Module #1: Introduction to Logic [Video]
Video Length	14:05
PPT	Module #1: Introduction to Logic [Slides]
Worksheet	Module #1: Activity #1 [Worksheet]
Additional	N/A

	Resources
Lesson	**Lesson Objectives** 1. Students will learn what logic is and how it can be used. 2. Students will demonstrate an understanding of logic by creating a logical argument in standard form. 3. Students will apply these logic skills to the problem being addressed by the class.
	Transcript 1. **SLIDE 1: Introduction to Logic** a. Welcome to module number one, an introduction to logic. 2. **SLIDE 2: Preview** a. What is logic exactly? We'll take a look at this through several questions. We'll ask: i. What do we mean by "logic"? ii. What will thinking logically do? iii. How do we think logically? iv. What's an argument? v. How do I make a logical argument? 3. **SLIDE 3: What is Logic? (a)** a. My favorite definition of logic is that it's organized common sense. What I mean by that is that you already have an intuition about it. It is very natural, just your common sense. And when we study logic, what we're doing is just organizing it in a way that you probably just haven't thought about before. b. I don't expect that any of you already have a background in logic. What you'll find here is that this will come very naturally to you. We'll be using new words in different ways and organize it in a specific way, but it's something that should feel right to you. c. One way we come across situations that should require our logic skills is when we see or hear advertisements. d. Imagine you're watching tv and you see an ad that says 50% off at your favorite store. What's your first reaction? Mine is, "Cool! I should check it out!" But think about what they're advertising. What are they promising? What needs to happen in order for what they said to be true? i. At least one item needs to be 50% off. Other items could be 20% off, 10% off, or even 0% off! As long as one item is 50% off, they kept their promise. 4. **SLIDE 4: What is Logic? (b)** a. Another example: a few years back I saw a commercial for cereal. It flashed a picture of the cereal and then said, "People who eat whole grains tend to have healthier body weights." When I saw

	this, my first reaction was, "wow, I'll be healthy if I eat this cereal!" and something like "I'll lose weight if I eat this cereal!" i. But, when you really think about it, what are they actually promising? Nothing! ii. All they're doing is telling you something about people who eat whole grains; they're making an **observation**. There was probably some study that showed that people who eat whole grains tend to have healthier body weights. b. That is not a promise that *if* you eat this cereal, *then* you'll have a healthier body weight. If I were to just sprinkle this cereal on my cheeseburger, would I be healthier? No way! 5. **SLIDE 5: What is Logic? (c)** a. So what's going on here? How often do we think about the commercials that we watch? And what's going on when we watch these commercials? b. We're usually in a pretty passive (as opposed to active) state. When you're in an active state, like when you're in school, you're thinking critically about the information you're hearing. But, when you're watching tv, you're in a passive state. Where are we, or what are we doing when we watch/listen to ads? We're watching tv, on an app on our phone, surfing the web, or watching a video. c. Are we active or passive thinkers when we listen to these ads? Well, when we hear them, we're usually just in our normal day, going about our business, not actively thinking about the information we're hearing. d. That doesn't mean it's a *bad* thing to be in a passive state. We all need to be in a passive state now and then; it would be exhausting for our brains to be actively thinking about every piece of information we hear. But we need to be careful not to jump to conclusions when we're listening to these ads. We need to think critically about the information that is given to us. 6. **SLIDE 6: What will thinking logically do?** a. So, what will thinking logically do? Will it make me a faster thinker? I get this question a lot, and I think that it's really easy to assume that when we think logically, we'll be much faster at making connections. b. Well, here's the thing: you're *already* quick at making connections. Think about watching the commercial for the cereal: you see a picture of the cereal, and hear the statement about a healthier body weight, and your brain is already trying to connect the two. And advertisers *absolutely* know this. Our brains are very quick at making these connections. c. So when you think about something logically, you may think that if I learn logic, I'll be a faster thinker. And that may end up happening. But for now, our goal is to slow down our brains. Sometimes we think quickly, and sometimes we think slowly. d. Our brains work really fast to make sense of information, but

	sometimes that might mean we make connections where they shouldn't be made. e. Thinking logically will mean slowing down to make sure that we're making the right connections. f. Think of your brain as a muscle. You need to practice thinking logically so you can build your muscle memory! **7. SLIDE 7: How do we think logically?** a. So *how* do we think logically? Thinking logically is natural but it requires some practice and guidance. Like I said earlier, we'll be using different terms and organizing it a specific way. So, it should feel "right" most of the time, but it'll take some time to get used to it. **8. SLIDE 8: What's an argument? (a)** a. So, what is logic really about? It's all about arguments. When you hear "argument" you might have a particular picture in mind. You might think of people getting in each other's face, or getting frustrated with each other and walking away. Or people just huffing and puffing. b. Where are you when you hear arguments? We hear them at home, maybe an argument with a family member. It could be at school, in the classroom or on a break. And political arguments seem to be everywhere these days. **9. SLIDE 9: What's an argument? (b)** a. In logic, when we say "argument" we're not talking about a personal disagreement or a fight. We're talking about something very organized. b. In logic, arguments are organized ways to get someone to believe us. If I want to convince someone to believe me, I'm going to tell them my point – *what* I want them to believe, and my reasons – *why* I think they should believe me. **10. SLIDE 10: What's an argument? (c)** a. So, in logic, there are two parts to an argument: one is our **conclusion -** *what* we want people to believe, and our **evidence**– *why* people should believe our claim. This is really the basis of all of logic: arguments. Conclusions and evidence. b. Have you ever had a conversation with someone, and you feel like they're just going around and around in circles? They're talking, and you don't understand what they're trying to do. You may feel like shouting at them, "WHAT is your point? What are you trying to convince me of?" That would be their **conclusion**– what they want you to believe. And then the next natural question to ask is, "Why should I believe you? What's your **evidence**?" That's all we're doing here.

	11. SLIDE 11: What's an argument? (d) a. Here's an example of an argument in logic. Imagine I told you, "Lei would make a great school president because she was vice president last year, and she has great ideas to lead the school." This is something you'd probably hear someone say. i. What do I want you to believe when I say this? I want you to believe that Lei would make a great school president – that's what I'm trying to convince you of. This is the "what" or the **conclusion**; what I'm trying to convince you of. ii. And if I were to tell you this, you would naturally ask, "Well, why should I believe you?" I've given two pieces of **evidence** here: 1. Lei was vice president last year 2. She has great ideas to lead the school. 3. Both of these count as the **evidence**– I'm giving you two pieces of evidence, or reasons, why you should believe my conclusion. **12. SLIDE 12: Constructing logical arguments** a. Speaking logically means speaking clearly. We're not trying to be mysterious here. We want to be very clear about what we mean. So when I'm giving an argument, what I'm really doing is creating a reasoning trail; I'm creating a path for someone so they can arrive at the destination I want them to. **13. SLIDES 13-15: Constructing logical arguments** a. To keep our arguments organized, we state our evidence first and then state the conclusion. When we do this, we're presenting the argument in logical form. b. Here is that previous example in logical form. i. My first piece of evidence is that Lei was vice president last year. ii. My next piece of evidence is that Lei has great ideas to lead the school. iii. If you believe my evidence, you should believe my conclusion that Lei will make a great school president. c. Now, I want to point out a couple things about having this argument in logical form. i. First, using the word "therefore" shows that we're arriving at our conclusion. It's like saying, if you accept my evidence, then you should accept my conclusion. We're showing that it's *because* of the evidence that we accept the conclusion. ii. The next thing is that there should be at least one piece of evidence to support the conclusion. iii. If there isn't any evidence, then we don't have an argument; we have an assertion. An assertion is a conclusion without anything to back it up. That basically means it's just an opinion!

	1. If all I said was "Hey, Lei would make a great school president," I haven't offered an argument; I've only given my opinion (made an assertion). **14. SLIDE 16: More examples of arguments** a. Let's take a look at a few more examples of arguments. b. Here's a more logical version of the second advertisement we looked at earlier. i. Cereal X has whole grains; whole grains are healthy; therefore, Cereal X is *probably* healthy. ii. This conclusion is supported by the evidence here. c. Here's another one: i. Crumbs attract roaches; my car has a lot of crumbs; therefore, roaches might be attracted to my car. ii. Again, the evidence here supports the conclusion. iii. (Oops! I couldn't find a roach emoji - that's probably a good thing. Here, enjoy this ant!) d. Here's another one: i. Climate change is affecting Pacific islands; Maui is a Pacific island; therefore, climate change will affect Maui. e. Finally: i. Many communities depend on fishing for food and to help their economy; rising ocean temperatures are threatening the world's fish populations; therefore, many communities will be affected by rising ocean temperatures. f. For all these, you can see that the evidence works to support the conclusion. The **conclusion** is always *what* I want you to believe; *what* I want to convince you of. And then the **evidence** is *why* I think you should believe me. **15. SLIDES 17-18: Activity: Constructing an argument** a. Finally, let's do an activity to help you create your very own argument! b. Think about the problem your class is investigating. Imagine telling a friend or a family member about the problem. i. First, I'd like you to take a look at: What is a conclusion you might make about the problem? ii. Next, what is some evidence you would use to support your conclusion? iii. Third, present your argument in logical form; meaning, show the evidence first, write "therefore" and then present your conclusion. c. After you've done that, discuss with your classmates: i. Do you think your friend or family member would accept your argument? ii. How can we tell whether an argument is good or bad? iii. And finally, how sure should we be about our arguments? d. In the next video, we'll be discussing how to evaluate arguments; meaning, how to figure out if they're good arguments or bad

	arguments. e. Thank you very much and we'll see you then!
Building Bridges Activity	Module #1: Activity #1 [Worksheet] Project STEMulate Name: ______________ Activity #1 Construct Your Own Argument After you've watched **Module #1: Introduction to Logic**, try out your new logic-skills! Think about the problem your STEMulate class is investigating. Imagine telling a friend or family member about the problem. 1. What is a conclusion you might make about the problem? 2. What evidence would support your conclusion? 3. Present your argument in logical form. Evidence *(Remember, you need at least one piece of evidence.)* Ev #1: ______________ Ev #2: ______________ Conclusion Therefore, ______________ Discuss these questions with your classmates: (This will get you ready for **Module #2: Evaluating Arguments**) 1. Do you think your friend or family member would accept your argument? 2. How can we tell whether an argument is good or bad? 3. How sure should we be about our arguments?
Up Next	Module 2: Evaluating Arguments

Module 2: Evaluating Arguments	
Overview	This module covers different ways to evaluate arguments, depending on whether they are deductive or inductive. Students will learn to distinguish between the two types of arguments and how to tell whether the arguments are strong or weak.
Learning Outcomes	Student Learning Outcomes: <u>Course SLO 1</u> Participants will be able to solve problems utilizing inductive and deductive logic and following the steps of the scientific method, including ability to process, analyze, and critique results of their own work while being familiarized with Native Hawaiian practices of science observation.

	Course SLO 2 Participants will be able to follow lab techniques and procedures, write lab reports, carry out experimental science, gather and analyze data in order to draw conclusions, find reliable sources of information and research, review current literature, write a technical report, and present results of their work. Course SLO 3 Participants will gain specific science and math knowledge related to the content area of the question stimulus.
Program Learning Outcomes (LIBERAL ARTS)	1. Demonstrate an understanding of theories, practices, histories, and key issues of a field of study using essential terminology and concepts of the discipline. (SLO1) 2. Use theories, concepts, and practices of a field of study to analyze evidence, artifacts, and/or texts and produce interpretations, hypotheses, evaluations, or conclusions. (SLO2) 3. Apply theories and/or methods of a field of study to perform practical, scholarly, and/or creative tasks that respond to social, cultural, environmental, or economic issues. (SLO3)
Course Competencies	At the completion of the course, students will be able to: a. Apply Logic, and steps of the Scientific Method to any problem solving situation. b. Observe and learn about Native Hawaiian perspective of observation. c. Carry out lab assignments confidently. d. Write technical lab reports. e. Learn to locate reliable sources, read, and interpret research journal articles. f. Learn to write a technical report and professional present results. g. Learn the Math and Science content knowledge related to the STEM Industry Partner.

Materials

Video	Module #2: Evaluating Arguments [Video]
Video Length	28:18
PPT	Module #2: Evaluating Arguments [Slides]
Worksheet	Module #2: Activity #2a [Worksheet] Module #2: Activity #2b [Worksheet]

	Additional Resources	N/A

Lesson

Lesson Objectives

1. Students will be able to distinguish between evidence and conclusions.
2. Students will demonstrate the ability to create an argument in *logical form.*

Transcript

1. **SLIDE 1: Evaluating Arguments**
   a. Welcome to Module #2
   b. In this video, we'll be discussing evaluating arguments.

2. **SLIDE 2: Preview**
   a. In the last video, you discovered what an argument is. In logic, we present arguments which have evidence and conclusions. The **evidence** is the reason that we think someone should accept our **conclusion**, or main point.
   b. Today's video will be broken up into two parts. In the first part, we will discuss how you can tell if an argument is good. We talked last time about what an argument is, and in this video, we'll talk about how you tell whether it's a good one.
   c. We'll go over two types of arguments: inductive and deductive. So "arguments" is the main category, and there are two sub-categories: inductive arguments and deductive arguments. Then we'll pause for an activity: a worksheet on the Magician or Logician puzzle. We'll come back for the second part of the video to discuss the purposes of inductive and deductive arguments, and then there will be another activity about inductive arguments.

3. **SLIDE 3: How can I tell if an argument is *good*? (a)**
   a. So how do we tell if an argument is a good one? One of the most important things about arguments is that conclusions should be *relevant* to the evidence provided. Here's what we mean by that: you can have three random statements put together, and it's not an argument if there's not clear evidence to support a clear conclusion.
   b. Let's take a look at the argument from last time. Lei was vice president last year. Lei has great ideas to lead the school. That's great evidence to accept the conclusion here, that Lei will make a great school president. So we see that the conclusion is drawn *from* the evidence. It's not totally unrelated.

4. **SLIDE 4: How can I tell if an argument is *good*? (a)**
   a. Look at how it could play out. Switch the conclusion to "Lei should go to the beach." Imagine our argument was: Lei was vice president last year; Lei has great ideas to lead the school; therefore, Lei should go to the beach. In this case, the **conclusion** is *not* drawn from the **evidence**. The evidence is not relevant to the conclusion. In order to make a point, your reasons should be supporting that point, not completely random statements. Good evidence to support the conclusion that Lei should go

	to the beach, would be something like, "Lei likes the beach", "Lei is five minutes away from the beach", "Lei doesn't have anything to do today." Whatever our conclusion is, our evidence needs to support that. 5. **SLIDE 5: Two types of arguments** a. Now as long as our evidence is relevant, we can discuss what *type* of argument it is. Remember, there are two types of arguments: inductive and deductive. In an inductive argument, the evidence supports the conclusion with probability. In a deductive argument, the evidence supports the conclusion with *certainty*. Just to be clear, when I use the words "reasoning" and "logic" these terms are used interchangeably. When I say "argument," I mean something specific – the logical sense of an argument. But I may switch between all three of these: reasoning, logic and argument. 6. **SLIDE 6: The sun rises everyday** a. Think about this: the sun rises everyday… right? 7. **SLIDE 7: Two types of arguments** a. If we take a look at an *inductive* argument, we might say something like: i. The sun has risen every day in the past. ii. Tomorrow is another day. iii. Therefore, the sun will rise tomorrow. b. This is pretty good evidence to support our conclusion. Think for a minute and see if you can tell what the **conclusion** of the argument is, and what **evidence** is used to support it. The conclusion is our point – you'll remember this from the first video. The point of this argument is that I'm trying to convince you that the sun will rise tomorrow. My evidence is that the sun has risen every day in the past, and that tomorrow is another day. That's good reason to believe the sun will rise tomorrow. i. But is it a guarantee? c. No. I'm pretty sure that the sun will rise tomorrow. But it's not an absolute guarantee. I can even say I'm 99.99999% sure, but I could never say I know it 100%. This is what it means for an inductive argument to support the conclusion with probability. Even though it's a very high probability, it's not an absolute guarantee. We don't know with 100% certainty that the sun will rise tomorrow. 8. **SLIDE 8: Two types of arguments** a. The other type of argument is called *deductive*. Here, the evidence supports the conclusion with *certainty*. Here's how an argument like look there. i. The sun rises every day. ii. Tomorrow is another day. iii. Therefore, the sun will rise tomorrow. b. Is this a guarantee? Well, my conclusion is that the sun will rise tomorrow, and my evidence is that (1) the sun rises every day and (2) tomorrow is another day. So, if my evidence is TRUE, then my conclusion HAS to be true. There's no way around it; it's guaranteed. So the focus isn't on whether or not the conclusion or evidence *is actually* true. Rather, the focus is on the relationship between the evidence and the conclusion. So *if* this evidence is true, then the conclusion is guaranteed.

c. Take a look at this evidence: the sun rises every day. That seems like a rule, or a stipulation. In the previous argument, we have: the sun has risen every day in the past. That's the difference. In the inductive argument, I'm stating an observation – something that we accept as fact, a way that something has always been done. But just because it's always happened one way doesn't mean it'll always continue to do so. In our deductive argument, it's like I'm making a rule. I'm telling you that the sun rises every day. That's a rule, or a stipulation. Tomorrow is another day, and so the sun will rise. It doesn't matter what the words say, or whether it's true or false in real life. The question is, how does the evidence support the conclusion? In this deductive argument, *if* the evidence is true, then the conclusion *has* to be true. I'm not discussing whether or not the evidence is true. I'm only saying *if* the evidence is true, then the conclusion is guaranteed.

d. Look at the inductive argument again. If that evidence is true, is the conclusion guaranteed? It *is* true, but that doesn't guarantee that the sun will rise tomorrow. The evidence in this argument doesn't support the conclusion with certainty. It supports it with very high probability, but it's not 100%.

9. **SLIDE 9: How can I tell if an argument is *good*?**
   a. Now, how do we tell if it's a *good* argument. What we're *not* doing here is judging whether the information in the argument is true or false – at least not directly. What we're looking at is how well the evidence supports the conclusion. When we look at an argument from a logical perspective, the only thing we care about is how the evidence supports the conclusion. As a *logician* it's not our job to discover whether or not the information in the argument is true or false; it's our job to look at how the evidence supports the conclusion. So, in this inductive argument, if the information in it is true, then the conclusion is probably true, but not guaranteed. When we are acting as *scientists*, we will care that the information in our argument is actually true in the real world. Of course, scientists will also want to use logical arguments to make sure they're following the evidence to the right conclusions.

10. **SLIDE 10: Two types of arguments**
    a. So, good inductive arguments are considered "strong." A strong inductive argument is one in which *if* the evidence is true, the conclusion is *probably* true; there's a very high probability.
    b. This is the type of reasoning used most often in science - it allows the scientists the flexibility to figure out how the world works without needing to have the pieces of the puzzle fit precisely.
    c. We'll cover more of this in Module 5.

11. **SLIDE 11: Two types of arguments**
    a. Here's our deductive argument. If the evidence is true, then the conclusion *has to be* true. So a good deductive argument is considered *valid*. A valid deductive argument is one in which *if* the evidence is true, then the conclusion *must* be true as well. It is guaranteed.
    b. This type of reasoning is especially important for mathematics and computer science. Here, we need precision - everything needs to connect like pieces of a puzzle.

c. Now, this can also be important for science as well. Once scientists start to figure out how things *probably* work in the world, they may need to test their theories using models. Those models will depend on math and computer science, telling the scientists what they can expect to happen *if* their theories are indeed true.
d. We'll cover more about this in Module 7.

12. **SLIDE 12: Activity**
    a. In the next activity, I'd like you to take a look at the Magician or Logician puzzle. You have a worksheet for this. Please read the puzzle and see if you can figure out what color hat Carla is wearing. More importantly, think about the type of reasoning being used. Is it inductive or deductive?
    b. Please continue on that worksheet and when we come back for the next video, we'll go over the answers. So please complete the worksheet *before* continuing to the next video.

Please pause this video for a moment to read and work on that worksheet.

13. **SLIDE 13:**
    a. Welcome to the second part of Module #2. I hope you had a good time reading the Magician or Logician puzzle, and I'd like to go through the answers with you.
    b. So, what color hat was Carla wearing? She was wearing a... blue hat! Now again, it's not so much the goal of this exercise that you figure out the "trick" of it. You can spend some more time trying to figure that out.
    c. I'll run through it very quickly here, but then I'll go over the more important part: What type of reasoning was being used by the participants? The reason that's more important is that it should show you the difference between inductive and deductive reasoning.
    d. So, quickly, what color hat is Carla wearing? A blue hat. Carla knows that because when Alani had her turn, she was hoping that she would see both Brandi and Carla wearing red hats. Remember, there are only two red hats and three blue hats. So, if she saw two red hats on Brandi and Carla, Alani would know her hat was blue. But Alani doesn't know. From this, we know that it's *not* the case that Brandi and Carla are wearing red hats; if they were, Alani would have cashed in on her prize!
    e. That leaves two open possibilities:
        i. one of them is wearing a red hat, or
        ii. they're both wearing blue hats. So, when Brandi looks at Carla, she's hoping that Carla is wearing a red hat.
    f. That would tell her that it's that one possibility where one of them is wearing red and the other one blue, and if Carla is wearing blue then Brandi must be wearing red. Well, she looks at Carla, is very disappointed and says she doesn't know. So that's why Carla, who is gathering this information, is able to tell with 100% certainty that she is wearing a blue hat! She knows that she's not wearing a red hat, because if she was, then either Alani or Brandi would have won the game.
    g. So what's important about this? What's important is that the participants are using deductive reasoning. What would this exercise sound like if the they were using inductive reasoning? Well, we know that there are two red hats and three blue hats, so the probability of

them wearing a blue hat is 3/5, or 60%. But, with the risk of being hypnotized, they want to be absolutely certain that their conclusion is true. So the important thing to note here is that if the information Carla gets from Alani and Brandi is true, then her conclusion has to be true.

h. Think about it, if the inductive argument had a higher probability, would you take the risk? How high would it have to be? 70%? 80%? 90%? And what would have happened to Carla if Alani or Brandi had given false information? What would have happened to Carla? Carla is only making her conclusion based on the evidence that's given; she has no idea whether that evidence is true. But if his evidence is true, then her conclusion is guaranteed with 100% certainty.

14. **SLIDES 14 & 15:**

a. So let's take a look at the purposes of inductive and deductive arguments. Which one is better? Well, we like certainty, so deductive arguments might seem better at first. But as we just saw, deductive arguments may not be the answer to all of our problems. That's because, Carla is basing her answer on the information Alani and Brandi gave her. But she doesn't know for sure that the information is true. All she knows is that if it is true, then her conclusion is guaranteed. So, in deductive arguments, we might have a false conclusion that is guaranteed by our evidence. We're not sure whether or not the information is true; we only know how the evidence supports the conclusion.

15. **SLIDE 16:**

a. So in a valid deductive argument, the evidence supports the conclusion with certainty, but it doesn't tell you whether the evidence is true. Let's take a look at another valid deductive argument.

All humans have purple hair.
Julius is a human.
Therefore, Julius has purple hair.

b. Well, we know that at least the first piece of evidence is false. But let's imagine some parallel universe where it's true that all humans have purple hair. And let's assume that the second piece of evidence is true, that Julius is a human. Wouldn't that guarantee that Julius has to have purple hair? Absolutely!

c. In a valid deductive argument, the evidence supports the conclusion with certainty. But is the evidence true? In a valid deductive argument, it doesn't matter whether or not the evidence is true. The only thing that matters is that if the evidence is true, then the conclusion is guaranteed. This is a hypothetical situation. Imagine this parallel universe where it's true that all humans have purple hair, and it's true that Julius is as human. Then it would absolutely be true that Julius has purple hair. It's not true in real life that all humans have purple hair, but that doesn't matter for a valid deductive argument.

16. **SLIDE 17:**

a. Ok, let's look at an invalid deductive argument.

All mice like cheese
Julius likes cheese
Therefore Julius is a mouse.

b. Let's say that the evidence here is true, that all mice like cheese, and that Julius likes cheese. Would that guarantee that Julius is a mouse? No!

The evidence could be true while the conclusion is false.

17. **SLIDE 18:**
    a. Here's another one.
       All humans have purple hair
       Julius has purple hair
       Therefore, Julius is a human.
    b. Let's say the evidence is true. Does that make Julius a human? Is the conclusion guaranteed? Nope! This is also invalid.

18. **SLIDE 19:**
    a. Let's change it to this:
       All mice like cheese
       Julius likes cheese
       Therefore, Julius is a mouse.
    b. It's invalid! But if we rearranged it, we could make it valid. If we said: Only mice like cheese; Julius likes cheese; therefore, Julius is a mouse. That would be valid!
    c. Do you see the difference between these two arguments? We only changed one word – we changed "all" to "only," and this made it valid. If it were the case that the only creatures that like cheese are mice, and Julius liked cheese, then Julius would have to be a mouse!

19. **SLIDE 20:**
    a. So deductive arguments are just word games. The evidence guarantees the conclusion, but we're not concerned with whether the evidence is actually true. It's just a puzzle! We want to make sure that the pieces fit together just right.
    b. In a valid deductive argument, we don't care about whether the information is actually true. We only care about whether the pieces fit together to guarantee us the conclusion.
    c. Think about a computer program. What can Siri tell you? A computer program can only do what it's programed to do. If you ask Siri how far the nearest Starbucks is, she gives us the answer that her programming allows her to give. She's not taking a yard stick and finding the all the nearby Starbucks and measuring the distance to make sure what she's telling you is true. She's basing her conclusion on the evidence given to her: GPS marks for you and GPS marks for Starbucks. If the GPS information she's been given is true, then her calculation of the closest Starbucks will be true. What if a new Starbucks popped up overnight and Siri hadn't received the update? Siri's calculation would be correct, based on the evidence she has. But it wouldn't be true in real life. This is much like deductive logic, which is the basis for computer science. We'll discuss that more in Module #7.

20. **SLIDE 21:**
    a. So inductive arguments allow us to hypothesize. A hypothesis is a tentative explanation or answer to the question posed, or a plausible solution to the problem. When we form a hypothesis, we're making an informed guess - we're proposing a conclusion that we think the evidence will support.
    b. We don't know for certain that our conclusion is true. We only know that our evidence gives us reason to think our conclusion is true. We're not

	looking for 100% certainty here; we're looking for support. If we were looking for that kind of certainty, we'd be dealing with deductive reasoning. But the problem we just saw with deductive reasoning is that we don't know whether or not the information is true. **c.** So which type of reasoning do you think is used in science? **21. SLIDES 22 & 23:** **a.** Science uses inductive reasoning. Are scientists ever 100% sure about their conclusions? No! Science is always open to revision. Scientists may talk sometimes like they're totally sure about some things, like gravity. But science is always open to revision if the information we gather is good enough to make us rethink things. **b.** So, if we're going to revise something that we're really, really sure about – like gravity – it would have to be amazing, incredibly strong evidence to get us to revise our conclusions. That's actually not unheard of. **i.** Einstein changed our views about gravity, and only recently was evidence gathered to support his conclusion. **c.** So, in science we use inductive reasoning because we need that sort of flexibility. We can state our evidence and come up with a conclusion that it seems to lead to. We don't need to worry about our evidence and conclusion fitting into some perfect puzzle. And, is the evidence true? This is a very important question in science. But it's a different question than what we're looking at in these modules. What we're looking at is how the evidence supports the conclusion. **d.** When you look at this from a logical perspective, that's the only question you're concerned about it. When you look at it from a scientist's perspective, then you care about whether or not the evidence is true. Now, these two ways to look at the information you're getting are very important, and it's important that they work together. It's important that you are able to investigate whether the evidence is true and it's important that you're able to investigate how the evidence supports the conclusion. So, that's how logic – especially inductive reasoning – and science really work well together. **22. SLIDE 24:** **a.** Now, deductive logic can also play a role in science. It can help us make sure that our theories are consistent. It can help us theorize and make predictions: if this evidence is true, then the conclusion would have to be true. So, deductive logic can definitely play a role in science, but it's not the basis for scientific reasoning. Science uses inductive reasoning and we'll be talking a lot more about that in Module #5. **b.** So, if our quest in science is to find out truths about the world around us, we need inductive reasoning to guide us because it gives us the flexibility to make predictions and hypothesize. We don't have to fit everything into this perfectly put together puzzle. **23. SLIDE 25:** **a.** So, what I'd like you to do next is to go through another activity. I'd like you to create an inductive argument based on the problem your class is investigating. And then make it deductive. Finally, I'd like you to discuss with your classmates which one is more meaningful. Remember to put your arguments into logical form.

	24. SLIDE 26: **a.** Here's an example: Many communities depend on fishing for food and economic development. Rising ocean temperatures threaten the world's fish population. Therefore, many communities will be affected by rising ocean temperatures. **b.** If our first piece of evidence is that many communities depend on fishing for food and economic development. And our second piece of evidence is that rising ocean temperatures threaten the world's fish population, then our conclusion can be that therefore, many communities will be affected by rising ocean temperatures. You can see that this is an inductive argument: the evidence supports the conclusion with a high probability. **25. SLIDE 27:** **a.** Here's how we could make it deductive. Remember that deductive arguments are just word-puzzles. So, our first piece of evidence can be, if ocean temperatures rise, then the world's fish population will be threatened. Second, if the world's fish population is threatened, then many communities will be negatively impacted. Therefore, if ocean temperatures rise, then many communities will be negatively impacted. **b.** You'll see that this fits together like a puzzle, but that doesn't mean that the information is true. It might be true! But in deductive reasoning, we're not worried about that. **26. SLIDE 28:** **a.** So, think for a little bit about which one is more meaningful. What makes the deductive argument different from the inductive argument? What kind of evidence should we use for each? And, what makes our conclusions scientific? **b.** We'll talk more about inductive reasoning and science in later modules.
Building Bridges Activity	Module #2: Activity #2a [Worksheet] Think about the problem your class is investigating. Which type of reasoning will be more helpful for your STEMulate problem? Why? ☐ Inductive ☐ Deductive Why? ____ ____ ____ Module #2: Activity #2b [Worksheet]

	Project STEMulate Name: ____________ Activity #2b Construct Your Own Arguments After you've watched **Module #2: Evaluating Arguments**, try out your logic-skills! Think about your STEMulate problem. 1. Create an inductive argument based on your class problem. Evidence #1 ____________ Evidence #2 ____________ Conclusion ____________ 2. Then, make it deductive. Evidence #1 ____________ Evidence #2 ____________ Conclusion ____________ 3. Which one is more meaningful? Why? ____________
Up Next	Module 3: Introduction to the Scientific Method of Inquiry

Module 3: Introduction to the Scientific Method of Inquiry	
Overview	Students will become familiar with and explore the scientific method of inquiry through examples in their everyday life and comparing and contrasting this with how native Hawaiians may have used this process.
Learning Outcomes	Student Learning Outcomes — Course SLO 1 Participants will be able to solve problems utilizing inductive and deductive logic and following the steps of the scientific method, including ability to process, analyze, and critique results of their own work while being familiarized with Native Hawaiian practices of science observation.

	Course SLO 2 Participants will be able to follow lab techniques and procedures, write lab reports, carry out experimental science, gather and analyze data in order to draw conclusions, find reliable sources of information and research, review current literature, write a technical report, and present results of their work. Course SLO 3 Participants will gain specific science and math knowledge related to the content area of the question stimulus.
Program Learning Outcomes (LIBERAL ARTS)	1. Demonstrate an understanding of theories, practices, histories, and key issues of a field of study using essential terminology and concepts of the discipline. (SLO1) 2. Use theories, concepts, and practices of a field of study to analyze evidence, artifacts, and/or texts and produce interpretations, hypotheses, evaluations, or conclusions. (SLO2) 3. Apply theories and/or methods of a field of study to perform practical, scholarly, and/or creative tasks that respond to social, cultural, environmental, or economic issues. (SLO3)
Course Competencies	At the completion of the course, students will be able to: a. Apply Logic, and steps of the Scientific Method to any problem solving situation. b. Observe and learn about Native Hawaiian perspective of observation. c. Carry out lab assignments confidently. d. Write technical lab reports. e. Learn to locate reliable sources, read, and interpret research journal articles. f. Learn to write a technical report and professional present results. g. Learn the Math and Science content knowledge related to the STEM Industry Partner.

Materials

Video	[Module #3: Introduction to the Scientific Method of Inquiry [Video]]
Video Length	25:45

PPT	Module #3: Introduction to the Scientific Method of Inquiry [Slides]
Worksheet	Module #3: Activity #3 [Worksheet]
Additional Resources	1. Big Bang Theory Video (Slide 17): https://www.youtube.com/watch?v=_7sSuhQ1_24 2. Samuel `Ohu Gon III TEDx talk (Slide 21): https://youtu.be/l9fv_2XIJBk?t=5m7s

Lesson

Lesson Objectives

1. Students will be able to describe some indigenous methods and ways of knowing, or learning, about the natural world.
2. Students will define the scientific method of inquiry.
3. Students will be able to list the five steps of the scientific method and describe the ways in which they use it in their daily life.
4. Students will compare and contrast the ways that western scientists and native Hawaiians try to understand the natural world.

Transcript

1. **SLIDE 1: Introduction to the Scientific Method of Inquiry**
    a. Today, we'll be learning about the Scientific Method of Inquiry. The primary goal is to introduce and familiarize you with the different ways that humans have looked at and explored the world around them throughout history and the tools that they have used to do this, including the Scientific Method. We'll put on our science "hats" and examine why scientists think and do science the way they do, and how best to use inductive reasoning. Remember, inductive reasoning doesn't just play word games like deductive reasoning does. Instead, it uses strong evidence to lead us to make conclusions about the world.

2. **SLIDE 2: Objectives**
    a. Your goal by the end of this lesson is to be able to:
        i. Explain some indigenous methods and ways of knowing, or learning, about the natural world.
        ii. Define the scientific method of inquiry.
        iii. List its five steps, and describe the ways in which you already use it in your daily life.

	iv. Compare and contrast the ways that Western science and Native Hawaiians try to understand the natural world. 3. **SLIDE 3: Worksheet Question #1: What is Science?** a. So, what is science? Using your worksheet, answer question #1. Think for a moment about what science means to you, and jot down several words that you think of when you hear the term, "science." I'll give you a few minutes. You can pause the video if you need to. See if you can come up with a few words that aren't listed here. 4. **SLIDE 4: Science is an approach to understanding the world around us - a way of knowing** a. We often think of scientists as people in white lab coats with crazy hair using colored liquids, but in fact, the word science is derived from the Latin verb *scientia*, which means "to know." And really, **science** is just one approach to understanding the world around us - one way of knowing. It developed out of our curiosity about ourselves, other organisms, our planet, and the universe itself. 5. **SLIDE 5: Traditional methods and ways of knowing** a. Let's begin by first gaining an understanding about the history of ways of knowing in our own backyard, with traditional Hawaiian practices. b. Hawaiians have been observing their environment for thousands of years, and much of that knowledge has been passed down through moʻolelo or stories, oli or chants, and mele or songs, as well as other cultural practices. 6. **SLIDE 6: Lessons from Hawaiian Culture** a. As we continue to learn more, it is important to keep in mind that western science is only one way of knowing and trying to understanding the world around us. Western and cultural views of science are different, but they can also be complementary. b. What we find in Hawaiian culture is that emphasis is placed on knowledge considered critical for survival and success, or **cultural continuity** c. Rules and required knowledge, or **skills**, were taught by experts and done in the field d. And that **the Environment is a teaching tool.** Skills are learned by observing and imitating nature; and signs and symbols in nature are thought to show the presence of a god and have meaning to man.

e. **Mastery** is obtained by learning whole "sets of knowledge" with specific terms, concepts, applications, and metaphors, instead of focusing on obtaining single data points and attempting to develop a conclusion from them
f. And lastly, behavior patterns are choices that are based on **values and social structure.**

7. **SLIDE 7: Lessons from Hawaiian Culture - A Case Study of the Kumulipo**
   a. To understand the traditional or cultural view of science Native Hawaiians, let's explore how the native Hawaiians used a specific chant, the Kumulipo, to describe and make sense of the world around them, and how western science and cultural knowledge can, and do, complement each other.
   b. The kumulipo is a sacred creation chant, used to describe the genealogy of Hawaiian al`i, or chiefs. Remember that when we look at legends and stories, these are ways in which ancient peoples tried to explain the world around them with what knowledge they had gained from observation.

8. **SLIDE 8: The Kumulipo - A Sacred Creation Chant**
   a. When Captain James Cook first landed at Kealakekua, Hawaii, in 1779, he was greeted with food, water, and a ceremony was called in his honor. This sacred creation chant, the Kumulipo, was recited to him during the ceremony.
   b. In later years, Queen Liliuokalani identified it as a genealogical prayer chant, which belonged to her family, and traced the family's divine origin through great rulers, heroes, and primary gods back to the first spark of life in the universe.

9. **SLIDE 9: The Kumulipo - A Creation Chant**
   a. The first part of the chant describes the origin of the universe as a combination of great heat, churning heavens, and light, which brought forth a slime "that established the earth."

10. **SLIDE 10: Could this have been Primordial Slime?**
    a. The origin of life on planet Earth has always been a debate in Western science, but in 1953 two scientists by the name of Miller and Urey did research, and asked the question if the building blocks of life, which are proteins, could be created from the non-living chemical elements that were available on the planet when life was thought to have come about. In a famous experiment, they tried to simulate the conditions thought to be present on early Earth and tested the chemical origin of life under those conditions.
    b. The conditions included water vapor - a churning gas, heat, and light in the form of an electrical spark, and lo and behold, they were able to produce amino acids, which are the building blocks for proteins. Could the native Hawaiians been onto something long before Western Science could explain it?

11. **SLIDE 11: The Kumulipo - a creation chant**

	a. The kumulipo goes on to describe the genealogy of the animals as though attempting to classify them into groups of related forms. The emergence of each animal type is through birth - or H(a)nau - one creature giving birth to another which is nearly but not exactly like it, which is very similar to Western views of evolution. b. In this context, the "birth" and groupings of these animals is very similar to our present system of taxonomy, the science of classification, whereby animals are grouped by characteristics based on the likeness of structure, shape, and ecological needs. As each new form of life appears in the Kumulipo, it seems to be more complex than its predecessor. This classification continues further in the chant from what's shown here. 12. **SLIDE 12: Western Scientific View of Taxonomy** a. If we examine the Western Science view of taxonomy, we see there are many similarities to the kumulipo, including the emergence of organisms from simple to more complex. b. There are corals, and groups of worms; sea stars, sea cucumbers and sea urchins all fit into one group, the Echinoderms, and barnacles and oysters fit within the molluscs or other shelled animals. c. When we start with the coral polyp, which belongs in a group called the Cnidarians that also contains sea anemones and jellyfish, it is described in the Kumulipo as the origin of the other animals...and western science also sees it as a basal, or early group. 13. **SLIDE 13: The Kumulipo - A Creation Chant** a. Even as the kumulipo describes the emergence, or evolution of plants, moving from the limu, or algae, to land plants such as the ferns, this lines up very well with modern Western scientific beliefs that plants moved from water to land, and one specific algae, called a charophyte, may resemble the algal ancestors to all land plants, including ferns. 14. **SLIDE 14: At the heart of science are curiosity and inquiry** a. At the heart of all science, or different ways of knowing and understanding the world around us, is both curiosity and ***inquiry.*** Inquiry is the search for information and explanations of natural phenomena. Hopefully our discussion has helped you see that there are many similarities in both Western and cultural views of science, and that they can be complementary. Now let's focus on how Western scientists use inquiry to "do" science. 15. **SLIDE 15: How scientists use inquiry to understand the world** a. It is important to note that there is no one formula for scientific inquiry, no single method that all scientists rigidly follow, and in fact, as we'll see later on, science is rarely linear or rigid - there are elements of adventure, challenge, creativity, reasoning, and logic involved, as well as careful planning, patience, and perseverance as we attempt to find solutions to problems and to answer specific

	questions about the living systems, organisms, and phenomena that we see around us. b. However, scientists do strive to produce produce reliable and repeatable results. Here is one of my favorite cartoons that shows how scientists are different from "normal" people, where this scientist gets zapped by lightning when they pull the lever, but still goes back for second try to determine if they will get the same results! c. Remember, it's important to use both our "logic hat" and our "science hat" when asking questions and doing experiments. The "science hat" makes sure that we're using good evidence, and the "logic hat" makes sure that good evidence is leading us to a good conclusion. d. In general, scientists use a process of inquiry called the **scientific method.** i. The scientific method is a way of looking at, or inquiring about, the world around us, through the process of asking questions about what we *observe* and attempting to answer them through *experimentation.* ii. While there is no "silver bullet" in how scientific inquiry is conducted, there are certain elements that characterize Western science and can help distinguish it from other ways of describing and explaining nature. 16. **SLIDE 16: The scientific method of inquiry.** a. Who uses the scientific method? i. You do! So do I, and so does every other human being. b. How often do you use the scientific method? i. Believe it or not, every day! We just don't call it "the scientific method." ii. <u>*For example*</u>*:* Imagine you wake up on a Saturday and looking around (**research**) realize (**observe**) that you can't find your iphone. You do a little **research** by thinking about the last time you had it, and ask yourself the **question**, "Where might I have left my iphone?" In thinking about it, you suspect the answer to your question might be in the pocket of the pants you wore yesterday - which is a **hypothesis**. When you find your pants and check them for your phone, you're doing an **experiment**...but things in life don't always go as planned and as a result, you find no cell phone in your pants pocket. So, you **analyze** the situation,

	concluding you must have been wrong. At this point, you may make a **second observation**; you think again about what you did yesterday and realize that you may have put it in your bag during school, deciding it must be there (a **second hypothesis**). Again, you go and check (your **second experiment**) and *lo and behold* life can continue - this time you find it! iii. You're so happy with this new result that you then **share (communicate)** with your best friend by explaining why it took you so long to text them back. c. In this scenario, you have just used all the steps the scientific method of inquiry! 17. **SLIDE 17: Inquiry in Action.** a. Let's see the scientific method in action in another example from the television show, The Big Bang Theory. (LINK: https://www.youtube.com/watch?v=_7sSuhQ1_24) 18. **SLIDE 18: Worksheet Question #2.** a. At this point, I'd like you to return to your worksheet and answer question #2. Write down at least *two* examples of when you have used the scientific method of inquiry in your daily life. i. It might be something as simple as baking a batch of cookies. If they don't come out exactly as expected, you might take steps to inquire about what went wrong. Be specific in your answers. How might you use the steps we just discussed? You can pause the video at this point to fill in your answer. **19. SLIDE 19: Steps of the Scientific Method** a. There are five official steps of the scientific method, which will be further explored and detailed in the next module. They are: 1. #1, **Make an observation** (or do *research*) about a phenomenon. a. Scientists (which includes you!) use personal observations of natural phenomena - or their study of previous research - as a basis for asking questions about them. 2. Next, use your observations or research to **ask a question** about some aspect of the phenomenon,

	including underlying causes or reasons why something might have occurred, or you could also identify a problem that you would like to study. a. Additionally, scientists will often propose a formal hypothesis that they can test. i. Recall that a *hypothesis* is a tentative explanation or answer to the question posed, or a plausible solution to the problem. There are certain rules for making a good hypothesis, and we'll explore those in detail the next module. 3. **Design and carry out an experiment** to test your hypothesis. a. It's also often helpful to make a *prediction* as to what results you might expect from your experiment. b. Thinking in terms of inductive logic, a prediction is like saying: "If this evidence is true, it should get us to this conclusion." So, if our prediction is successful, we'll see that when we have good evidence, it gives us good reason to accept the conclusion. 4. **Analyze the results** of the experiment, **and draw a conclusion** as to whether or not your hypothesis was supported by the results. 5. And finally, **communicate, or share, your results** with others. b. It is important to note that the scientific method is an idealized process, and does not need to be followed in a strict fashion, but each of the elements listed above is usually present in some form or another. 20. **SLIDE 20: The steps of the Scientific Method.** a. Also, notice that you can go back and repeat steps in the process. This typically occurs after you conduct an experiment and conclude whether or not your results actually answer the question you posed originally, much like our example with the phone. If not, you can always go back and try something different out! 21. **SLIDE 21: Samuel `Ohu Gon III: Ecologist and Cultural Practitioner**

	a. Lastly, I'd like you to watch a video about a real-world example of how Western and traditional ways of knowing can be used to explore a very real and relevant issue of environmental sustainability in Hawaii. Dr. Samuel `Ohu Gon III has been an ecologist for the last 35 years, and is also a Native Hawaiian cultural practitioner. Watch his TEDx talk, and then fill in the remainder of your worksheet by comparing and contrasting the two different methods for scientific discovery and ways of knowing that we've discussed today. You'll also examine your Project STEMulate issue in the context of this information. We'll see you with our next module, where we'll explore the steps of the Scientific Method in detail. (LINK: https://youtu.be/l9fv_2XIJBk?t=5m7s)
Building Bridges Activity	Module #3: Activity #3 [Worksheet] 4. **Think about the issue(s) or problem your group is considering working on for the rest of Project STEMulate. In what ways might the Native Hawaiians might have dealt with the same problem, or a closely related one, in the past? Or, perhaps even solved it?** Write the issue(s) you have chosen, and explain your thoughts and potential connections between your group's potential issue(s) and how Native Hawaiians might have dealt with it, or a similar problem, below.
Up Next	Module 4: Steps of the Scientific Method

Module 4: Steps of the Scientific Method of Inquiry	
Overview	Students will explore the steps of the scientific method in detail. The Scientific Method itself is best taught through the lens of the PBL problem, but listed here are important details for both instructors and students to consider, and other activities to illustrate certain points. I've also incorporated opportunities/suggestions where you could discuss and integrate the PBL process into the lesson plan.
Learning Outcomes	<table><tr><td>Student Learning Outcomes</td><td><u>Course SLO 1</u> Participants will be able to solve problems utilizing inductive and deductive logic and following the steps of the scientific method, including ability to process, analyze, and critique results of their own work while being</td></tr></table>

	familiarized with Native Hawaiian practices of science observation. Course SLO 2 Participants will be able to follow lab techniques and procedures, write lab reports, carry out experimental science, gather and analyze data in order to draw conclusions, find reliable sources of information and research, review current literature, write a technical report, and present results of their work. Course SLO 3 Participants will gain specific science and math knowledge related to the content area of the question stimulus.
Program Learning Outcomes (LIBERAL ARTS)	1. Demonstrate an understanding of theories, practices, histories, and key issues of a field of study using essential terminology and concepts of the discipline. (SLO1) 2. Use theories, concepts, and practices of a field of study to analyze evidence, artifacts, and/or texts and produce interpretations, hypotheses, evaluations, or conclusions. (SLO2) 3. Apply theories and/or methods of a field of study to perform practical, scholarly, and/or creative tasks that respond to social, cultural, environmental, or economic issues. (SLO3)
Course Competencies	At the completion of the course, students will be able to: a. Apply Logic, and steps of the Scientific Method to any problem solving situation. b. Observe and learn about Native Hawaiian perspective of observation. c. Carry out lab assignments confidently. d. Write technical lab reports. e. Learn to locate reliable sources, read, and interpret research journal articles. f. Learn to write a technical report and professional present results. g. Learn the Math and Science content knowledge related to the STEM Industry Partner.

Materials

Video	https://screencast-o-matic.com/watch/cqhFeBThcv
Video Length	19:06
PPT	Module #4: Steps of the Scientific Method of Inquiry [Slides]
Worksheet	Module #4: Activity #4 [Worksheet]
Additional Resources	*Instructor's note: If needed, please see the following paper for a discussion on the difference between hypotheses and predictions: http://datanuggets.org/wp-content/uploads/2014/03/Strode-2015-Hypothesis.pdf*

Lesson

Lesson Objectives

1. Students will be able to distinguish between quantitative and qualitative data.
2. Students will Identify the difference in reliable and unreliable sources for scientific research.
3. Students will be able to identify and write proper hypotheses and predictions for a controlled scientific experiment.

Transcript

1. **SLIDE 1: The Steps of the Scientific Method**
    a. Aloha and welcome back. By now, you should have a good understanding of what the five steps of the scientific method are, and also what each of them entails. In this module, we'll be going into some of the details and considerations that must be made as you go through the process of this method of inquiry.

2. **SLIDE 2: Objectives**
    a. Your goal by the end of this lesson is to:
        i. Distinguish between quantitative and qualitative data.
        ii. Identify the difference in reliable and unreliable sources for scientific research.
        iii. Identify and write proper hypotheses and predictions for a controlled scientific experiment.

3. **SLIDE 3: The Steps of the Scientific Method**
    a. Let's review the five steps of the Scientific Method of Inquiry.

b. Recall that we first:
   1. Make an observation about a phenomenon, or do background research on something that interests us.
   2. Next, we ask a question, or several, and develop a testable hypothesis, which is a proposed answer to the question.
   3. Then, keeping this in mind, we can design and carry out an experiment to test the hypothesis, at which point it's helpful to make a prediction for the results we expect to see based on our observations or research.
   4. After that, we analyze the results of our experiment and draw conclusions as to whether or not our hypothesis is supported or not, and lastly,
   5. We communicate, or share, our results.

c. There are several things that scientists must take into consideration when doing science in order to produce repeatable, reliable results. So, let's explore each of these steps in detail.

4. **SLIDE 4: Making Observations (Step 1)**
   a. Let's begin with Step 1, Observation. In the course of their work, scientists describe natural phenomena as accurately as possible through careful observation and analysis of *data*. Sometimes this step is left out when you see the steps listed elsewhere, but you must make observations before asking a question, whether you recognize it or not.
   b. You also always need to have some background information about the topic of interest, and often can find out what has been done previously and build from there. However, it's a good idea to be systematic about your observations and to record them in a lab notebook or some other place. Often, these initial observations can help you identify a specific question that you'd like to study.
      i. **Observation** is the gathering of information, either through the use of the five senses, or with the help of the tools of science, such as microscopes, thermometers, and balances that help extend our senses.

5. **SLIDE 5: Making Observations (Step 1)**
   a. Recorded observations are called **data**, and data can be either quantitative or qualitative.
      i. **Qualitative data** is data that is often in the form of recorded descriptions or qualities that can be described, rather than numbers.
      ii. **Quantitative data,** on the other hand,is data that is generally expressed as numerical measurements and can often be organized into tables and graphs.

	iii. Scientists analyze their data in the form of a type of mathematics called *statistics,* in order to test and determine if their results are significantly different from what could have been obtained by chance. 6. **SLIDE 6: Worksheet Question 1** a. Now turn to your worksheet, pause the video, and answer question #1. See if you can identify the type of data you would collect for each statement - qualitative or quantitative. 7. **SLIDE 7: Worksheet Question 2** a. Next, examine the picture of the reef shown here, and answer question number 2 on the worksheet. I want you to come up with three examples each of qualitative and quantitative data that could be collected about the reef. i. Don't be afraid to think outside the box on the type of data you might collect, not just the obvious things you can see... for example, what about temperature? You can't see it in the picture, but in the field, this would be important data to collect. Come up with your own examples, and remember, if we're measuring a quantity or number of something, we're collecting quantitative data. If we're describing the qualities of something, we're collecting qualitative data. 8. **SLIDE 8: Research** a. Because science is cumulative, or builds on the work of others, observations can and do include *research* - or the reading and studying of what others have done in the past, such as collecting and analyzing important background information about a subject. b. It's important to note that any research should always be from *reliable* sources - ones that deliver information that can be, or are, backed up by scientific data, and are not just opinions of a specific group or organization.. c. Think about what kind of research materials would be considered "reliable"...if you came up with, books, scientific journal articles, and websites from *.gov* and *.edu* you're correct. These tend to be the most reliable in terms of getting information for research. d. Unreliable sources are things like blogs, out-of-date textbooks, and other types of websites, like *.com* or *.org*, which are not usually objective. Wikipedia also comes up often for students, and while it's true that you should not take information directly from Wikipedia, it can be a good starting place to identify sources (which are often cited at the end of an entry). However, anyone can write or edit a Wikipedia entry, so you have to be careful to identify where the information came from. 9. **SLIDE 9: Asking Questions and Proposing Hypotheses (Step 2)**

	a. Our innate curiosity as humans often stimulates us to wonder about the natural world and stirs a desire to determine the basis for the phenomena we have been observing. b. This can come in the form of a question, such as "Why do plants grow towards the light?" or "Do female mice prefer males with normal or droopy ears?" Or it can also involve the identification of a specific problem you would like to study within the context of a larger problem, which is the second step of the scientific method of inquiry: Asking a question. c. For example, pause the video for a moment and ask yourself: i. First of all, what do you notice (observe) about this picture? ii. Then, what types of questions might you ask about it? iii. You can pause the video now. d. It's important to note that science has limits. We can only investigate certain types of questions. A "good" scientific question must be *clearly defined and testable.* If something is testable, it is also both measurable, meaning that it is quantifiable, and that it is controllable; there must not be too many variables present at any one time or we will not be able to determine an answer to our question. 10. **SLIDE 10: Asking Questions and Proposing Hypotheses (Step 2)** a. Next, let's try our hand at identifying "good" scientific questions. See if you can identify which of the following questions could be answered scientifically - or which of them are clearly defined, measurable, and controllable. Pause the video, turn to your worksheet and answer question number 3, identifying which of the questions listed could be answered scientifically. i. (PAUSE) ii. In general, all of the questions except for #3 are clearly defined and testable. #3 has a key word in it that you should watch out for - "*should.*" It brings values and ethics into the question, and therefore cannot be answered using scientific inquiry. As you will learn in the logic lessons, questions concerning religion and supernatural activity are considered outside the bounds of science, and are therefore untestable. iii. #1 is sometimes also sometimes considered untestable, but notice it is only attempting to determine a link - or correlation - between the two items, which *can* be assessed with research and supporting data, but note that positive correlation does not necessarily indicate cause and effect. 11. **SLIDE 11: Asking Questions and Proposing Hypotheses (Step 2)** a. After we have determined that our question is both clearly defined and testable, we can propose a hypothesis. Many students think of a hypothesis as "an educated guess" but this isn't the most accurate definition. Rather, a hypothesis is a proposed explanation for an observable phenomenon, based on research or many

observations. Or, as I like to think of it, it's a tentative answer to the question we have just proposed. It can also be a plausible solution to the problem we are working on. It's essentially an explanation on trial through the process of scientific inquiry and experimentation.

b. Hypotheses can be broad, but a good hypothesis must follow two rules: it must be *testable* and it must be *falsifiable* (for example, it must be possible that the test results do not support the hypothesis). Let's examine this further. If any result we got could support the hypothesis, where would that leave us? Would we have actually answered our question? No. And in fact, it is often better to be able to find out something is false because it rules one solution out and we've then narrowed down our quest. Note, however, that "falsifiable" does not mean "false".
    i. For instance, the hypothesis "all swans are white," could be falsified by observing all available swans and finding a black swan. On the other hand, the statement that "there is a black swan somewhere" could only be falsified by observing every swan in existence and noting that none of them are black.
    ii. For statements like "there is intelligent life elsewhere in the universe," this may be falsifiable, but is at best impractical and may well be considered impossible...thus, it fails in testability.
    iii. Similarly, as discussed earlier, questions of ethics (such as, how would you disprove a statement like "murder is evil"?) or aesthetics (how could you disprove a statement like "flowers are pretty?") are usually held to be unfalsifiable since they rely on a degree of personal judgement, values, and/or assumptions and are thus, outside the realm of science.

12. **SLIDE 12: Asking Questions and Proposing Hypotheses (Step 2)**
    a. Note that our initial observations can lead to multiple hypotheses. Let's say you're out camping and drop your flashlight. When you pick it up, it no longer works. The question here is obvious, "Why doesn't the flashlight work?"
        1. What possible hypotheses could answer this question?
        2. Your hypothesis might be, "The bulb is burnt out." Or perhaps, "The battery is dead." Both are equally testable and falsifiable, and therefore, scientifically sound hypotheses. But what if it is both the battery *and* the bulb? You could still test this scenario as well.
        3. Another type of hypothesis is what is called a "**null hypothesis**" or "no difference" hypothesis. An example of a null hypothesis could be: "There is *no difference* in the growth rate of plants grown under

red light compared to plants grown under white light."
4. Remember that your hypothesis should be a simple statement that *answers* the question you are interested in. It does not start with "if...then" - we'll get to that in a minute.
5. Pause the video and answer question number 4 on your worksheet.

13. **SLIDE 13: Conduct an experiment to test your hypothesis (Step 3).**
    a. Since a hypothesis must be testable, we are able to design an experiment with which test our hypothesis. An *experiment* is a scientific test carried out under controlled conditions.
    b. We'll talk more later about how to design and perform a controlled scientific experiment in our next module, but for now, let's talk about some general considerations.

14. **SLIDE 14: Conduct an experiment to test your hypothesis (Step 3).**
    a. Prior to actually carrying out an experiment, it's helpful to make a *prediction* as to what results you might expect if your hypothesis is true - this way it's easier to determine if your hypothesis was supported by your data, or if it wasn't..
        i. Based on our earlier observations and data collection, Step 1 of the scientific method, we can extrapolate to determine the specific results we expect from our experiment if our hypothesis is indeed true. We can then test the hypothesis to determine if the results of carrying out our experiment meet with our expectations.
        ii. Predictions always come in the form of an "*if...then*" statement, which include the <u>results</u> that are expected from the experiment. Basically, "*if* my hypothesis is true, *then* I expect these results" when tested by my experiment.It should be the thing you are measuring, testing, or recording. In the case of the flashlight example, your prediction might be "*If* the battery is dead, *then* the flashlight will work when the batteries are replaced with new ones."
        iii. Or here is another example. The statement, if gummy bears are placed in water for 24 hours, then they will swell to over twice their original size. It has "if, then"; it is specific, and it relays the expected results to the experiment in such a way that we can determine if our hypothesis is supported by the data we get (or if the opposite is true and we should reject our hypothesis).

15. **SLIDE 15: Conducting experiments to test your hypothesis (Step 3).**

	a. While experiments are great ways to test hypothesis, sometimes we are unable to carry out an experiment in a lab or even in the field. When experiments aren't possible, we can often still test a hypothesis in other ways, by making additional observations or even analyzing available data. i. Let's revisit our flashlight example. If your hypothesis was, "The bulb of the flashlight is burnt out," or perhaps, "The battery inside the flashlight is dead," what happens if you don't have a spare bulb or spare batteries with which to test your hypothesis? Are there ways you could still figure out which hypothesis is more likely? Yes. How? 1. **By making additional observations:** You could examine the bulb to see if it looks burnt out or check the expiration date on the battery. Or, 2. **By analyzing additional data**: Another example might be to look at all the available data on the problem you're interested in. For instance, if you're interested in the effects of sea level rise on shore erosion in Maui, you might check databases containing shore erosion data on specific areas over the last 50 years, provided it was available. **16. SLIDE 16: Analyze the results of the experiment, and draw a conclusion as to whether or not your hypothesis was supported by the results (Step 4).** a. Based on the results of our experiment and the data available to us, we can determine if our prediction was correct and assess whether or not our hypothesis was the likely explanation for the phenomenon we observed. The results, however, do not absolutely prove it is correct, which leads us to another cardinal rule of science: *Hypotheses can only be supported, never proven.* b. Testing a hypothesis in various ways and producing different sets of data can increase our confidence in our results, but no amount of testing can prove a hypothesis beyond a shadow of a doubt. c. If it turns out that the hypothesis is <u>not</u> supported by the available data, we can always make a *new* hypothesis, and test it anew - this is the great thing about science - scientific inquiry doesn't end when we get our results, it continues in a circular pattern. The more science we do, the more questions can arise. We can even begin by looking at data and go backward to form testable hypotheses! d. As we said before, the scientific method is rarely a linear process. A more realistic version might look something like the picture on the SLIDE, which also can include societal issues in the process. We know economics and other issues can be important considerations when working with real-world problems. **17. SLIDE 17: Communicate your results to others (Step 5).** a. Finally, the last step of the scientific method of inquiry is to share what you have learned with others, or as I like to think of it, "shout

	it from the rooftops." Imagine for a moment you find the cure for cancer. But then follow that with the idea that you keep it to yourself and never share it with anyone… what good is that scientific knowledge if it's not shared with others that can put it to good use? b. In order to be published in a scientific journal, scientists must pass a process of **peer-review**. Peer review is the evaluation of work and author's research, ideas, and data to the scrutiny of others who are experts in the same field. i. Peer review is generally considered necessary in science and is used in most major scientific journals, which is why they are considered reliable sources, but by no means does it prevent publication of all invalid research. While the numbers are relatively low, retractions - the formal withdrawal of the paper by the journal - are an important part of maintaining trust and integrity within the scientific community. ii. By now, you should be very familiar with each of the steps of the scientific method. Return to your worksheet and answer the last question, number 5, and we'll see you next time.
Building Bridges Activity	Module #4: Activity #4 [Worksheet] **Question #4. Write three possible questions you might want to ask about the issue you and your group are working on this summer for Project STEMulate, then come up with a hypothesis statement that answers that question.** **Question #5. Now think about the issue and list three types of qualitative data and three types of quantitative data you might collect to begin to work toward testing any or all of the hypotheses you listed above.**
Up Next	Module #5: Inductive Logic and Science

Module 5: Inductive Logic and Science	
Overview	Deeper look into inductive reasoning and why it's a good fit for science.
Learning Outcomes	Student Learning Outcomes: Course SLO 1 Participants will be able to solve problems utilizing inductive and deductive logic and following the steps of the scientific

		method, including ability to process, analyze, and critique results of their own work while being familiarized with Native Hawaiian practices of science observation. Course SLO 2 Participants will be able to follow lab techniques and procedures, write lab reports, carry out experimental science, gather and analyze data in order to draw conclusions, find reliable sources of information and research, review current literature, write a technical report, and present results of their work. Course SLO 3 Participants will gain specific science and math knowledge related to the content area of the question stimulus.
	Program Learning Outcomes (LIBERAL ARTS)	1. Demonstrate an understanding of theories, practices, histories, and key issues of a field of study using essential terminology and concepts of the discipline. (SLO1) 2. Use theories, concepts, and practices of a field of study to analyze evidence, artifacts, and/or texts and produce interpretations, hypotheses, evaluations, or conclusions. (SLO2) 3. Apply theories and/or methods of a field of study to perform practical, scholarly, and/or creative tasks that respond to social, cultural, environmental, or economic issues. (SLO3)
	Course Competencies	At the completion of the course, students will be able to: a. Apply Logic, and steps of the Scientific Method to any problem solving situation. b. Observe and learn about Native Hawaiian perspective of observation. c. Carry out lab assignments confidently. d. Write technical lab reports. e. Learn to locate reliable sources, read, and interpret research journal articles. f. Learn to write a technical report and professional present results. g. Learn the Math and Science content knowledge related to the STEM Industry Partner.

Materials

Video	Module #5: Inductive Logic and Science [Video]
Video Length	30:57
PPT	Module #5: Inductive Logic and Science [Slides]

Worksheet	Module #5: Activity #5a [Worksheet] Module #5: Activity #5b [Worksheet]
Additional Resources	N/A

Lesson

Lesson Objectives

1. Students will be able to distinguish between scientific and non-scientific explanations.
2. Students will demonstrate understanding of inductive methods in scientific reasoning.

Transcript

SLIDE 1

1. Welcome to Module 5, where we will be discussing inductive logic and science.

SLIDE 2

1. This video will be broken up into two separate parts. In the first part, we will talk about what scientific explanation is, and you'll complete an activity about scientific explanation.
2. We will also discuss the type of reasoning that should be used in science.
3. In the second part of the video, we'll take a look at Mill's methods for inductive science, and you'll complete another activity about correlation and causation.

SLIDE 3

1. First, let's take a look at what scientific explanation is. What is science, after all? Science studies phenomena in the physical, or natural, world.
2. Now, when I say that word 'phenomena', I don't want you to get intimidated – it's a big word and can feel a little scary.
3. A *phenomenon* is just a fact or event. And when we use that in the plural sense, we call it *phenomena*. So when you hear me use that term, just think of some kind of event, or something that happens.

SLIDE 4

1. So what does this mean? Science studies phenomena in the physical or natural world. Is it limited to our five senses or what we can perceive? We might sometimes need technology to assist us in our observations.
2. So, for example, our eyes cannot see infrared light, but with the use of technology, we can see it in an indirect sense. It might be easier to think of a physical or natural world in opposition to what is *not* covered in scientific explanation.

	SLIDE 5 1. Ok, so what would it mean for a phenomenon to be outside the natural world? You might have heard the term 'supernatural' before, so that would be something that is beyond the natural world. You might think of examples like ghosts or spirits. Those would not be included in the natural world; they are considered to be outside the natural world. So those would not be in the scope of science – science studies the *natural* world. So we wouldn't – we couldn't – use science to study anything supernatural. **SLIDE 6** 1. So supernatural explanations are not scientific. Now, when I say they're not scientific, that doesn't mean I'm saying they're *bad* or they're *wrong*. So just because an explanation isn't scientific, it doesn't mean that it's meaningless or that it's worthless. After all, we don't use science to explain everything in life. **SLIDE 7** 1. In fact, in your first activity, I'll have you look at an explanation for Gangster Smith's death. You'll look at scientific explanations for how he died, as well as non-scientific explanations. So first, please read that and decide if the explanations for his death are scientific or non-scientific. Then, consider your class problem: can you come up with a scientific explanation and a non-scientific explanation? **Please pause this video for a moment to read and work on that worksheet.** 1. When you're ready, go ahead and take out that worksheet and let's go through the bottom half – all those questions. 2. So, the first part I asked you is, do the following explanations seem scientific or non-scientific, and why? 3. The first one is that Smith died because it was his time to go. This would be a non-scientific explanation. In philosophy, we might consider this a fatalist, determinist or some kind of religious explanation. There's something about his fate, and how the universe and our lives should work. But this should not be a scientific explanation of how he died. 4. The next one, that Smith died because he deserved it: this is non-scientific. We might consider this a *moral* explanation for why he died – he deserved it. But this isn't something we could study or set up a test for in a scientific way. 5. Third, smith died because his heart stopped beating. Absolutely, this is a scientific explanation for why he died. We can measure this in scientific terms. **SLIDE 8** 1. So consider the topic that you are going through right now. What sorts of explanations do you think will be important when looking

	at something, like sea levels rising, or ocean temperatures rising. It's important to study these matters in a *scientific* way, but it might also be important to study these sorts of issues that may not be scientific, but that are still important for science. 2. For example, what role do humans play in ocean levels rising? We could study this in a scientific way, and that will be very important. In addition to that, we can study this in a *moral* way, or in a *political* way. We can think about the laws or political actions that might be important in preventing ocean temperatures rising. We might look at it in a moral way to talk about the role that humans play in the environment. So although these things might not be scientific up front, they're still important *to* science. **SLIDE 9** 1. So now let's take a look at what type of reasoning should be used in science. 2. The scientific investigation begins with observations. When someone observes a phenomenon and wonders how it happens, that's the beginning of the scientific process. You have studied this as the scientific method. So scientists form a hypothesis, they make predictions, then they test the hypothesis and then draw conclusions from the data they collect. So let's take the example of tsunamis and consider what might be a better process for scientific reasoning. 3. We're going to look at inductive and deductive reasoning here. Let's look at deductive first. **SLIDE 10** 1. Here's a deductive argument for the issue of tsunamis. 2. Our first piece of evidence is: If earthquakes cause tsunamis, then they can cause damage thousands of miles away. Our second piece of evidence is: Earthquakes cause tsunamis. Our conclusion is: Therefore, earthquakes can cause damage thousands of miles away. 3. As you should be able to recognize by now, this is a valid deductive argument, meaning it's a great deductive argument. If the conclusion is true, then the conclusion is guaranteed 100%. But we should ask if the evidence is true. Look at what it says: *if* earthquakes cause tsunamis, *then* they can cause damage thousands of miles away; earthquakes cause tsunamis; therefore earthquakes can cause damage thousands of miles away. 4. Notice that all we're doing here is turning it into a logic game. It's just a puzzle; we're making the pieces fit together. IF the evidence is true, then the conclusion is also true – but this doesn't tell us *whether* the evidence is actually true. **SLIDE 11** 1. For that, let's look at an inductive argument. 2. In this argument, the first piece of evidence is that when we study

tsunamis, we notice that distant earthquakes are often recorded hours before the tsunami impact.

3. The second piece of evidence is that we can trace the direction of the surge to the area of the earthquake.
4. This brings us to the conclusion which is that earthquakes probably have the power to cause tsunamis, even across great distances.
5. So notice that we don't have absolute certainty here, but we are making an effort to find out a truth about the world. Remember that in inductive reasoning, if our evidence is true, then it will give us good reason to accept the conclusion; it doesn't guarantee the conclusion. If it did guarantee the conclusion, we'd be talking about a deductive argument.
6. And so the important thing about the inductive argument is that we're not locked into proving the conclusion with 100% certainty; we will never know the conclusion with 100% certainty. The benefit of this type of argument is that it allows us to provide the best evidence we have instead of making it fit together like pieces of a puzzle. So we can offer the evidence we find, through the scientific method, and then we can show what our conclusion *should* be and we're not tied down to making it fit 100%; we can just show the best conclusion from what we have.

SLIDE 12

1. So deductive reasoning might get us a guaranteed conclusion, but it tells us nothing about whether our information is true.
2. Inductive reasoning allows us to present our best evidence and show where it seems to lead; where we have a high likelihood of it being true.

SLIDE 13

1. Another way to consider the difference between inductive and deductive reasoning is to consider this triangle approach. So deductive arguments go from general conclusions to specific conclusions. Think about this argument:
   a. All mice like cheese.
   b. Julius is a mouse.
   c. Therefore Julius likes cheese.
2. Here you see it starts off with something very general – that all mice like cheese. Then it gets to be much more specific – that this particular mouse, Julius, likes cheese.
3. So our conclusion is a lot more specific, talking about Julius and his preference for cheese, even though it started off with something about mice in general.

SLIDE 14

1. In an inductive argument, it goes from specific evidence to a general conclusion.
   a. Julius likes cheese, and he's a mouse.
   b. Molly likes cheese, and she's a mouse.

	c. Therefore, most mice probably like cheese. 2. Notice that this is inductive; it is not a guarantee. If the premises are true, they give us some reason to believe the conclusion. It might be true that all mice like cheese, or that most mice like cheese. It's definitely true from what we've shown that at least some mice like cheese. Notice what's happening though – we're going from specific information and generalizing up to wider conclusions, that are *not* guaranteed. **SLIDE 15** 1. So, what it means to use inductive reasoning in science is that we gather our evidence and see where it leads us. We're not trying to force our evidence into some word puzzle that gives us 100% guaranteed conclusion. The conclusion will go outside the scope of the evidence, like in this example [Inductive argument from previous slide]. 2. Notice that the conclusion here, that most mice probably like cheese, is going outside the scope of the evidence – that these two particular mice like cheese. So we're taking specific evidence and making general conclusions about it – we can never have a 100% guarantee in this type of reasoning. 3. But, the nice thing about that is that it allows us to take leaps; to take a look at the evidence and see where it leads us to. If we're trying to learn about tsunamis, and we take these instances of tsunamis to generalize about all tsunamis, we need to have that sort of flexibility to see where the evidence takes us, rather than trying to fit it all into some word puzzle. 4. This is really all we have in science. Even if we had evidence of every tsunami that has ever happened in the past, that won't necessarily guarantee that tsunamis will always occur in the same way in the future. We're taking the evidence that we have, finding patterns, and using that to make a general conclusion about how tsunamis, in general, work. We're always going to be taking a leap when we use inductive reasoning. In any scientific investigation, we *cannot* test for everything. We use samples, and that allows us to generalize our finding. Ok, that's the end of this part. Please continue to the next video, where we will take a look at Mill's Methods and correlation vs. causation. **SLIDE 16** 1. Welcome to the second part of Module 5, inductive reasoning and science. We're going to start off this video by discussing Mill's Methods. 2. John Stuart Mill was a 19th century philosopher who left a lasting impression in several areas of philosophy. He believed strongly in women's right to vote and argued for women's suffrage, which allowed them to get that right. His father was also a philosopher: James Mill. That's why we use John Stuart's initials: JS, when we talk about him.

	3. One of the areas he's well known for is his contributions to inductive logic. He developed five different ways to establish causality. These methods can be used to show us how inductive reasoning can be used in science. 4. Now in order to look at these methods, we're going to imagine that there's a potluck where 10 people got sick. We're going to see that in that situation, we can use each of these five methods to figure out what made them sick. **SLIDE 17** 1. The first method is Mill's Method of Agreement. Here, a causal connection is revealed based on features that "agree." 2. So in our potluck example, we might ask the 10 people who got sick, what they ate. Let's say they all ate the chicken salad. So, we would conclude that it was probably the chicken salad that made them sick. 3. Now, do we know that with 100% certainty? No. But this is a very normal, everyday, sort of way to investigate a problem. It's not conclusive evidence; there could be some other thing that caused the food poisoning. But it would give us a good way to start investigating this. 4. So, Mill's Method of Agreement means taking a look at how different features agree: we're asking these ten different people what they have in common and looking there for the cause of the problem. **SLIDE 18** 1. The next method is Mill's Method of Difference. Here, a causal connection is revealed based on features that are different. 2. So, in this potluck example, we should also ask the people who didn't get sick, what they ate. Let's say that they ate all the same things as the sick people, except that they didn't eat the chicken salad. So none of the non-sick people at the chicken salad. This is even more evidence that the chicken salad is probably the culprit. 3. So if we talked to the people who didn't get sick, and find out what they ate and none of them ate the chicken salad, this makes what they ate different from what the sick people ate. 4. Now, again, this isn't conclusive evidence. It could have, for example, been the serving spoon that was contaminated, and not the chicken salad. So it's possible that it could be something else. But this is giving us strong evidence to believe that it's the chicken salad that is responsible for the food poisoning. **SLIDE 19** 1. Now these two methods, the Method of Agreement and the Method of Difference, seem to work really well together. You might have noticed that already. 2. So what Mill does in his third method, is he combines the first two methods. 3. If, at this potluck, we interviewed people who did get sick and

people who didn't get sick, this would be a really good way to investigate what made the people who got food poisoning, sick.

4. So these two methods work really well together to give us strong evidence to support our claim.

SLIDE 20

1. The next method is Mill's Method of Residues. Here, we identify a causal agent – the thing that caused the problem – by screening out – or getting rid of – other known factors – things we're pretty sure didn't cause the problem – and isolating – or singling out – what's left over.
2. In the potluck example, let's say Lei got sick but Carlos didn't.
3. To figure out what caused it, they make a list of all the possible causes, one by one, and see what's left over.
4. This is a lot like the Method of Difference, except that the Method of Residues uses a specific list and uses a process of elimination to see what's left unaccounted for.
5. The Method of Residues can also let us throw out possible causes that the Method of Difference doesn't let us get rid of.
    a. Let's say that Lei was wearing a purple sweater but Carlos was wearing a blue sweater.
    b. The Method of Difference would make us count that as a difference, and therefore a possible cause of the food poisoning.
    c. But we know that the color of Lei's sweater probably has nothing to do with her getting sick, so we can just eliminate it as a possible cause because we can consider it a "known factor."
    d. This means that we accept her sweater color as a normal thing and don't want to include it in our list of possible causes of the food poisoning.
6. Now, is there some strange scenario we can make up, where we can link her sweater-color to getting food poisoning?
    a. I don't know, maybe there's some really really weird way we can imagine that – like some sort of Twilight Zone or X-Files episode?
    b. But all this just means that we can't be 100% sure it's not her sweater color that played a part in her getting food poisoning – and that's ok because remember, we're working with inductive reasoning here!

SLIDE 21

1. Finally, Mill's Method of Concomitant Variation. Now that's a pretty big term: 'concomitant variation.'
2. So, 'concomitant' means that (at least) two things are naturally associated with each other. And 'variation' would mean that there's some sort of change over time.
3. So, the Method of Concomitant Variation says, is that if two things are correlated, there's probably some sort of connection between them. Events are correlated if they happen in similar ways or at

	similar times. Mill's Method states that if they're correlated, there's probably some sort of causal connection between them. **SLIDE 22** 1. So, let's investigate this: a. Let's say this group of friends had weekly potlucks for six months. b. The same person was responsible for making chicken salad and he made the chicken salad in the same way each time. c. Every time he brought the chicken salad to the potluck, everyone who ate it got sick. d. Every time he did not bring the chicken salad to the potluck, no one got sick. e. So if we were to make a graph showing the times he brought chicken salad, and the times people got sick, we would see that both those things happened at the same times. Every time people got sick, he brought the chicken salad there. Every time he brought the chicken salad there, people got sick. **SLIDE 23** 1. So there seems to be some sort of correlation between the chicken salad and people getting sick: they happen in similar ways and at similar times. **SLIDE 24** 1. This method is one of the most obvious causal patterns. Even toddlers figure this out quickly. My two-year-old niece gets so excited to flip a light switch and watch the light turn off and on. We see this all the time. When I press the keys of a piano, it makes a sound. When I am driving and press on the brake pedal, the car slows down. **SLIDE 25** 1. There are many things that are correlated with one another and our brains automatically make a causal connection between them. 2. But, does this give us conclusive evidence? Does it give us deductive certainty? 3. We need to be careful when using this method. Mill definitely has a point here that if two things are correlated, then there's probably some sort of causal connection between them. But we shouldn't read into this that there's absolutely some sort of causal connection between them. **SLIDE 26** 1. So go ahead and complete this activity, reading the Correlation and Causation worksheet. Then think of some examples of correlation and finally, consider a surprising correlation involving ice cream!

	2. After this, I'd like you to think about a correlation that can be made with your class problem and consider whether there's enough evidence to prove causation here. 3. For example, imagine our problem was that the sea levels are rising. Let's say we showed that sea levels have been rising at the same rate as Twitter has been gaining in popularity. I have no evidence for this – it's just a hypothetical example. Let's say that I could graph the increase in sea levels and the number of accounts opened on Twitter, and that these graphs match up. Would that mean that Twitter is somehow causing the sea levels to rise? Or that rising sea levels make Twitter really popular? Of course not. **So keep that in mind while you pause this video. Come back when you're done with your worksheet, and we'll talk about the third point here – the one about the ice cream.** 1. Ok, so I hope you were able to look at the worksheet. I hope that you were able to think of some correlations and apply them to your topic. Let's get started by looking at the third question here. 2. Did you know that when ice cream sales increase, so does the murder rate. This trend has been shown in various cities like New York and Chicago! There's an article cited at the bottom that you can take a look at. If we were to graph on a chart the rates of murders and the rates of ice cream sales, we would see they happen in the same ways at the same times. Does this mean that ice cream is causing people to kill each other? Or that killers just really like ice cream and they go out for a scoop after they've killed someone? Of course not! So there has got to be something else involved here. And that's that it's hot – it's summertime. When the heat increases, it causes both these things to happen. It causes more ice cream to be sold and also more people to be killed. We might still look into why heat would cause more murders to happen. Maybe it's that more people are outside, or more windows are left open at night. Maybe people are more irritable and getting into more fights. Some people have looked into whether testosterone levels increase in the heat, which may contribute to more altercations, resulting in more murders. So, the point here is that just because there's a correlation between two things doesn't mean that one of those things is causing the other. There could be another factor involved, just like the heat is involved in causing ice cream sales to increase and murder rates to increase. They're both caused by something else entirely. **SLIDE 27** 1. So, although the Method of Concomitant Variation is pretty common-sense, it's also related to a pretty common mistake, and that is it's tempting to place too much weight on correlation. 2. Remember the first module: our brains like to make sense of our surroundings. They make connections faster sometimes than we

	realize. 3. But we need to be careful to remember that we're using inductive reasoning here and our claims are *not* guaranteed. If we notice there's a correlation between two events, we shouldn't think that it means one of those events caused the other event. Rather, what we should do is present our evidence and see where it leads us. SLIDE 28 1. So the bottom line is that correlation is a good place to start an investigation; it's not a good place to end one. 2. Think about whether this is a weakness in inductive logic in science. 3. By the way, not all philosophers of science agree that inductive logic should be the basis for scientific investigation. However, the scientific method is largely based on inductive reasoning; it fits very well together. Inductive reasoning is the most widely approach. There's other theories about what sorts of reasoning should be used in science. **SLIDE 29** 1. But I hope you've seen here why it works so well with science, which is why we're going through it today. It really allows us in science to make claims without having the burden of deductive certainty. Remember that science is always open to revision – we want to make sure we're always using the best evidence to support our conclusions. And inductive reasoning is what allows us to have that flexibility. 2. So Mill had a great point here with the Method of Concomitant Variation – if there is correlation between two things, it's a good place to start looking for a cause. Just remember that the cause might not always be as simple as one of those things causing the other. It may be something else causing both. And it could always be a coincidence. The point here is that it's a good place to begin our investigation. And with our inductive tools, we can search for the conclusion that best fits our evidence.
Building Bridges Activity	Module #5: Activity #5a [Worksheet] Think about your STEMulate problem. What is one scientific and one unscientific explanation for the problem? Scientific ________________________________ Unscientific ________________________________ Module #5: Activity #5b [Worksheet]

	3. Consider your STEMulate problem. Think about some event that might seem correlated to your problem. Do people assume it's the cause? Do you think there's good reason to believe it's the cause? ____ ____
Up Next	Module 6: Designing and Performing Experiments

Module #6: Designing and Performing Experiments		
Overview	Students will explore how to design and perform scientifically sound experiments.	
Learning Outcomes	Student Learning Outcomes	Course SLO 1 Participants will be able to solve problems utilizing inductive and deductive logic and following the steps of the scientific method, including ability to process, analyze, and critique results of their own work while being familiarized with Native Hawaiian practices of science observation. Course SLO 2 Participants will be able to follow lab techniques and procedures, write lab reports, carry out experimental science, gather and analyze data in order to draw conclusions, find reliable sources of information and research, review current literature, write a technical report, and present results of their work. Course SLO 3 Participants will gain specific science and math knowledge related to the content area of the question stimulus.
	Program Learning Outcomes (LIBERAL ARTS)	1. Demonstrate an understanding of theories, practices, histories, and key issues of a field of study using essential terminology and concepts of the discipline. (SLO1) 2. Use theories, concepts, and practices of a field of study to analyze evidence, artifacts, and/or texts and produce interpretations, hypotheses, evaluations, or conclusions. (SLO2) 3. Apply theories and/or methods of a field of study to perform practical, scholarly, and/or creative tasks that respond to social, cultural, environmental, or economic issues. (SLO3)

	Course Competencies: At the completion of the course, students will be able to: a. Apply Logic, and steps of the Scientific Method to any problem solving situation. b. Observe and learn about Native Hawaiian perspective of observation. c. Carry out lab assignments confidently. d. Write technical lab reports. e. Learn to locate reliable sources, read, and interpret research journal articles. f. Learn to write a technical report and professional present results. g. Learn the Math and Science content knowledge related to the STEM Industry Partner.
Materials	Video: Module #6: Designing and Performing Experiments [video] Video Length: 16:40 PPT: Module #6: Designing and Performing Experiments [slides] Worksheet: Module #6: Designing and Performing Experiments [worksheet]] Additional Resources: Mythbusters video, The Five-Second Rule: https://www.youtube.com/watch?v=FoONY-ip7hQ
Lesson	**Lesson Objectives** 1. Students will be able to identify and explain the difference between an independent and dependent variable in a experiment. 2. Students will be able to explain the difference between an experimental and control group in a scientific experiment. 3. Students will be able to describe the difference between a control group and a controlled variable. 4. Students will be able to explain why replication is important in scientific studies.
	Transcript 1. **SLIDE 1: Designing and Performing Experiments**

a. Welcome back! Today, we'll explore the design and use of experiments in scientific study.

2. **SLIDE 2: Objectives**
   a. Your goal by the end of this lesson is to be able to:
      i. Identify and explain the difference between an independent and dependent variable in a experiment.
      ii. Explain the difference between an experimental and control group in a scientific experiment.
      iii. Describe the difference between a control group and a controlled variable.
      iv. Explain why replication is important in scientific studies.

3. **SLIDE 3: The 5-second Rule**
   a. I'm sure most if not all of you have heard of the the **five-second rule**, or maybe even practiced it. It states that there is a defined time window where it is permissible to pick up food after it has been dropped and thus exposed to contamination. Some people may actually believe this assertion, whereas most people employ the rule as an amusing social fiction that allows them to eat a dropped piece of food, despite the potential reservations of their peers. How many and what type of bacteria might stick to a piece of dropped food depends on many factors, the food or the floor being wet or dry among them.

4. **SLIDE 4: Mythbusters**
   a. A number of different people have tested this theory, including the show Mythbusters, on the Discovery Channel. While the show has gone through a series of hosts now, they have had more than 205 episodes, and subjected nearly 1,000 cultural legends, historical myths, and internet rumors to the crucible of the scientific method.
   b. In a moment, we'll watch a clip from their test of the 5-second rule. But first, let's make a hypothesis. On your own sheet of paper, write down a hypothesis to answer the question, "Will food dropped on the floor for less than 5 seconds be free of bacterial contamination?" Pause the video if you need to, and try to write a proper hypothesis. You do not need to write "yes" or "no" but it should be a statement that answers the question. Remember not to put "I think" or "I believe." Instead, write a statement that is clearly defined and testable.
   c. (PAUSE) What did you come up with? If you came up with something like, "Bacteria will not contaminate food that has been on the floor for less than 5 seconds" or the opposite, that "bacteria will contaminate food that has been dropped on the floor for less than 5 seconds" then great job!! You wrote a proper hypothesis. Let's watch the video now:
      i. Mythbusters video, The Five-Second Rule: https://www.youtube.com/watch?v=FoONY-ip7hQ
   d. Think about what you noticed in the video, and what parts of the scientific method were or were not used during the experiment. Did you notice how the Mythbusters actually tested multiple hypotheses, one

right after another, when they realized their original experiment and results did not conclusively answer their question. Sound familiar?

5. **SLIDE 5: Experimental Variables**
    a. In scientific inquiry, our goal is to have reliable, repeatable results, even if someone comes in after us and tries to repeat what we did, based on what we have shared about our experiments. We discussed earlier that an *experiment* is a scientific test, carried out under controlled conditions. More specifically, an experiment involves the manipulation of a single factor (or *variable*) in the experiment, in order to see the effects of changing it.
    b. There are two types of variables in a scientific experiment - independent and dependent.
        i. The **independent variable** is the variable that I like to call the "I" variable - it's the one that I, as a scientist, decide to study, manipulate, or change in the experiment, in order to determine the effects of doing so.
        ii. The **dependent variable** is the variable that I will *measure, count,* and/or *record* and that will change in *response* to the independent variable. I like to think it as the dependent variable *depends* on the independent variable.

6. **SLIDE 6: Experimental Variables**
    a. Since we want to know if the hypotheses we make are supported according to our data from our experiment, let's return for a moment to the prediction we used in our last module, "if gummy bears are placed in water for 24 hours, then they will swell to over twice their original size." Remember that the prediction is what we use to determine if our hypothesis is correct, or if we need to make a new one. See if you can determine the independent and dependent variables in the statement. (PAUSE)

7. **SLIDE 7: Experimental Variables**
    i. For this prediction, our independent variable is what we are changing, which would be the placement of the gummy bear in water for this experiment.
    ii. Our dependent variable is what we will measure in response to the independent variable, in this case, water. If you're thinking it's the size of the gummy bear due to it swelling in the water, you're correct!

8. SLIDE 8: Experimental Variables

a. Let's try another example. Say you want to study the effects of global sea level rise on the number of agricultural areas within a 200-mile stretch of the Maui coastline. What would be the independent variable in this case? How about the dependent variable? (PAUSE)
    i. Global sea level rise is your independent variable - YOU have decided that this is the factor you are most interested in the effects of on agriculture
    ii. The number of agricultural areas within a 200 mile stretch of coastline is the dependent variable. Notice that anything measured, observed or recorded is an easy way to identify the dependent variable.
    iii. Our activity today is a worksheet where you will read a number of testable scenarios and be asked to identify the variables. You can do the worksheet now and pause the video, or do it at the end of the lesson.

9. SLIDE 9: Controlled experiments

a. A **controlled experiment** is the most common experiment used in science. In this type of an experiment, a scientist will compare an **experimental group** (one where the independent variable has been changed) with a **control group** (one where it has not). Ideally, the two groups should vary *only* in the one, single factor the experiment is testing, which is the independent variable. Without a control group, you cannot rule out other factors that might have been the cause of the results you obtain. By comparing the results you get to a control group, you can be confident that any observed differences are due to the one change that was made to the independent variable - it acts like a baseline measurement for your experiment.
b. Using negative and positive control groups can increase confidence that the test is valid and that any observed changes in the dependent variable are only due to the independent variable.
    i. A **negative control group** is a group for which no change is expected in the dependent variable.
    ii. A **positive control group** is a group for which a change is expected in the dependent variable. This is useful because if the expected change is not observed, something may be flawed in the experimental design.
c. A common misconception is that a controlled experiment means that you can control everything in the experiment, and this is not always the case - it's nearly impossible in the field and not even realistic in the laboratory.
d. The truth is, we simply do the best we can with what we have. We can attempt to control unwanted variables- not by eliminating them, but by <u>cancelling out their effects</u> using the control group. This means that all other variables that we are not studying, such as temperature, humidity, population size, etc. (called **controlled variables**) should be kept the same

between the control and experimental groups.

10. SLIDE 10: Experiments in the field

a. Variables in experiments are relatively easy to see in the lab, but what if we're in the field?
b. Simply remember that the variable that you are measuring, counting, recording or observing is your *dependent variable*. In any good scientific experiment, there should be only one independent variable being tested at one time, but there can be multiple dependent variables.
c. Experimental design outside the lab can be a bit more challenging, but is still doable.
    i. Recall that sometimes scientific study doesn't follow the general pattern and steps of the traditional scientific method.
    ii. Observations can be made by looking at data sets in databases, or observing real variables in the field. Remember that you can cancel out excess variables by keeping them relatively consistent between your control and experimental groups.
    iii. **Discovery science** can also be just as exciting a process, and simply involves utilizing the scientific method in a new and different way. Oftentimes in discovery science, research takes place in the field, and the experiment involves simply seeing what's there in a definable and measurable way (for example, counting the number of live organisms in 1 square meter), and making hypotheses about it that fit the data after the fact.
e. Let's talk for a moment about **sample size -** the number of participants, trials, or data points that are used in your experiment. No exact sample size is required for any particular study, however, all else being equal, larger sample sizes can lead to increased precision in understanding whether or not your results are due to chance, or to your independent variable. We'll discuss this more in a future lesson.

11. SLIDE 11: Replication in Scientific Studies

a. Lastly, scientists aim for their studies' findings to be replicable, so that an experiment will yield similar or the same results when repeated in different labs. Similarly, two different researchers studying the same thing in the same way should come to the same conclusions. This goal of replicability makes sense. After all, science strives to reconstruct the unchanging rules by which the universe operates, and those same rules apply, 24 hours a day, seven days a week, from Sweden to Saturn, Hawaii to Honduras, regardless of who is studying them. If a finding can't be replicated, it suggests that our current understanding of the study system or our methods of testing are insufficient.
b. Does this mean that scientists are constantly repeating what others before them have already done? No, of course not — or we would never get anywhere at all. The process of science doesn't require that *every* experiment and *every* study be repeated, but many are, especially those

	that produce surprising or particularly important results. In some fields, it is standard procedure for a scientist to replicate his or her own results before publication in order to ensure that the findings were not due to some fluke or factors outside the experimental design. c. The desire for replicability is part of the reason that scientific papers almost always include a *methods* section, which describes exactly how the researchers performed the study. That information allows other scientists to replicate the study and to evaluate its quality, helping ensure that occasional cases of fraud or sloppy scientific work are weeded out and corrected. d. That's it for our lesson today. We'll see you next time for Module 7!
Building Bridges Activity	From Module #6: Activity #6 [Worksheet]: **6. Think about the problem or issue you and your classmates are studying this summer. Identify what you think the potential independent variable you are interested in, and then what you will measure, record, or observe as your independent variable in your research. Lastly, identify any variables you will want to ensure are kept constant (your controlled variables) in order to not complicate your results – so that you can tell that you're really getting the data and information to answer the question about your independent variable that you are truly interested in. Write this information below.** Independent: Dependent: Controlled variables:
Up Next	Module #7: Deductive Logic and Computer Science

Module 7: Deductive Logic and Computer Science	
Overview	Here, we return to deductive logic. We've seen how well inductive logic fits with the scientific method. Where is deductive logic's natural partner? We find it with computer science! Students will learn some fundamentals of Boolean Algebra, which is the basis for a type of deductive logic. These fundamentals were also an important part of the beginnings of computer science.
Learning Outcomes	<table><tr><td>Student Learning Outcomes</td><td><u>Course SLO 1</u> Participants will be able to solve problems utilizing inductive and deductive logic and following the steps of the scientific method, including ability to process, analyze, and critique results of their own work while being familiarized with Native Hawaiian practices of science observation.</td></tr></table>

	Course SLO 2 Participants will be able to follow lab techniques and procedures, write lab reports, carry out experimental science, gather and analyze data in order to draw conclusions, find reliable sources of information and research, review current literature, write a technical report, and present results of their work. Course SLO 3 Participants will gain specific science and math knowledge related to the content area of the question stimulus.
Program Learning Outcomes (LIBERAL ARTS)	1. Demonstrate an understanding of theories, practices, histories, and key issues of a field of study using essential terminology and concepts of the discipline. (SLO1) 2. Use theories, concepts, and practices of a field of study to analyze evidence, artifacts, and/or texts and produce interpretations, hypotheses, evaluations, or conclusions. (SLO2) 3. Apply theories and/or methods of a field of study to perform practical, scholarly, and/or creative tasks that respond to social, cultural, environmental, or economic issues. (SLO3)
Course Competencies	At the completion of the course, students will be able to: a. Apply Logic, and steps of the Scientific Method to any problem solving situation. b. Observe and learn about Native Hawaiian perspective of observation. c. Carry out lab assignments confidently. d. Write technical lab reports. e. Learn to locate reliable sources, read, and interpret research journal articles. f. Learn to write a technical report and professional present results. g. Learn the Math and Science content knowledge related to the STEM Industry Partner.

Materials

Video	Module #7: Deductive Logic and Computer Science [Video]
Video Length	30:17
PPT	Module #7: Deductive Logic and Computer Science [Slides]
Worksheet	Module #7: Activity #7a [Worksheet] Module #7: Activity #7b [Worksheet]
Additional	

<table>
<tr><td></td><td><table><tr><td>Resources</td><td></td></tr></table></td></tr>
<tr><td>Lesson</td><td>Lesson Objectives
Students will be able to solve a logic puzzle, demonstrating knowledge of deductive logic.
Students will complete truth tables in Boolean Algebra.
Students will demonstrate knowledge of validity by creating their own valid deductive argument.</td></tr>
<tr><td></td><td>Transcript
SLIDE 1
Welcome to Module #7: Deductive Logic and Computer Science.
SLIDE 2
We begin today by reviewing deductive arguments and validity. And we'll also take a look at the history of deductive logic. There, we'll discuss three important figures in the history of deductive logic: Aristotle, Alan Turing and George Boole.
SLIDE 3
Let's remember the difference between deductive and inductive reasoning. By this time, you're pretty familiar with inductive reasoning.
So let's remember how deductive logic is different.
Remember that in deductive reasoning, a conclusion is supported by the evidence with 100% certainty, whereas in inductive reasoning, a conclusion is supported by the evidence with just probability.
In the Module 5, we talked about how inductive reasoning fits well with science because it allows us to look at our evidence and see where it leads us. We don't need to have 100% certainty about the claim. Deductive reasoning is more like a word-game or a logic puzzle.
SLIDE 4
When a deductive argument is successful, we consider it "valid."
Note: Unlike inductive arguments, deductive arguments depend on ONLY the evidence given in order to guarantee their conclusion.
SLIDE 5
So, in a deductive argument, IF the evidence is true, then the conclusion will also be true.
Note: Valid deductive arguments do NOT state that the evidence is true. That's not their job. They're not telling you that the information is true. The only promise they can make is that IF it is true, then the conclusion will also be true.
SLIDE 6
Here's an example of that:</td></tr>
</table>

	If cats eat dog food, then they will become dogs. *Cats are eating dog food.* *Therefore, they will become dogs.* ● This is a VALID argument even though we know the evidence is untrue. ● Deduction doesn't care! Look at that first piece of evidence: if cats eat dog food, then they will become dogs. Well we know that's not true. I have a cat that's always eating our dog's food, and he's still a cat! ● So how do we know that the second piece of evidence is true? Well, I just told you I have a cat who eats dog food – is that good enough evidence? Should we plan a study where we'll observe cats eating dog food? This is a question for science, but we don't need to answer it for this deductive argument. ● All we need to know for our deductive argument is whether these two statements happened to be true, that they would lead us to a true conclusion. The question is more, Can the conclusion be false if the evidence were true? In this case, we can see that *if* the evidence were true, the conclusion would *have to* be true as well. **SLIDE 7** ● Think about computers… ● Does Siri really "know" the answers to your questions? When you ask her a question, does she really know about the answer she's giving you? No, in fact, here are some funny questions you can ask her (you can click on the link in the PDF of these slides). ● Questions for Siri ● Siri can only respond to the extent of her programming. What that means is that she only "knows" what she was programmed to know, or what she was programmed to find out (like doing an internet search for a key word. Programmers can tell Siri how to look up a new word, even if they don't know all the words people will ask her to look up.) But Siri can't answer what her programmers couldn't predict. When she gives answers, Siri is only using the evidence she's already been given. **SLIDE 8** ● This is very much like deductive reasoning. If you set up the programming, Siri will be able to use that evidence to find the conclusion that fits. But she's limited to whatever she was programmed to do – limited to the evidence she's been provided with. ● Think of deductive arguments. They are just like programs: If they're set up correctly (valid), they work **SLIDE 9** ● In just a minute I'd like you to pause this video in order to complete the next activity. It's a logic puzzle – I'll show you how to get started. Here's what you'll do: **Activity: Logic Puzzle** 1. Read clues to the logic puzzle about people who gave their dogs

	mythological names. 2. Use the clues to find out who's who. 3. Check your answers. Let's go through one part of this puzzle together. **SLIDE 10** ● Clue #2 tells us: The 24 year-old named their dog Lycurgus. ● From this, we know not only that Lycurgus is the 24 year-old's dog, but also that Lycurgus does *not* belong to any of the other dog owners. So you can eliminate them as possibilities. Think of this activity as a process of elimination. See what you can figure out and see how it leads you to figure out more answers. **SLIDE 11** ● As you complete this puzzle, think about this question: What happens if the information (evidence/clues) we're given is wrong? Does it matter for the puzzle whether this information is true in the real world? Does this remind you of the Siri example? **Please pause this video for a moment to read and work on that worksheet.** ● I hope you had fun with the puzzle! Your instructor will have an answer key, so you'll be able to check your answers and see if you got them right! ● So, let's continue. I want you to think a little bit about what might happen if the information in the puzzle happened to be wrong. If you remember back to the Magician or Logician puzzle, we used it to describe the difference between deductive and inductive reasoning. Remember that in a deductive argument, we're limited to the information – or evidence – given to us. We can't look into the real world to find out if it's true. We can only make our conclusion based on the assumption that it is true. Remember that for our purposes, it's not so important that you get the "trick" of it; that you can solve the problems correctly. I mean, that's great if you can! But the focus – the most important part for our purposes – is that you can see the difference between inductive and deductive reasoning. **SLIDE 12** ● Ok, so looking at the history of deductive logic, the first very important person that we'll look at here is Aristotle. You've probably heard of him before. He lived from 384-322 BCE (that means Before Common Era; also known as BC). He lived in Ancient Greece, and was a student of Plato and he was a tutor to Alexander the Great. ● Aristotle invented what we consider to be the first system of deductive logic. ● Many to be credited with the development of modern deductive logic – it's not just to be credited with one person. In this video, I'll be picking out three of the most important people to be credited with the creation of deductive logic, which became the creation of computer science.

	● What I mean by that is that the history of logic is shared with the history of computer science. **SLIDE 13** ● **Aristotle** invented what we consider to be the first system of deductive logic. ● In a philosophy class, the founders of logic are called *logicians*. ● In a math class, the same people are called *mathematicians*. ● In modern times, we often consider recent mathematicians/philosophers to be *computer scientists*. There is no clear line between philosophers, mathematicians, logicians, and computer scientists. **SLIDE 14** ● **Alan Turing (1912-1954)** ● A great example of that is Alan Turing. He lived in the early 1900s and was a World War II hero, cryptanalyst, mathematician, and logician. ● He is considered the "Father of computer science." ● Turing was the subject of the recent film, *The Imitation Game*, which highlighted his personal and professional life. You may have seen this movie – it came out in 2014 and stared Benedict Cumberbatch. **SLIDE 15** ● Turing broke the Enigma Code used by German troops to exchange messages during WWII. So while he wasn't on the front lines, he was behind the scenes, breaking the codes Germany used to communicate with their troops. This allowed Britain and the Allied Forces to know what moves they were about to make, thereby changing the course of the war. ● The way he did this was by developing the Turing Machine, allowing it to simulate any computer algorithm. So, not only would computers be different if it weren't for Alan Turing, but history – the outcome of World War II – may have been very different if it weren't for him. ● Another interesting thing about Turing is that he proposed the Turning Test, which defines when a machine is considered artificially intelligent. This is where his role as a philosopher is especially clear. Alan Turing wondered what it would mean for a machine to become intelligent. He came up with a test, where if it were passed, we should consider a machine to be artificially intelligent. The test is that a person communicating with the machine should not be able to tell that he or she is talking to a machine. It should be able to trick a person into thinking it's human. There have been many claims, especially in recent times, that researchers have "passed the Turing Test." This hasn't yet been officially agreed upon, but we are certainly close to it. The Turing Test was developed a little more than half a century ago, and we're already close to passing it. Imagine what will happen a half century from now. Do you think that machines will eventually have minds like humans? **SLIDE 16** ● George Boole (1815-1864) is another person that should be credited with

	developments in deductive logic. He lived a little before Turing. He was focused on mathematical sentences rather than the calculation of mathematics and coding, like Turing. ● His sentences considered a few important operations: "and," "or," and "not." We'll be focusing on these in just a few minutes. ● His mathematics also limited his range to a binary system instead of an infinite. This means he was only concerned with two answers. **SLIDE 17** ● In logic, we call this the "Law of Excluded Middle" ● You can think of this as a very black and white system. It's very cut and dry: it's all or nothing. ● Everything *is* or *is not*. ● We have it or we don't, it's all or nothing ● In logic, we use variables often – a variable is just a lowercase letter that you can substitute with another value. For example, if you have the sentence: 4 + x = 10, we know that x is 6. 6 is the value that x stands for here. In Boolean logic, we just have two values: True and False. So, if we have the variable *p* standing for something True, then we know either that thing, p, is true or it's not true. Because there are only two possible outcomes: it's true or false. So we say: p or *not* p ● Another way to represent this is with "True" and "False." **SLIDE 18** ● In logic, we call sentences true or false, but in a mathematics or computer science class, we represent this with 1s and 0s. Think of times when you've seen computer code. In the movies or wherever. You see a bunch of 1s and 0s. ● That's what these mean: a 1 tells a computer "on" or "true" and a 0 tells a computer "off" or "false." A chain of these 1s and 0s end up telling the computer's hardware what to do. ● Think of a power button that works to turn an appliance – like your cell phone – off and on. Since it's the same button, it has both a 1 and a 0. It used to be the case that there would be different buttons or a different position of a button that would have a different placement for on and off. Think of a light switch or battery-operated toys. They would have one button/position with "1" and another with "0." **SLIDE 19** ● Let's continue to look at Boolean Algebra. Here, we'll look at the following questions: ● What is Boolean Algebra? ● What is a truth table? ● Negations, Conjunctions and Disjunctions (You probably haven't heard of these word before, but don't worry – we'll go over them!) ● We'll also discuss computer science and logic

SLIDE 20

- First are "NOT" Truth Tables. When you have a sentence with something like a "not" in it, we call it a negation. And in order to symbolize it, we use this symbol, a tilde, to stand for a negation.

SLIDE 21

- Let's make some statements to see how it works out.
- Let's assign a variable, p, to statement to
- understand what it means to add a "not" to it.
- Let's have p stand for "Alani is wearing a hat"
- Then ~p means "Alani is NOT wearing a hat"
- You can also think of it as "it's not the case that... Alani is wearing a hat." Or "NOT: Alani is wearing a hat." It's like if you told your friend "Hey, Alani is wearing a hat" and then your friend said "NOT!" They're calling your sentence false.
- **Negations** flip the truth value....
- If Alani was not wearing a hat, and your said "Alani is not wearing a hat" then your sentence, ~p, would be true.
- So when there's a negation in front of a true statement, it becomes false, and if there's a negation in front of a false statement, it becomes true.

SLIDE 22

- Negation Truth Table (Logic)
- So we can see this by putting it into a truth table. A truth table might look scary at first, but really it's just an organized way of seeing all the possibilities of a sentence when an operator – like a negation – is used in a sentence.
- Think of it like this: the statement p can either be true or false.
- In the case that it's true, then ~p is false – because the negation flips the truth value.
- So in this case, when the statement p is false, then the statement ~p is true!

SLIDE 23

- Negation Truth Table (Boolean Algebra)
- In Boolean Algebra, we have the same thing going on. Just remember that here, "true" is represented by "1" and "false" is represented by "0". So the truth table matches the logic truth table, it just has 1s for true and 0 for false.

SLIDE 24

- The next type of truth table we'll look at is for conjunctions. "Conjunction" is just a fancy word for an "and" statement.
- We'll assign two variables, p and q, for the statement before the "and" the statement after the "and" to understand what an "and" sentence means.
- In logic, it's called a **conjunction**.

	• They symbol ^ ("carrot") indicates a conjunction
	
	SLIDE 25
	• "And" Truth Tables
	• Here's what this means:
	• Let's say…
	  ○ p means "Alani is wearing a hat."
	  ○ q means "Brandi is wearing a hat."
	
	SLIDE 26
	• Conjunction Truth Table (Logic)
	• So if I want to say "Alani *and* Brandi are wearing hats" then it would look like this.
	• p stands for "Alani is wearing a hat."
	• q stands for "Brandi is wearing a hat."
	• If we stick those together with an "and" then we'll see every possible outcome for that sentence.
	• In the first row, both p and q are true, and the sentence is true.
	• In any other case, the sentence is false.
	• Let's think about why: in all of these three cases, there's at least one "false." Think about how that would sound in the real world. If I comment "Alani and Brandi are wearing hats" but one (or both) of them were *not* wearing hats, wouldn't you say I'm wrong? My sentence is *only* true in the case that they're both wearing hats.
	
	SLIDE 27
	• Conjunction Truth Table (Boolean Algebra)
	• Just like for negation, we'll see here that the Boolean truth table matches the logic truth table. Every "true" is replaced with "1" and every "false" is replaced with "0."
	• So it's only a "1" in the top row, when both p and q are "1" as well.
	
	SLIDE 28
	• "And" Truth Tables
	• What does it mean?
	• A conjunction is only true if BOTH parts of the sentence are true.
	
	SLIDE 29
	• This changes a little bit when we talk about the next type of truth table: for "or" statements.
	• We'll assign two variables, p and q, for the statement before the "or" the statement after the "or" to understand what an "or" sentence means.
	• In logic, it's called a **disjunction**
	• They symbol "v" (wedge) indicates a disjunction

	SLIDE 30 ● Let's say… ● p means "Alani is wearing a hat." ● q means "Brandi is wearing a hat." **SLIDE 31** ● Disjunction Truth Table (Logic) ● So here is the truth table for the disjunction. It's set up the same way as the conjunction. The difference you'll see is in whether the whole sentence is true or false. Let's look at what happens. ● In this top case, "Alani or Brandi is wearing a hat," we see that if both of them are wearing hats, that's ok, we'll call it "true." This one has a deeper explanation that we won't go into detail about. I'll just leave it at saying: We're thinking of the word "or" in a very inclusive way. Like if you order a sundae at a restaurant and the server asks you, "Would you like chocolate syrup or whipped cream?" and you say "Yes, both please." We don't always use the word "or" in this inclusive way in English, but for logic, this is what we mean by it: an "or" statement is true when *at least* one part of it is true. ● That's why, unlike the conjunction, it's true when only p is true, or when only q is true. ● A disjunction is only false when *both* sides are false. So if neither Alani nor Brandi were wearing a hat, we would say the sentence "Alani or Brandi is wearing a hat" is false. **SLIDE 32** ● Disjunction Truth Table (Boolean Algebra) ● Like we've seen before, the disjunction truth table for Boolean Algebra looks just like logic. We just replace the "T" with "1" and the "F" with "0." **SLIDE 33** ● What does it mean? ● A disjunction is only true if at least one part of the sentence are true. ● I hope that this was helpful to showing you how deductive logic relates to computer science. Of course, computer science has grown a lot since Boolean Algebra. But knowing the history of it can help make sense of the goals and limitations of computer programming. **SLIDE 34** ● For our next activity, you'll review some truth tables, completing parts of it on your own. ● **Activity: Truth Tables** ● Consider the link between logic and Boolean Algebra. ● Complete truth tables for conjunction and disjunction. ● Create a valid deductive argument for your STEMulate topic. ● For this last problem, it may be helpful for you to think of how you would phrase a question for Siri or how you would program a computer to help

	you out in your STEMulate project. For example, if my topic was about the sea levels rising in Maui, I might imagine I'm writing a computer program that can calculate how many people will be affected in the next five years. So it could give evidence like: ● If sea levels rise more than 1 meter, it will affect 10% of Maui's residents. ● Sea levels will rise more than 1 meter. ● Which would leave us with the conclusion: ● 10% of Maui's residents will be affected by rising sea water. ● I am making this statistic up – don't quote me. But again, the point here is that we're testing the consistency of our ideas. This isn't the inductively-motivated scientist who is going out into the world to find evidence and see where it takes her. ● This is the computer scientist, who wants to set up models that can tell us what we should expect *if* our evidence is correct. I hope you've enjoyed this video. Have fun with the worksheet and we'll see you for the next module!
Building Bridges Activity	Module #7: Activity #7a [Worksheet] No Building Bridges Activity (it's just a logic puzzle). Module #7: Activity #7b [Worksheet] **3. Consider the following deductive argument:** — In logic: Alani is wearing a blue hat *or* Brandi is wearing a blue hat. — p v q Alani is *not* wearing a blue hat. — ~p Therefore, Brandi is wearing a blue hat. — Therefore, q This argument is *valid*! Remember Module #2, a deductive argument is valid when the evidence *guarantees* the conclusion. If it's true that (1) either Alani or Brandi is wearing a blue hat, (2) it's not Alani, then we are guaranteed the conclusion, that Brandi is wearing a blue hat! **Using the model above, make a valid deductive argument for your STEMulate problem:** ____________________ or ____________________ Not ____________________ Therefore, ____________________
Up Next	Module 8: Analysis and Presentation of Scientific Data

Module #8: Analysis and Presentation of Scientific Data	
Overview	Students will explore the analysis of scientific data, including statistics, and how to present their results.

Learning Outcomes		
	Student Learning Outcomes	Course SLO 1 Participants will be able to solve problems utilizing inductive and deductive logic and following the steps of the scientific method, including ability to process, analyze, and critique results of their own work while being familiarized with Native Hawaiian practices of science observation. Course SLO 2 Participants will be able to follow lab techniques and procedures, write lab reports, carry out experimental science, gather and analyze data in order to draw conclusions, find reliable sources of information and research, review current literature, write a technical report, and present results of their work. Course SLO 3 Participants will gain specific science and math knowledge related to the content area of the question stimulus.
	Program Learning Outcomes (LIBERAL ARTS)	1. Demonstrate an understanding of theories, practices, histories, and key issues of a field of study using essential terminology and concepts of the discipline. (SLO1) 2. Use theories, concepts, and practices of a field of study to analyze evidence, artifacts, and/or texts and produce interpretations, hypotheses, evaluations, or conclusions. (SLO2) 3. Apply theories and/or methods of a field of study to perform practical, scholarly, and/or creative tasks that respond to social, cultural, environmental, or economic issues. (SLO3)
	Course Competencies	At the completion of the course, students will be able to: a. Apply Logic, and steps of the Scientific Method to any problem solving situation. b. Observe and learn about Native Hawaiian perspective of observation. c. Carry out lab assignments confidently. d. Write technical lab reports. e. Learn to locate reliable sources, read, and interpret research journal articles. f. Learn to write a technical report and professional present results. g. Learn the Math and Science content knowledge related to the STEM Industry Partner.

<table>
<tr><td>Materials</td><td>

Video	Module #8: Analysis and Presentation of Scientific Data [video]
Video Length	19:25
PPT	Module #8: Analysis and Presentation of Scientific Data [slides]
Worksheet	Module #8: Analysis and Presentation of Scientific Data [worksheet]
Additional Resources	N/A

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<tr><td>Lesson</td><td>

Lesson Objectives

1. Students will be able to identify and avoid common mistakes and misconceptions about data analysis.
2. Students will determine the proper way to analyze data for the field of their research.
3. Students will be able to generate and interpret tables and figures to present your data.
4. Students will use basic statistical methods as required, such as mean, median, and mode.

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Transcript

1. **SLIDE 1: Analysis and Presentation of Scientific Data**
   a. Welcome back! Today we'll focus on the analysis and presentation of scientific data.
   b. Whether your goal is to present your findings to the public, or your peers, or even to publish your research in a scientific journal some day, it is imperative that data from scientific projects be rigorously analyzed. Without careful data analysis to backup your conclusions, the results of your research won't be taken seriously by other scientists. It is also important to present it in a format that makes the data easy to see and interpret for both you, and your audience.

2. **SLIDE 2: Objectives**
   a. By the end of this lesson, you should be able to:
      i. Avoid common mistakes and misconceptions about data analysis.
      ii. Determine the proper way to analyze data for your field of research.
      iii. Generate and interpret tables and figures to present your data.
      iv. Use basic statistical methods as required, such as mean, median, and mode

3. **SLIDE 3: Common mistakes when analyzing data**
   a. First, let's discuss three of the most common mistakes that many young scientists make when analyzing data. They include three major assumptions.
      i. First, that data analysis occurs only after you are done collecting all your data.

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	ii. Second, that data analysis is quick—you pick your analytic methods, "plug" your data in, and then you are done. iii. And lastly, that data can stand alone without any additional context. b. However, none of these things could be further from the truth. Data analysis is an ongoing process. Planning what kinds of analyses you're going to perform with your data should be and is a critical part of designing your experiments. If you skip this step, you might find yourself with insufficient data with which to draw a meaningful conclusion. 4. **SLIDE 4: Common Mistakes when Analyzing Data** a. Once you have designed your experiments and are carrying them out, it can be wise to do some data analysis even while you are collecting your data, to ensure that the observations are within expected parameters. For example, you might want to make sure the first part of a procedure or your plan worked well before moving on to the next step. This kind of analysis prevents you from wasting valuable experimental time if something is wrong with your procedure or plan, and can eliminate confusion later. b. Data should also be analyzed between independent replicates in case the trends or observations from one experimental repeat offers insights on how to better design additional repeats. This is also important in case the data from your replicates don't match, or aren't even close...again, there may be a problem with your procedure. c. Although it might be tempting to quickly plug your data into a spreadsheet, create a graph, do some basic statistics, and celebrate your project as "finished," this methodology might lead you to miss relevant information. Instead, you should plan to spend a good chunk of time "playing" with your data. The more variables you test, the longer this "playing" takes. By looking at the data from various perspectives, trying different ways of organizing the data and representing it visually and mathematically, you might stumble upon connections or trends for which you were unaware of when starting the project. 5. **SLIDE 5: Putting data in context** a. Lastly, it is always important to not just have your data stand alone, but to put it into context. Simply put, expressing your data relative to other data can much more enlightening. For example, the data in a study on the height of Chinese male professional basketball players might show that the average player height is 6 feet 5 inches. This data becomes more informative if you compare it to the average height of males in China, which is 5 feet 7 inches, thus allowing you to conclude that in China, basketball players are likely to be 14 percent taller than the average male. Similarly, if your research is based on or a replicate of previous work, it is critical to analyze your data in direct comparison with previously published data.

	6. **SLIDE 6 : Determining Standards for Data Analysis** a. Every field has standards and norms for how to analyze data. How do you conclude what the standard analytical techniques are in your field of study? The best way is to take a careful look at a wide range of scientific papers in your field. Pay special attention to papers that are collecting the same types of data as you are, or looking to answer similar types of questions. b. Make note of things like: i. How they organize their data. ii. What types of trends they are seeing and how they are detecting those trends. iii. Which statistical tests they use to evaluate the data, c. Once you're familiar with the types of analyses common to the field you are working in, you can pick and choose the ones that make the most sense in the context of your project. 7. **SLIDE 7 : Three different ways to present and examine data** a. Now let's look at how to present and examine our data. First, as we said before, take some time to carefully review all of the data you have collected from your experiment. You should have performed multiple trials of your experiment. Think about the best way to summarize your data. Often, you will need to perform calculations on your raw data in order to get the results from which you will generate a conclusion. A spreadsheet program such as Microsoft Excel may be a good way to perform such calculations, and then later the spreadsheet can be used to display the results. b. Do you want to calculate the average for each group of trials, or summarize the results in some other way such as ratios, percentages, or error and significance for really advanced students? Or, is it better to display your data as individual data points? c. Generally speaking, scientific data analysis usually involves one or more of following three tasks: i. Generating tables, ii. Converting data into graphs or other visual displays, and/or iii. Using statistical tests. d. Let's look at each of these in turn. 8. **SLIDE 8 : Tables and figures are the key to effective data presentation** a. Have you ever heard the saying "a picture is worth a thousand words"? This is certainly true when it comes to presenting data! Complex information, like experimental procedures and the resulting data, are usually best encapsulated using tables and figures. This allows a judge, or any viewer, to quickly assess what you did, how much they understand, and what types of explanations or additional information they need from you.

b. The kinds of figures you use to present your data will depend on the types of information you are conveying. Keep in mind a figure might be a photograph or diagram, as well as a graph.

9. **SLIDE 9: Tables are read in columns and rows**
   a. *Tables* are used to organize data in one place. Relevant column and row headings facilitate finding information quickly. One of the greatest advantages of tables is that when data is organized, it can be easier to spot trends and anomalies. Another advantage is their versatility. Tables can be used to encapsulate either quantitative or qualitative data, or even a combination of the two. Data can be displayed in its raw form, or organized into data summaries with corresponding statistics. Be sure to label the rows and columns—and do not forget to include the units of measurement (grams, centimeters, liters, etc.).

10. **SLIDE 10: Different graphs are used to represent specific data**
    a. *Graphs* are a visual means of representing data. They allow complex data to be represented in a way that is easier to spot trends by eye. You might think of graphs as the primary way to present your data to others; and although graphs *are* excellent ways of doing that, they're also a good analytical mechanism. The process of manipulating the data into different visual forms often draws your attention to different aspects of the data and expands your thinking about it. In the process, you may stumble upon a pattern or trend that suggests something new about your science project that you hadn't thought of before.
    b. There are many different types of graphs, the most common of which are bar graphs, line graphs, and pie charts. Which type of graph you use depends on the kind of data you have collected.
    c. In general, for any type of graph, you should place your independent variable on the x-axis of your graph (the axis on the bottom) and the dependent variable on the y-axis. Be sure to label the axes of your graph — and don't forget to include the units of measurement (grams, centimeters, liters, etc.). If you have more than one set of data, show each series in a different color or symbol and include a legend with clear labels.

11. **SLIDE 11: Bar graphs**
    a. Bar graphs are used when your independent variable is not numerical, or is in categories. For instance, men vs. women. Or in this example, you can clearly see that in comparing my milkshake to your milkshake, my milkshake brought more boys to the yard than your milkshake.

12. **SLIDE 12: Line graphs**
    a. You should use a line graph, or scatter plot, when the independent variable is continuous, such as when you are measuring temperature, or if you are measuring something over time, including age. This example

shows the number of swears per conversation by age and we can clearly see that there are two peaks in life, such as around 12 years old and again after 60.

13. **SLIDE 13: Pie Chart**
    a. A pie chart shows how all the parts of something relate to the whole value, such as here, where according to this particular chart, time spent studying is really mostly staring at your cat, while homework would encompass the least amount of the total time spent.
    b. You'll have to tell me if that one is true or not.

14. **SLIDE 14: Identifying Outliers in Scientific Data**
    a. Take some time to carefully review all of the data you have collected from your experiment. Did you get the results you had expected? What did you find out from your experiment? Really think about what you have discovered and use your data to help you explain why you think certain things happened.
    b. Seeing your data in different graphical formats can highlight new conclusions, new questions, or the need to go and gather additional data. It can also help you to identify *outliers.* These are data points that appear to be inconsistent with the other data points. Outliers can be the results of experimental error, like a malfunctioning measurement tool, data-entry errors, or rare events that actually happened (let's say, like a 70° degree day in January in Alaska), but don't reflect what is normal.
    c. When statistically analyzing your data, which we'll talk about in the next video, it is important to identify outliers and deal with them so that they don't disproportionally affect your conclusions. It's not always easy to identify which data points are or aren't important. Identifying outliers also allows you to go back and assess whether they reflect rare events and whether such events are informative to your overall scientific conclusions.

15. **SLIDE 15: Statistics: Mean, Median, and Mode**
    a. *Statistics* are the third general way of examining data. Often, statistical tests are used in some combination with tables and/or graphs. There are two broad categories of statistics: descriptive statistics and inferential statistics. *Descriptive statistics* are used to summarize the data and include things like average, range, standard deviation, and frequency. *Inferential statistics* rely on samples (the data you collect) to make inferences about a population. They're used to determine whether it is possible to draw general conclusions about a population, or predictions about the future based on your experimental data.
    b. So now you have collected your raw data, and you have results from multiple trials of your experiment. How do you go from piles of raw data to summaries that can help you analyze your data and support your conclusions?

c. Fortunately, there are mathematical summaries of your data that can convey a lot of information with just a few numbers. In most cases, the first thing that you will want to know about a group of measurements is the "average." But what, exactly, is the "average?" Is it the mathematical average of our measurements? Is it a kind of half-way point in our data set? Is it the outcome that happened most frequently? Actually, any of these three measures could conceivably be used to convey the data. Most often, the mathematical average or **mean** of the data is used, but two other measures, the **median** and **mode** are also sometimes used.
d. We'll use a plant growth experiment as an example. Let's say that we did an experiment to test whether plants grown in soil with compost added would grow faster than plants grown in the same soil without compost. Let's imagine that we used six separate pots for each condition, with one plant per pot. One of the growth measures chosen was the number of leaves on each plant. Suppose that the following results were obtained.

16. **SLIDE 16: Mean**
    a. The *mean* value is what we typically call the "average." You calculate the mean by adding up all of the measurements in a group and then dividing by the number of measurements. For the "without compost" case, the mean is 5, as you can see in the illustration.
    b. For the "with compost" case, the mean is 8. Use the numbers in the table mentioned to do the calculation for yourself to confirm that this is correct. You can pause the video if you need to.

17. **SLIDE 17: Median and Mode (Median)**
    a. The easiest way to find the median and the mode is to first sort each group of measurements in order, from the smallest to the largest. Here I've sorted the values sorted in order.
    b. The median is a value at the midpoint of the group. More explicitly, exactly half of the values in the group are smaller than the median, and the other half of the values in the group are greater than the median. If there are an odd number of measurements, the median is simply equal to the middle value of the group, when the values are arranged in ascending order. If there are an even number of measurements (as here), the median is equal to the mean of the two middle values (again, when the values are arranged in ascending order). For the "without compost" group, the median is equal to the mean of the values of the 3^{rd} and 4^{th} values, which happen to be 4 and 5. To get the median, we can find the halfway point between these two numbers, and thus the median is 4.5
    c. Notice that, by definition, three of the values (3, 4, and 4) are less than the median, and the other three values (5, 6, and 8) are greater than the median. What is the median of the "with compost" group? If you guessed 8.5, you're correct. Sometimes there is one median, or in these cases, there are two.

18. **SLIDE 18: Median and Mode (Mode)**
    a. The mode is the value that appears most frequently in the group of measurements. For the "without compost" group, the mode is 4, because that value is repeated twice, while all of the other values are only represented once. What is the mode of the "with compost" group?
    b. It is entirely possible for a group of data to have no mode at all, or for it to have more than one mode. If all values occur with the same frequency (for example, if all values occur only once), then the group has no mode.

19. **SLIDE 19: Which one should I use?**
    a. In general, the mean is the descriptive statistic most often used to describe the statistics of a group of measurements. Of the three measures, it is the most sensitive measurement, because its value always reflects the contributions of each of the data values in the group. The median and the mode are less sensitive to "outliers"—data values at the extremes of a group. Imagine that, for the "without compost" group, the plant with the greatest number of leaves had 11 leaves, not 8. Both the median and the mode would remain unchanged. (Check for yourself and confirm that this is true.) The mean, however, would now be 5.5 instead of 5.0.
    b. On the other hand, sometimes it is an advantage to have a statistical measure that is less sensitive to changes in the extremes of the data. For example, if your data set contains a small number of outliers at one extreme, the median may be a better measure of the data than the mean.
    c. If your results involve categories instead of continuous numbers, then the best measure will probably be the most frequent outcome, the mode. For example, imagine that you conducted a survey on the most effective way to quit smoking. A reasonable measure of the central tendency of your results would be the method that works most frequently, as determined from your survey.

20. **SLIDE 20: When in doubt, check your sources**
    a. Beyond the basic descriptive statistics like mean, mode, and average, you might not have had much exposure to statistics. So how do you know what statistical tests to apply to your data? A good starting place is to refer back to published scientific articles in your field. The "Methods" sections of papers with similar types of data sets will discuss the statistical tests the authors used. Other tests might be referred to within data tables or figures.
    b. Try evaluating your data using similar tests. You might also find it useful to consult with statistical textbooks, math teachers, your project mentor, and other science or engineering professionals.

21. **SLIDE 21: Pau**
    a. This concludes our lesson! Your assignment today is to complete the data interpretation worksheet and problems identifying the mean, median and mode of data. Next we'll learn about writing technical papers.

Building Bridges Activity	Module #8: Analysis and Presentation of Scientific Data [worksheet] **12. Think about the problem or issue you have chosen to study this summer. Will you have a table of your data? How might you present your data in a figure? What type of figure will you use? Are there any statistical measures that might be helpful? Write down your ideas below.**
Up Next	Module #9: Communicating Results through Technical Writing

Module #9: Communicating Results through Technical Writing	
Overview	Students will be introduced to technical writing in the form of a scientific paper / laboratory report - including format, requirements, and APA style.
Learning Outcomes	

Student Learning Outcomes	Course SLO 1 Participants will be able to solve problems utilizing inductive and deductive logic and following the steps of the scientific method, including ability to process, analyze, and critique results of their own work while being familiarized with Native Hawaiian practices of science observation. Course SLO 2 Participants will be able to follow lab techniques and procedures, write lab reports, carry out experimental science, gather and analyze data in order to draw conclusions, find reliable sources of information and research, review current literature, write a technical report, and present results of their work. Course SLO 3 Participants will gain specific science and math knowledge related to the content area of the question stimulus.
Program Learning Outcomes (LIBERAL ARTS)	1. Demonstrate an understanding of theories, practices, histories, and key issues of a field of study using essential terminology and concepts of the discipline. (SLO1) 2. Use theories, concepts, and practices of a field of study to analyze evidence, artifacts, and/or texts and produce interpretations, hypotheses, evaluations, or conclusions. (SLO2)

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<tr><td></td><td>3. Apply theories and/or methods of a field of study to perform practical, scholarly, and/or creative tasks that respond to social, cultural, environmental, or economic issues. (SLO3)</td></tr>
<tr><td>Course Competencies</td><td>At the completion of the course, students will be able to:
a. Apply Logic, and steps of the Scientific Method to any problem solving situation.
b. Observe and learn about Native Hawaiian perspective of observation.
c. Carry out lab assignments confidently.
d. Write technical lab reports.
e. Learn to locate reliable sources, read, and interpret research journal articles.
f. Learn to write a technical report and professional present results.
g. Learn the Math and Science content knowledge related to the STEM Industry Partner.</td></tr>
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<td>Materials</td>
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<table>
<tr><td>Video</td><td>Module #9: Intro to Communicating Results through Technical Writing [video]</td></tr>
<tr><td>Video Length</td><td>27:35</td></tr>
<tr><td>PPT</td><td>Module #9: Intro to Communicating Results through Technical Writing [slides]</td></tr>
<tr><td>Worksheet</td><td>Module #9: Intro to Communicating Results through Technical Writing [worksheet]</td></tr>
<tr><td>Additional Resources</td><td>Resources for free scientific journal articles:
1. NCBI Pubmed for journal articles - look for free text articles http://www.ncbi.nlm.nih.gov/pubmed?cmd=search
2. Directory of Open Access Journals: https://doaj.org/search?source={%22query%22%3A{%22query_string%22%3A{%22query%22%3A%22dungeness%22%2C%22default_operator%22%3A%22AND%22}}%2C%22from%22%3A0%2C%22size%22%3A10}
3. Elsevier Open Access: https://www.elsevier.com/about/open-science/open-access/open-access-journals</td></tr>
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	A quick (but complete) online guide describing APA format for all major types of sources (also see writing resources folder for this module): https://owl.purdue.edu/owl/research_and_citation/apa_style/apa_overview_and_workshop.html *Recommended:* Have students turn in their rough drafts into www.turnitin.com for experience in understanding plagiarism. This website identifies to the students areas that look too similar to other sources so they have a chance to correct them before turning it into the instructor. *Optional extension:* Native Hawaiians shared information through mo'olelo and that this is also a valid sharing of observational results. An optional activity is to have students read through and compare mo'olelo or have students write mo'olelo about their own results.
Lesson	**Lesson Objectives** 1. Students will be able to explain the different ways in which scientists formally share the results of their research. 2. Students will be able to identify the difference in primary and secondary source materials for research. 3. Students will be able to list the major sections used to format formal scientific writing. 4. Students will be able to describe and correctly include all information required in each section. 5. Students will be able to properly format and label tables and figures. 6. Students will avoid plagiarism by citing sources correctly in-text and in a "References Cited" section of their paper.
	Transcript 1. **SLIDE 1: Communicating Results through Technical Writing** a. Welcome back! Now that you've learned how to collect, analyze, and present your data, we're going to learn about that last step of the scientific method of inquiry - sharing our results. In this module, we'll focus on how to communicate our results using technical writing - including a formal scientific report. b. Technical writing is the process of writing and sharing information in a professional setting, and your primary task is to convey information to your peers, the public, and/or other scientists in the most clear and effective manner possible. The information and data that you have collected and analyzed is often complex, and you will want to present it in a format that is easy to read and understand. 2. **SLIDE 2: Objectives** a. By the end of this lesson, you should be able to:

	i. Explain the different ways in which scientists formally share the results of their research. ii. Identify the difference in primary and secondary source materials for research. iii. List the major sections used to format formal scientific writing. iv. Describe and correctly include all information required in each section. v. Properly format and label tables and figures. vi. Avoid plagiarism by citing your sources correctly in-text and in a "References Cited" section of your paper. 3. **SLIDE 3: Scientists share their data in different ways** a. As discussed previously, one of the most important steps in scientific inquiry is sharing your results. To do so, scientists have to present their data in a format that is acceptable to the scientific community, which generally means: i. Publishing a peer-reviewed research paper in a scientific journal; ii. Writing a review of the available literature, for other scientists to read and get a sense of what's happening in a particular field or an overview of a particular subject; iii. Presenting a scientific poster and/or formal presentation for a live audience at a local, national, or international conference. b. For this lesson, we'll discuss how to present your data in writing, and in our next module, we'll focus on how to present it professionally for a live audience. 4. **SLIDE 4: Literature Reviews** a. Let's first discuss what a Literature Review entails. A literature review is a scientific paper which includes the current state of knowledge for a particular field of study, including all major and recent findings, as well as important methods and theories in the literature on a particular topic. 5. **SLIDE 5: Identifying source material for scientific writing** a. Let's quickly review how to identify a reliable source of scientific information. b. Note that different sources for information have different levels of reliability. For instance, we've already discussed how Wikipedia may not be a very good or reliable source for scientific information, but that it can also be a great starting point for identifying other places to look for information. c. No matter the source, however, it's a good idea to ask yourself the questions listed here to help you judge whether or not a source is reliable. As it says, the more checks on this list, the better, while a source with only a few or no checks at all would not be considered "reliable." d. The questions are: i. Is the information current? ii. Is the source primary (and not secondary)? 1. Literature reviews are "secondary" sources, as opposed to "primary" sources like journal articles (or in our case,

scientific reports), and do not report new or original experimental work.
- iii. Is/are the authors identifiable and well qualified?
- iv. Does the author lack potential conflicts of interest?
  1. For example, you wouldn't necessarily want to take a drug company at their word if they are telling you their drug is the "best" if all the research is done by their company!
- v. Other questions include if the references are cited, if the experiment could be reproduced from the information provided, and if there is peer-review in the process.

6. **SLIDE 6: Peer Review**
   a. Peer review is the evaluation of work by impartial, qualified, often anonymous experts who are not involved in the work - again, back to the drug company example. If their data is verified by an outside source, then you might find their claim to be the "best" more reliable as well.
   b. And remember, we can all use a little editing and an outside perspective.

7. **SLIDE 7: Databases for Scientific Research Writing**
   a. Scientific journal articles are often the best resource for scientific research - they are most often published monthly and contain the latest breaking news in every field.
   b. Your school library and librarian are often a fantastic source of information and reliable sources, including scientific journal articles.
   c. The sources listed on this slide are some other reliable sources for journal articles and peer-reviewed primary literature and literature reviews, including
      i. NCBI Pubmed for scientific journal articles. You can search for free text articles on this source.
      ii. There is also the Directory of Open Access Journals
      iii. And Elsevier Open Access

8. **SLIDE 8: Scientific Writing Follows a Specific Format**
   a. Once you have determined you have all the information you need, you may begin to write.
   b. Scientists write to convey information objectively and efficiently, and follow a special, robust format of technical writing that allows them to quickly determine all of the information they need.
   c. As future scientists, engineers, technical experts, or any kind of professional dealing with scientific information, you will practice writing up your experiments in a general format that is used in scientific writing worldwide. Scientific/Technical writing involves 5 main sections, followed by a "References Cited" section. It also often includes an abstract at the beginning of the paper.
   d. We'll discuss each of these in turn in the next several slides.

	9. **SLIDE 9: Scientific Writing Follows a Specific Format** a. Some general considerations when writing your paper include: i. Make sure that your title is specific and states exactly what you were researching or testing. ii. Using headings for each of the sections, and make sure they are succinct and clear. iii. Use subheadings if you need to divide information, and keep those subheadings the same throughout the entire paper. iv. Subheadings should appear beginning in the Methods section, and be carried throughout the Discussion section. **10. SLIDE 10: The Importance of Grammar** a. Grammar is also very important! b. You should write your paper in the past tense. You already did your experiments, so it should be written to showcase that. c. Read it out-loud to yourself or another person – if it sounds awkward, fix it! d. Remember, this is a *scientific report of your data and what you did during your research.* 11. **SLIDE 11: Introduction** a. Science naturally requires building or expanding upon the work of others, and the introduction is the section that sets the context and provides the background information necessary to understand your experiment. b. Imagine an upside-down triangle. In your introduction, you want to start with a general statement about the nature of the biological process or concept (the broad part of your triangle), and then move to more specific information that reviews the particular topic being addressed in your experiment(s). i. Note that the introduction is not where you list information about *how* you did the experiment or the research – it is the information about *why* you did the research and experiment. ii. The background information should lead up to a clear statement of the hypothesis that the experiment was aimed at testing or addressing, as well as your predictions for the outcome of the experiment (it's OK if your predictions turned out not to be true or your hypothesis was falsified!). iii. If you did more than one experiment, your report should have background and a hypothesis and predictions for *each* experiment. 12. **SLIDE 12: Hypotheses vs. Predictions** a. A hypothesis is a statement (or proposal) explaining an observation, phenomenon or scientific problem *that can be tested...* i. It must *answer the question* you are interested in ii. It does NOT start with *if...then* iii. It does NOT need to say why or because you don't know WHY something is happening if you haven't tested it!

iv. However, you *SHOULD* include how you came to your hypothesis in your intro...
v. Always clearly state that what you are saying IS a hypothesis.

13. **SLIDE 13: Hypotheses vs. Predictions**
    a. A prediction is a statement that helps *clarify* our hypothesis and predicts the results of the experiment you will do to test it.
        i. Predictions are always framed as "if...then" statements.
        ii. So, IF your hypothesis is true, THEN ________ must also be true.
        iii. While your hypothesis gives an explanation for what you feel the underlying cause of a phenomenon, your prediction should state what you think your RESULTS will be.
        iv. Thus, it should include how you measured your results!

14. **SLIDE 14: Hypotheses vs. Predictions**
    a. Let's look at an example to help us distinguish between the two.
    b. If our question is, "How does fertilizer affect plant growth?
    c. Our hypothesis might be, "The presence of Miracle Grow fertilizer will increase plant growth." Note that the hypothesis can be quite broad. It is simply a statement answering the question.
    d. However, our prediction needs to show how we will test our hypothesis, and include how we will measure our results. Such as, "If 1 tbsp of Miracle Grow is used, plants will grow taller in height and have more leaves."
    e. In our prediction, we show we will be using 1 tablespoon of Miracle Grow, and measure plant "growth" by height of the plant and number of leaves." If we indeed see this result, we will know our hypothesis is supported by our data.
    f. Think about what kind of controlled variables might we want to use in this example...maybe the same type of plant, and definitely the same amount of fertilizer (which we even stated in our prediction), same soil, etc.

15. **SLIDE 15: Still Awake?**
    a. A little joke to make sure you're still awake...

16. **SLIDE 16: Materials and Methods**
    a. This section should describe the experiment(s) you used to test your hypothesis. This includes the experimental procedures you followed, the different treatments you used, the controls, and number of replications.
    b. Do not list equipment or steps of the procedure; this section should be written in paragraph form as a narrative description of *how* you did the experiment. You may identify materials and equipment used as they are discussed.
    c. As this is a description of what you already did, it should be written in the past tense. Keep it as brief as possible. You do not have to list trivial details such as how to use equipment. However, if you did something creative or unique do report that.
    d. The reader should be able to reproduce your experiment after reading this section, but make certain this does not read like a list of things to do. You should include sub-headings in this section if the experiment is divided into several parts.

	e. Make sure that your audience understands *why* you did each step of our experiment if it is unclear. **17. SLIDE 17: Results** a. In this part of the report you <u>organize and summarize the data</u> generated by your experiment. Look at your data tables and figures – what story do they tell? Include a few major data points, but do not cite every data point. Rather, you should report the ***major trends*** in the data (ranges, averages, and extreme values may be important). b. Do <u>**not**</u> interpret, nor discuss the meaning, of your data in this section - save that for the Discussion. c. This section needs to be efficiently organized with subheadings, if needed (and they should match any used in previous sections). The reporting must be detailed, but also completely objective. Again, write it in the past tense. d. ****<u>Very important</u>: Refer to tables and figures within the text** as you describe your results, using the word "Figure" (for any graphs, drawings, photos, etc.) or "Table," followed by its number (e.g., Table 1, Figure 1, etc.). We'll talk more about this later. **18. SLIDE 18: Still Awake?** a. Just another little joke here to make sure you're following along. **19. SLIDE 19: Discussion** a. The Discussion section is where <u>you answer the question you posed in your introduction, show if your hypothesis was supported or not supported by relating your findings to the information known previously, and describe what your experimental data shows</u>. b. You should use subheadings if needed, and write a statement of your ***conclusions***, discussing your predictions and the actual outcome of the experiments. Clearly indicate if your hypotheses and predictions were supported or not supported by the data. Use specific examples of data (ie. your numbers and figures!) to support your conclusion statements, and be sure to refer to them as described in the Results section. c. You may discuss alternate explanations, but conclude with the best explanation based on the data in your results. d. Focus on carefully analyzing and interpreting <u>your</u> results. Do not concentrate on searching for the "right" answer or results that match those found by others. You should always consider the possibility that you have made an error; however, you should not reject your data just because they disagree with previously reported results. e. When drawing a conclusion, you must discuss and consider all of your data, not just those that support your views or hypothesis. If your hypothesis was not supported and you would change something next time or have another hypothesis about your results, suggest them!

f. Include also any discrepancies or outliers in your data or weaknesses in your experiment, including what would you have done differently or would do next time if given the opportunity to repeat your experiment.

20. **SLIDE 20: Discussion**
    a. Your Discussion should, in a sense, have the opposite structure to your Introduction section - it should start out specific, expanding to include your data's relevance to the "bigger picture" and scope of things.
    b. Thus, make your conclusions pertinent and relate them to the broader world as a whole – why is this type of data important?

21. **SLIDE 21: Tables and Figures**
    a. Only Tables and Figures referred to in the text should be included in the report and placed together at the end of the report, numbered and in the order in which you described them.
    b. All of the tables should go first, in order, followed by all of the figures. Each table and figure requires a number, title, and caption that concisely describes what is shown - making the table or figure interpretable *without needing to read the full report.*
    c. Figures include both pictures and graphs. If your figure is a graph, it should also have the x- and y-axes labeled properly and units of measurement included.
    d. Be sure to reference all of your figures in your report, properly, as we discussed earlier.

22. **SLIDE 22: Requirements for Tables**
    a. Tables must have:
        i. A table number
        ii. A title that tells us what (specifically) is being tested or researched, and
        iii. An Explanation of all abbreviations used

23. **SLIDE 23: The Importance of Telling us what your Abbreviations Mean**
    a. Let's see why an explanation of your abbreviations are important.
    b. Examine the table here. We have Table 1: The hotness scale (1-10) for girls in my physics class. Who is the hottest? Just by looking at it you might guess Barb E. Dahl is the hottest (since she scored a 1) and Emma Royds is perhaps the least hot of the three girls.
    c. However, when we understand what our hotness scale is calculated by - our "gpc" - we see that it's actually the opposite. Emma Royds is definitely the hottest of the group.

24. **SLIDE 24: Requirements for Figures:**
    a. Recall that a figure is a drawing, model, picture or graph.
    b. All figures must have:
        i. A Figure number
        ii. A Title that tells us what the figure is or what is being tested – be specific in all your titles.

	iii. A caption that should summarize the results in the figure iv. And again, an explanation of all abbreviations used c. Remember that your independent variable should be on the X axis of the graph, while the dependent variable should be on the Y axis. 25. **SLIDE 25: Abstract** a. An abstract is often the last part of the paper written and is arguably the most important. It's a succinct description of the paper as a whole - and does three major things: it introduces the paper, informs the reader about the content, and helps the reader (usually another scientist) decide if they want to read the paper. An abstract typically contains 5-6 sentences, each addressing five major categories: the topic, research question, methods, results, and conclusion of the paper. b. One way to do this is to read your paper in its entirety. Keep the above categories in mind and underline key points as you read. After you finish reading, create your abstract step-by-step, based on your underlined material. c. Another way to do it is to ask yourself five questions, turning each one into a single sentence in your abstract. i. **Introduction. In one sentence, what's the topic?** Phrase it in a way that your reader will understand. If you're writing a paper about your experiments, the readers are the peer reviewers, or your industry partner, and eventually others in your field interested in your research, so they will know the background work, but want to know specifically what topic your paper covers. In our case, this will be the PBL problem being addressed. ii. **State the issue or question you tackled**. What's the key research question? Again, try to do it in one sentence. Remember, your first sentence introduced the overall PBL topic, so now you can build on that, and focus on the one key question you chose within that topic. iii. **Explain, in one sentence, how you tackled the research question. How did you go about doing the research that follows?** Did you run experiments? Build a piece of software? Remember, the word 'abstract' means a summary of the main ideas with most of the detail left out. So feel free to omit detail! iv. **What were your results?** Again, narrow your results and conclusions down to a single sentence, or at most, two. v. **What is the key impact of your research?** Here your audience is looking for a summary of the implications. What's it all mean? Why should other people care? What can they do with your research? This is the sentence that "brings it all home" and will really tell a reader if it's worthwhile to read your report, so make it count!

	26. SLIDE 26: Don't plagiarize! a. Our last topic is plagiarism. Plagiarism is the practice of taking someone else's work or ideas and passing them off as your own. b. All of the following are considered plagiarism: i. Turning in someone else's work as your own ii. Copying words or ideas from someone else without giving credit iii. Failing to put a quotation in quotation marks iv. Giving incorrect information about the source of a quotation v. Changing words but copying the sentence structure of a source without giving credit vi. Copying so many words or ideas from a source that it makes up the majority of your work, whether you give credit or not **27. SLIDE 27: Cite Your Sources to Avoid Plagiarism!** a. Most cases of plagiarism can be avoided by citing sources. Simply acknowledging that certain material has been borrowed and providing your audience with the information necessary to find that source is usually enough to prevent plagiarism. b. The References Cited section is the last section of your paper. It is where you will cite all of your sources used for background research, including journal articles, books, interviews, and websites. c. The most commonly used format for a References cited section, in scientific papers is the APA, or American Psychological Association, format. d. Your activity worksheet for today will help you to explore APA format in more detail. 28. **SLIDE 28: That's all folks!** a. That's it for today! I know this is a lot of information, so take your time to do the activity worksheet today, and make sure you ask your instructor if you have any questions. Also be sure to refer to the rubrics given to you for the scientific paper for this course as you do your writing. b. We'll see you next time for our next and last module on professional presentation skills.
Building Bridges Activity	**From** Module #9: Intro to Communicating Results through Technical Writing [worksheet] 5. Using ONE of the databases below, find a scientific journal article about the issue you are researching by entering search terms relevant to your topic and/or choosing a journal, and in the space below, write the citation – both as you would write in-text and in the References Cited section of your paper.
Up Next	Module 10: Professional Presentation Skills

Module #10: Professional Presentation Skills

Overview	Students will be introduced to professional presentation skills - including tips for creating and delivering a polished oral scientific presentation, and to avoid common mistakes.
Learning Outcomes	

Student Learning Outcomes	<u>Course SLO 1</u> Participants will be able to solve problems utilizing inductive and deductive logic and following the steps of the scientific method, including ability to process, analyze, and critique results of their own work while being familiarized with Native Hawaiian practices of science observation. <u>Course SLO 2</u> Participants will be able to follow lab techniques and procedures, write lab reports, carry out experimental science, gather and analyze data in order to draw conclusions, find reliable sources of information and research, review current literature, write a technical report, and present results of their work. <u>Course SLO 3</u> Participants will gain specific science and math knowledge related to the content area of the question stimulus.
Program Learning Outcomes (LIBERAL ARTS)	1. Demonstrate an understanding of theories, practices, histories, and key issues of a field of study using essential terminology and concepts of the discipline. (SLO1) 2. Use theories, concepts, and practices of a field of study to analyze evidence, artifacts, and/or texts and produce interpretations, hypotheses, evaluations, or conclusions. (SLO2) 3. Apply theories and/or methods of a field of study to perform practical, scholarly, and/or creative tasks that respond to social, cultural, environmental, or economic issues. (SLO3)
Course Competencies	At the completion of the course, students will be able to: a. Apply Logic, and steps of the Scientific Method to any problem solving situation. b. Observe and learn about Native Hawaiian perspective of observation. c. Carry out lab assignments confidently. d. Write technical lab reports. e. Learn to locate reliable sources, read, and interpret research journal articles.

	f. Learn to write a technical report and professional present results. g. Learn the Math and Science content knowledge related to the STEM Industry Partner.

Materials

Video	Module #10: Professional Presentation Skills [Video]
Video Length	11:50
PPT	Module #10: Professional Presentation Skills [Slides]
Worksheet	No worksheet for this module
Additional Resources	N/A

Lesson

Lesson Objectives

1. Students will be able to describe the structure of an oral scientific presentation, and create a successful presentation of their own.
2. Students will be able to explain some common pitfalls and mistakes that are made during presentations – and avoid them.

Transcript

1. **SLIDE 1: Professional Presentation Skills**
   a. Welcome back! Today we'll focus on the analysis and presentation of scientific data - our last module.
   b. Your preparation and organization of your presentation will help the audience understand your main points. Ultimately, a presentation is one of the ways of influencing how others perceive your science and your professionalism. Here, we'll discuss some ideas for creating polished and professional presentations of your scientific research.

2. **SLIDE 2: Objectives**
   a. By the end of this lesson, you should understand and be able to:
      i. Describe the structure of an oral scientific presentation, and create a successful presentation of your own.
      ii. Explain some common pitfalls and mistakes that are made during presentations – and avoid them in yours.

3. **SLIDE 3: Building your presentation - Some Tips**
   a. First, consider your goals and the context for your talk or presentation...what do you want to communicate or to achieve with your talk?
   b. Identify your audience: are they expert researchers in your field? Non-scientists? Who?

i. When speaking to experts, you should focus less on background and more on data.
ii. When presenting to non-scientists, speak more broadly about your interests without boring anyone with highly detailed data.
iii. Or, if you're talking to both (which you are!), tailor your talk to your audience and include a bit of both! Go into the interesting data, but be sure to consider people who don't know much about the problem you're presenting, and explain to them what they need to know.

c. Consider your time and stick to it. You should plan on about 1-2 minutes on most slides. Be sure to practice your talk too - so that you keep within the timing that is allotted to you.
d. Lastly, use as many visuals as possible - include your figures from your paper and great photos of the places and/or people you used in your research.

4. **SLIDE 4: Structure of an Oral Scientific Presentation**
   a. An oral scientific presentation follows a format very similar to a scientific paper, so this should look familiar. Your presentation should include each of the following parts
      i. A title slide which includes your full name
      ii. An outline giving an overview of what you will be covering during your presentation
      iii. Background and Introduction material to set the context for your research
      iv. Your Question and Hypothesis
      v. The Materials and Methods you used during your research
      vi. Your most important Results
      vii. The Discussion and Conclusions you drew from your data, as well as any changes you would have made or errors that might have happened.
      viii. Acknowledgments for those that helped you
      ix. Leave time enough included at the end for a question and answer period - usually an extra minute or two.

5. **SLIDE 5: Don't forget to introduce yourself as well as your presentation**
   a. Include a title slide in your presentation that clearly states what your research was about
   b. Don't forget to introduce yourself to your audience! What is your name? What school do you go to?
   c. Speak clearly and slowly and stay positive and upbeat for your entire talk - even if things didn't work out as planned; your audience still wants to hear what you have to say - you're the expert on your research and what you did!
   d. Lastly, make sure that everyone in your group shares and does some of the talking.

6. **SLIDE 6: Start with an outline and stay focused**
   a. Clarify from the start what you'll cover in your presentation by presenting your audience with an outline. An example of an outline might be similar to the outline presented to you two slides ago, and as simple as including the major sections of your scientific paper about your research.
   b. The very best presentations have been focused, effectively paced, and on time. To achieve this, carefully refine your presentation's story. Narrow

	things down by asking yourself, if the audience remembers one or two points from your presentation, what should they be? 7. **SLIDE 7: The introduction should set the context for your presentation** a. Introduce the main ideas and the bigger problem that led to your scientific question b. Tell the audience what is known or not known about your topic - where are the gaps in the information that you decided to research? c. Explain why your work is significant and important in the context of the problem, and why you decided to work on it. d. Clearly state and specify the question that addresses the issue you chose to research and tell them your hypothesis 8. **SLIDE 8: Explain your experiment and conclusions** a. After your introduction, you can start in on the bigger part of your presentation. Include your materials and methods, using visuals of equipment, places or people that were a part of your research. b. Present your results - but simplify them by presenting only the most important information. c. State your conclusions and discuss how you came to them and why they are important in the broader context of the problem that was studied. Include any pitfalls and what you would have liked to have done differently or that you want to do in the future. d. Thank your audience and ask for questions. 9. **SLIDE 9: Delivery of your presentation** a. Briefly introduce each slide by stating its purpose b. Refer to your slide as you talk – and talk through each slide, especially for data slides that show your results. c. Your spoken words should correlate with the slide but don't simply read each slide. d. Watch the time - remember to calculate between 1-2 minutes per slide. e. Be concise and complete in your information by presenting only what is truly essential and relevant to present the whole story f. Clearly explain each of your graphs and figures. Be sure to tell your audience what each of your axes are - and the overall summary or important points from each figure. If you have a legend, include what the colors in your graph mean. 10. **SLIDE 10: Tips for the day of your presentation** a. Dress for success! Wear something that makes you look like the professional scientist you are! b. Be sure to rehearse your talk - practice is key to a successful presentation, and rehearsing helps decrease nervousness. It's also helpful to practice by yourself, and in front of others, if you have friends or family who might be willing to help you out by listening to your talk. c. Check your images and animations to ensure they are in the correct order or work properly. d. Time your talk when you rehearse it to ensure you can keep within the allotted time and still leave time for questions. e. Lastly, if someone asks you a question, try to answer honestly. Be willing to admit that you don't know–you can say, "That's an interesting question. I honestly hadn't thought about that, but it seems to me that it might be..." It's also OK to ask for a question to be clarified if you're not sure what someone is asking. Practicing your talk will also help you to anticipate questions and think on your feet. 11. **Slide 11: Common mistakes and pitfalls** a. Some common mistakes that students often make during presentations include going too quickly. Sometimes this is due to nervousness, so the more you practice, the more confident you will feel.

	b. Avoid distractions: empty your pockets, make sure you turn off your phone. c. Face the audience, not the screen, and don't block the view of the screen while you are trying to talk about your figures. d. Speak loudly and clearly – avoid words like "um", "uh", "like", "OK" e. Express your enthusiasm in your topic – don't be bored or your audience will be too! **12. Slide 12: Summary** a. In summary, prepare your talk in advance - preparations often take longer than you might think, so start early and make sure you understand your own outline and data thoroughly and completely, as well as a complete picture of what you want to present to your audience. b. Consider what the audience actually needs to hear not just everything you want to tell them. This will help you pare your presentation down to the essentials. c. Practice, practice, practice! Remember, this will help every aspect of your talk - from your successful delivery of it, to decreasing nervousness, to even making you more confident about the information you are talking about. d. Seek feedback and more opportunities to give talks - the more you give, the more comfortable you will become. Developing your oral communication skills will also sharpen your scientific skills! 13. **SLIDE 13: Remember: The star of the presentation is not your slides - it's YOU** a. In a good presentation, the audience focuses on the presenter – not their slides! This may be uncomfortable, but confidence will develop with practice. Remember, you're the expert on your research - everyone there is just interested in hearing what you did! b. Your goal is to create an engaging presentation that is well balanced, on time, and tailored for the audience. Putting effort into presentation structure and performance will ensure that your delivery is effective. This effort will pay off: your audience will be left with a lasting impact about the research and impressed with the hard work you did! **14. SLIDE 14: Congratulations!** a. This is the end of our modules and where we say goodbye to you for now. b. Great job on learning to be better a scientist and working toward solving a real-life problem during this program! c. We're excited to learn about your research - from you, during your presentation and in your scientific paper, and wish you all good luck on the rest of your research and we'll see you at the symposium!
Building Bridges Activity	No worksheet for this module.
Up Next	N/A - pau!

Next Steps

Your interest in this curriculum manual is the first step to transforming classrooms to support the next generation of STEM learners in developing the skills. If you are interested in learning more about Project STEMulate and STEM PBL curriculum please contact:

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